Research, Design and Development of a STEM Strategy

March – July 2017

Helping to empower future generations of KwaZulu-Natal through Science, Technology, Engineering and Mathematics (STEM) to grow a dynamic and innovative economy
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Research, Design and Development of a STEM Strategy

**STEM as an ECONOMIC CATALYST - helping to empower future generations of KwaZulu-Natal through Science, Technology, Engineering and Mathematics (STEM) to grow a dynamic and innovative provincial economy**

**INTRODUCTION:**
The world is changing at great pace and to keep abreast, let alone stay ahead of the pack requires radical strategies. At a generic level, KZN must build an innovative economy that is open to all Citizens – who want their children to have access to good, well-paying jobs—the kind of jobs that make it possible for them to repay their student debt, buy a home and start a family of their own. More must be done to give every KZN’er - including those who are traditionally underrepresented in the workforce, such as Minorities, women, People with disabilities and older workers—greater opportunities to succeed. It’s not good enough to build an economy that benefits only a select few. KZN will succeed when all its citizens have a chance to learn, work and help grow the economy.

It is said that the old paradigms of intelligence predicated upon IQ (intelligence Quotient), which has been superceded by Emotional Quotient (EQ) will now be surpassed by Technology Quotient (TQ)

Help adapt to the changing nature of work: Jobs today are different from those that existed even a generation ago. The rise of contract and temporary work challenges our understanding of what it means to be fully employed, and employers and governments need to be more responsive to workers’ needs than ever before. By better supporting hard-working citizens and giving them more opportunities to learn and strengthen their skills, we can keep more people in the workforce, grow our economy and strengthen our middle class. This is especially true for Millennials, who are entering the workforce at a time of tremendous change.

Help young KZN’ers as they enter the workforce: To give the next generation of workers a real and fair chance at success, and to ensure that KZN has enough workers to keep the economy strong and growing, the Plan must take into account the needs of the youth. Barriers to youth employment must be addressed, and more must be done to help young people make the transition from school to work, in a way that gets them working sooner, in jobs that make the best use of their skills.

Encourage a culture of lifelong learning: Just a generation or two ago, workers could expect to train for a good, well-paying job and then keep that job through to retirement. This is increasingly rare. Today, innovation is both changing the skills, workers need to succeed, and accelerating the need to learn and develop new skills. However, it can be difficult for adults who are already employed and who may have family responsibilities to pursue learning or upgrade their credentials. To better support workers in an innovation-driven economy, KZN must do more to support and encourage lifelong learning.

Create an open and creative society that attracts the best and brightest from around the world. From its earliest days, the developed country success has been driven by the hope and hard work of those who came here in search of better opportunities for themselves and their families. The talents, skills and entrepreneurial spirit of those who migrate to study and work help to grow the economy, and create new jobs. Attracting the best and brightest from around the world benefits all, and should be one of the Government’s top priorities.
Alignment to STEM PILLARS

The four identified STEM PILLARS have been incorporated into the broad discussion of this paper.

1. STEM Capacity Development Initiatives Pillar
   *Strategic STEM education and skills development strategies and interventions*
   a. These have been discussed at length throughout the document including the physical infrastructure required to reach a greater audience, innovative approaches to STEM education within an economic development context
   b. The optimal use of technology in achieving the desired goals
   c. The centrality of an “out-of-school” approach

2. STEM Institutional Support and Model Initiatives Pillar
   *Shape and business model of the STEM Division, required internal policies, systems and processes*
   a. These have been incorporated in various threads in this document.
   b. Form and function is heavily dependent upon the options chosen, but the MKI STEM Fund should be the paramount driver of funding the initiatives and attendant infrastructure; judicious co-option of sister government agencies and departments, alignment with the DBE, DHET, DST, DTI, etc

3. STEM Governance Initiative Pillar
   *Monitoring and evaluation of impact, define mechanisms for stakeholders/service delivery management, external support mechanisms*
   a. Governance to be driven by the appropriate MKI sub-board function that will incorporate the associated partners, experts, funders, site-specific collateral, etc
   b. M&E strategy via the existing DPME/Premier’s office guidelines in terms of the PFMA and associated legislation

4. STEM Alignment to Economic Growth Pillar
   *Alignment to local economic development, provincial, national and regional policy framework and initiatives, etc*
   a. Throughout this document, the theme of STEM as an economic catalyst is inter-woven into every proposed intervention.
   b. Cognizance is taken of the National Development Plan, the KZN Provincial Growth and Development Plan, existing MKI policy and initiatives, etc and incorporated as reference points
   c. In addition, the policy pronouncements and discussion documents of the ruling party have been taken into account.
   d. The emerging guidelines of the OECD, UN, the World Economic Forum and similar think tanks have been interrogated, dissected and assimilated where appropriate to constitute this document.

Acknowledgements:
The guidance, access and interaction of the Moses Kotane Institute senior management including Acting CEO Mr Ranveer Persad, Ms Thandeka Ellenson (CFO) and Capt. Bheka Zulu is acknowledged and appreciated.
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The team would like to also acknowledge the guidance and critical input of the core team - especially in the wake of a personal tragedy and trying personal circumstances.
Executive Summary

Contextual Background

• The Moses Kotane Institute (MKI) is one of twelve entities of the KwaZulu-Natal Provincial Department of Economic Development, Tourism and Environmental Affairs (KZN EDTEA). Historically the Moses Kotane Institute (MKI) was set-up to develop the knowledge base to enhance the knowledge economy and to promote high performance and value-based culture. The majority of its thrust was funding Education and Training initiatives that sought to increase the participation of marginalised communities including the youth, women, etc. in the Science, Engineering and Technology domains.
• The MKI Board has since changed its focus to be centred on developing strategies that act as a catalyst for Economic Development in the province.
• Given the discussions vis-à-vis rationalization of the number of public entities; this may be an opportune time to re-position the organization to effectively become the:
  • One-stop shop, a think –tank, thought-Leader, research hub and knowledge repository for the KZN EDTEA and its related entities:
    1. Tourism KZN,
    2. KZN Sharks Board,
    3. Ezemvelo KZN,
    4. KZN Growth Fund,
    5. Trade Investment KZN (TIKZN)
    6. Ithala
    7. Dube Trade Port
    8. Richards Bay Industrial Development Zone (RBIDZ)
    9. KZN Film Commission
    10. Liquor Authority
• In addition, the KZN province has arrange of Clusters (some of which are entities solely funded by the KZN EDTEA and some co-funded by third-parties such as the Ethekwini Municipality.
  • Maritime,
  • Automotive,
  • ICT,
  • Fashion
  • Tooling
  • Clothing and Textiles
  • Craft
  • Materials Recovery
  • Electronics
  • Furniture
  • Chemical,
• This creates an opportunity for the MKI to provide research-based inputs to service the requirements of the political and administrative leadership, for strategy, planning and implementation purposes; and act as a developmental resource.
• Essentially this would entail that in future - MKI will develop strategies and programmes over and above, yet complementary to the formal “Education” vertical. Thus shifting from a “FUNDER role to that of “PARTNER” to the Education sector); i.e. Assume the role of a “strategic partner, not service provider” role.
• This will result possibly result in a new operating modality that will inter alia promote/provide:
• A transformative and empowerment agenda that creates opportunities for the citizens of KZN and unlocks the KZN economy; primary (agriculture), secondary (manufacturing/processing) and tertiary (Services)

- Create broad public awareness of the changing world of work, the disruptive nature of the digital economy, the Fourth Industrial Revolution, and manufacturing and industrialisation challenges; adaptability and mobility; and equipping the stakeholders for the global challenges

- Applied and Economic research to unleash the potential of the economy; discover new opportunities; in oil & gas, maritime, ocean economy, tourism, aquaculture, agriculture & agro-processing, tourism, energy,

- Collaboration with the educational sector, the public and private (corporate) sector, organized business and social partners

- Develop human Resources equipped with STEM skills to implement the KZN Agenda for Sustainable Economic Growth, Radical Economic Transformation, Industrialisation (IPAP), Manufacturing, Empowerment, Job-creation & competitiveness.

- Seeks to make KZN the leading education and training and research hub of the region

- The enhanced supply of skills and qualifications to increase the competitiveness of labour markets

- Promote Youth Development via programmes that promote innovation, entrepreneurship and sustainability via skills training in partnership with the various SETA’S, donor agencies, diplomatic-core, CSI funders, Operation Phakisa, Tooling Initiative, Foundry Network, Techno-parks, etc...

Implementation of a STEM Strategy as an Economic catalyst

- KZN - the second largest economy in South Africa with a very progressive outlook towards new initiatives and has many economic projects e.g. Richards Bay IDZ, Dube Trade Port, Aerotropolis, Techno-hubs, Ship-building and ship-repair, Maritime Clusters, the Ocean Economy, Automotive Supply Park, Aquaculture, Green/Renewable economy, Renewable Energy, Chemical Parks, etc.

- The economy is still largely driven by agriculture and tourism; gainful employment is a major issue for the youth; as well as the re-training of the existing workforce as well as re-purposing of jobs.

- However a strong STEM-inspired thread can be catalytic e.g. A more scientific approach to farming without the difficulties of studying “high level science” understanding and implementing the applications thereof.

- The desired shift to Industrialization - developing a manufacturing economy; such growth is driven by innovation and participation of youth (and older stakeholders); followed by a vibrant service economy.

- Beneficiation - a seismic shift from exporting primary resources to continuous and sustained value-addition (e.g. conversion to value-added intermediate and/or consumer products) is the key to increased prosperity.

- Provide appropriate human resources for the pivotal role of driving these new challenges.

- A comprehensive approach to implementation of a well-defined STEM Learning Strategy - A Strategy that starts working with learners in pre-primary (ECD) primary, middle and high school itself when they need guidance the most and are open unlearning the old and re-learning the new will be apt. An action plan that involves the teachers, parents as well as the corporates and community to address the aspirational needs of its youth is imperative. By necessity, this strategy must be wholly inclusive of those who have dropped out of school, job-seekers, unemployed graduates (to enable greater and improved employability) as well
as enhance the employability of the graduate cohort. The repository should ideally also be a resource to those seeking to re-purpose their inherent skills and knowledge, adjust their existing skillset as well as serve as a career-guidance resource for parents, teachers, learners, employers, etc.

**STEM skills are increasingly important for the competitiveness of the KZN economy**

- Skills Development in terms of Economic Development priorities for KZN is a growing imperative as the specific need for STEM skills become increasingly critical to retaining business competitiveness and attracting strategic industries and investments.
- South Africa under-performing internationally (WEF) compared to STEM strong countries
  - Participation by primary and secondary school learners in STEM related subjects is decreasing and performance is below many countries in terms of international comparisons.
  - There is a need to develop more engaging school curriculum and pedagogy to attract learners to STEM-aligned careers
  - Participation by university learners in STEM related disciplines is not keeping pace with the needs of the economy and is low compared to other like-economies.
- South Africa unlike many other comparable countries (OECD) lacks a national STEM skills strategy driven in concert with industry.
  - School – industry STEM initiatives are characterised by un-coordinated and non-systemic activity.
  - University – industry collaboration, including STEM fields, is low by international comparison.
  - Financial assistance to STEM is thinly dispersed, non-systemic and does not contribute to a national approach.
- There is a need to increase the qualified STEM teaching workforce. Employers report significant difficulties recruiting technicians and trades workers with STEM skills. Those employers that promote STEM skills most commonly do so through work placements, work experience and internships.

**The broad goals of the proposed STEM Strategy**

**STEM EDUCATION AND TRAINING: Background**

- Integrates science, technology, engineering, & math into a seamless learning experience
- Uses project-based learning
- Reinforces real world application
- Prepares learners for integrated careers (allowing easy movement across disciplines)
- Develops “soft” and technical skills

**Role of STEM Strategy:**

- Increase of interest, awareness and understanding of community in the STEM-related skills to participate meaningfully in the Fourth Industrial Revolution and leveraging the Digital Economy; the criticality of STEM Learning as an imperative for innovation, wealth creation (personal & national) and for success in the 21st Century
- Develop an ecosystem relevant for active economic participation by the unemployed, out-of-school and retrenched
- Establish the infrastructure and ecosystem of people, process and pedagogy that will deliver the STEM learning
- Initiate career guidance strategies related to STEM fields to promote enrolment in the TVET and higher education institutions
- Develop strategies that enhance job-readiness, increased employability, entrepreneurship, innovation, etc.
• STEM Learning will also lead to an atmosphere where entrepreneurship and job creation strategies are also given prominence along with access to STEM-orientated careers at school level via dynamic career guidance strategies.

The next waves of disruptive technology — AI, robotics, virtual reality, IoT and sharing economy platforms — will create an enormous degree of labour displacement. To appreciate the scale of blue-collar displacement ahead from driverless vehicles alone, for instance, consider that driving is the single largest occupation of US men today.

Even white-collar and creative work will be affected

Algorithms have uprooted white-collar work in the financial sector (high-frequency trading) and are starting to do so in health care (mobile health apps, robotic surgery, diagnoses by algorithm). Algorithms are writing articles indistinguishable from those written by humans and have even recently composed a musical play. Not all jobs will be affected, and not all affected jobs will be eliminated — as always, automation will both replace and supplement human labor — but jobs that are truly untouched will be the exception rather than the norm.

Moving from the gig economy to the machine economy

The future of work evolving in two stages:

• The gig economy. The rise of platforms such as Uber, Airbnb, Etsy, Didi Kuaidi, Deliveroo and TaskRabbit has already spawned a gig economy in which non-employee freelancers provide labour in temporary assignments.

• The machine economy. The next stage of disruption will be driven by AI and robotics: the mass disruption of labour and the rise of the machine economy.

We are in the early stages of these shifts, and it’s hard to know exactly how they will play out. History shows that automation surprises us with new sectors and forms of employment. Just as digital disruption spawned jobs for web designers and app developers, the machine economy is likely to generate jobs, companies and even entire sectors that we are unable to envision today.

Fourth Industrial Revolution, Disruptive Economy, Artificial Intelligence (AI), Robotics and 21st Century Skills

Technology powers growth and transforming economies; Technology represents new ways of doing things and creates lasting change, which allows economies to create more value with less input. Technology often alters the way people live and work, rearrange value pools, lead to entirely new products and disrupts, rendering old skills and organizational approaches irrelevant. The “fourth industrial revolution”, some call it “Industry 4.0” - the combination of cyber-physical systems (CPS), the Internet of Things (IoT), the Internet of Systems (IoS) and "cloud computing.” It’s a revolution of networks, platforms, people & digital technology. The fourth industrial revolution is marked by the digitization of production processes, disruption of the status quo, and the use of new materials (nanotechnology), artificial intelligence, drone, autonomous driving, smart factory, etc.

The term 21st century skills refers to:

• a broad set of knowledge, skills, work habits, and character traits - important to success particularly in education; contemporary careers and workplaces; and can be applied throughout life.

• encompasses a wide-ranging body of knowledge and skills that is not easy to define

• a number of related terms—including applied skills, cross-curricular skills, cross-disciplinary skills, interdisciplinary skills, transferable skills, transversal skills, non-cognitive skills, and soft skills, among others - for the purposes of practicality.

• The six core elements of 21st Century Learning are:
• Emphasize core subjects
• Emphasize learning skills
• Use 21st Century tools to develop learning skills
• Teach and learn in the 21st Century context
• Teach and learn new 21st Century content
• Use 21st Century assessments that measure core subjects and 21st Century skills.


How do we go about promoting these experiences and understandings in our learners?
The development of extra-curricular and co-curricular activities that are academically rigorous and based around inquiry or project-based learning. Extending the typical classroom beyond the physical walls of the school by engaging the learners in the world around them and by using the resources of the places (Home, community, local public and private facilities, museums, libraries, etc that they and their teachers have come from. Digital technologies and international mindedness are embedded into all areas of the curriculum.

How can we do better?
There needs to be more emphasis on the Arts and Design, to promote creativity and self-expression. There is no doubt that teachers and administrators could probably do a better job of being engaged with one other in a process of continuous learning and that the entire community (parents, business, etc) could all do more to actively participate, innovate and support one another. Most important of all is transformational leadership which questions the way things have always been done, is open to discussion about the issues the community feels are important and inspires everyone in the community to embrace a shared vision and to change and move forward. The nature of leadership has changed. We have gone from leaders who operate like the conductors of symphony orchestras (command and control with individual musicians playing as directed) to leaders who see their role more like that of a jazz ensemble: there is a main theme but the final piece is the result of improvisation and innovation by all the musicians. Most importantly of all the leader is not the only star on stage, but each person has a role in the spotlight to add to the development of the theme. A transformational leader provides the theme and the environment where the most inspired development can take place.

Just as dissonance, a lack of harmony, is important to jazz music. It's important in schools too, so that issues are brought out and discussed in an atmosphere of trust. Just as all the players in a jazz ensemble don't always know where the music will take them, the start of an inquiry can be hard for teachers as they don't know where the unit will go or where the learners' questions will lead them.

STEM Strategy for KZN: a Suggested Approach
Specific to the economic and social goals of KZN along with the availability, maturity of the capacity and capability of the system, a three-phase approach of implementing the STEM Learning Strategy is suggested. It is envisaged that it will be designed around the proven STEM Immersion Model that moves a community from Exploratory and Introductory stages to Partial Immersion Model and finally to the Full Immersion Model. This will also ensure work is done on the easy periphery to show quick results before making deeper inroads to build positive momentum and stakeholder acceptance and adoption.
• Policy Makers.
• Policy makers could benefit from an informed and comprehensive view of how economies benefit from new technologies. They should encourage development of the technologies that are most relevant to the local economies.

• **KZN Government leaders.**
  • As disruptive technologies continue to evolve, it beckons leaders to maximize the opportunities while dealing with the challenges. Leaders need to be on the winning sides of these changes: by being early adopters or innovators or by turning a disruptive threat into an opportunity. The first step is for leaders to invest in their own knowledge. Leaders need to know what technologies can do and how to “bend” it to their strategic goals: they cannot wait until technologies are fully baked to think about how they will work for – or against – them.
  • Gig economy start-ups are already challenging regulations governing the operation of hotels, restaurants, taxis and more. As the trend accelerates in the machine economy, governments will need regulatory regimes designed for the future – nimble, real-time and powered by big data and smart technologies.

• **Business.**
  • Business will need to find ways to get the workforce they need, by engaging with policy makers and their community to shape education and training, as well as by investing in talent development and training. Business will also need to disrupt their own business models before a rival or a new competitor does it for them.
  • The disruption of work is already spawning business model innovation. The ultimate resource that companies will use more efficiently is the human resource. Just as disruption unbundled music albums into songs, it will unbundle jobs into tasks, with each task performed in the most efficient manner.

• **Disrupting society.**
  • Income inequality could be greatly exacerbated by wholesale labour displacement and by the dismantling of key elements of the social safety net – requiring new solutions. Meanwhile, the machine economy promises to deliver an unprecedented “leisure dividend,” with profound social implications.

**STEM Strategy Implementation – an Immersive option**

**Phase 1:**
• Introduce STEM learning to stakeholders without disrupting existing school systems. External points of stakeholder engagement beyond the ‘formal’ school system such as community facilities, government department facilities, public facilities Libraries, Museums, KZN Techno-hubs; digital innovation hubs and industry-academia collaboration sites, Public and Private Science Centres, the workplace, Strategic alliances with entrepreneurs, etc. can be utilized as STEM Learning Centres to ensure STEM activities that are easily accessible and available as optional but incentivized to be consumed.
• The strategic use of Digital, Mobile and E-learning platforms should be investigated and implemented.

**Phase 2:**
• Providing STEM learning engagements within the school system as a complementary and supplementary program.
• Focuses on exciting, shorter duration, easy to immerse-in STEM engagements to pre-primary (ECD), primary, and high-school learners leading to development of skills with career-guidance initiatives; develop college readiness strategies.
• Start capacity building through educator (teacher/principal) on STEM relevance, skills and processes for implementation.
• Build collaborations with Industry; alignment of programme goals & industry needs: essential for employment, entrepreneurship

Phase 3:
• This is a ground-breaking phase requiring the entire ecosystem (not just the education system) to be re-aligned at a conceptual level to deliver all learning through a project-based learning methodology (trans-disciplinary and multi-disciplinary immersion) and every classroom/workplace/facility is an integrative STEM Learning Centre in itself.
• This Full immersion model is more like a 21st Century workplace and is the aspirational and desirable future to be in.

STEM Strategy Implementation – suggested options

Public Awareness Campaigns
• STEM education plays a big role as the catalyst to meet the challenges and demands of the present and future economy
• Encourage more youth and learners to select STEM subjects; Educate the public about the diversity of career opportunities in STEM
• Informal approach to strengthening interest in STEM education and careers; Provide hands-on learning opportunities for learners and parents

Enthusiastic young people is vital, but teachers remain key
• After-school programs – encourage learners participate in extra-curricular (out-of-school) programs; by providing with engaging materials with preparation and guidance on how to use those materials to enrich experiences in STEM.
• STEM contests – that can reward creativity and problem solving. Science fairs to show-case projects in this fair so as to introduce them to a community of like-minded peers. Designing and building – which is another form of out-of-class is another program that is suitable for stimulating student’s interest in STEM program; extended projects based on inquiry, construction, and discovery for learners.
• Vacation programs - learning with the objective of building the interest of science-orientation; as well as professional development for the teachers, unemployed youth etc.

Source other public sector-implementation partners – an example
The KZN Provincial Developmental Finance agency - Ithala is well positioned to serve emerging markets in outlying/rural areas — where a dire need for a better quality of life exists — with its empowerment programmes.

• The Siyasebenza initiative ("we are working") is a series of development-based outreach programmes created to uplift & empower aspiring youth, women and SMMEs in townships and rural areas to become entrepreneurs.
• Imbokodo lyazenzela ("women doing it for themselves") is an enterprise development for women.
• The Inkunz’isematholeni ("Youth in Business") programme to tackle unemployment.
Moses Kotane Institute – a new modus operandi
Some thoughts and ideas??

As one of the agencies of the KZN Economic Development, Tourism and Environmental Ministry, the Moses Kotane Institute (MKI) has recently decided to change its mandate from primarily a funder of education programmes (as it has from its inception) to acting as a catalytic economic developmental agency for the KZN provincial Ministry of Economic Development, Tourism and Environmental Affairs (KZN EDTEA).

As per the founding document: “MKI’s aim is to enhance economic development through science, engineering, technology and mathematics skills. This skills enhancement is not only for the current and future workforce, but encompasses all levels of government officials. MKI runs focussed programmes in line with national government’s objective of a developmental state. The broad aim of the institute is to contribute to a people-centred economic development achieved through a service delivery system led by technically skilled South Africans. It is essential that this is supported by a clear understanding of South Africa’s political history – one that was characterised by poor skills and underdevelopment amongst the majority of people.”

Examining this change in focus contextually within the national agenda, South Africa’s struggle for democracy encouraged intellectual activism at various levels of abstraction. Over the years, the country also developed areas of excellence in some natural sciences and application of technology. The South African story fascinates humanity because it represents the confluence of successes, challenges and aspirations that relate to global human advancement and solidarity across race, social status, religion and other attributes.

The Moses Kotane Institute (MKI) is constructed on these foundations, drawing lessons from the past and contributing to charting a course towards a future of peace, prosperity and general human fulfilment in our country and the continent of Africa, and across the globe. It is envisaged that the re-constituted MKI will also incorporate a research institute that takes a long-term view on the strategic challenges facing KwaZulu-Natal – with centrality on acting as a catalyst in the domain of economic and human resource capital development of the province.

A Visioning statement for KZN:
The vision is deliberately bold, aspirational and provocative. The implicit challenge for MKI is to lead a new phase of transformational change for KZNs economy. The vision demands that KZN exceed expectations, compete in a global context, and become internationally recognised as a leading region.
Furthermore, the vision carries the notion that prosperity, vibrancy and liveability are symbiotic. Each quality enhances the other two, and success requires coordinated management of all three. We see KZN thriving in 2030, with robust growth and high social mobility. Commercially, KZN will be known as a ‘living lab’, a globally connected leader in creative solutions and design thinking. Our reputation will be as ‘the place of the possible’; a destination of choice to visit, study, work, live, invest and succeed.
Realising this vision requires us to think and behave differently. KZN has a distinctive set of skills, resources and opportunities. MKI is committed to pursuing the realisation of this unique potential with the same boldness and ambition that informed our founding vision.

KwaZulu-Natal is the third-smallest province in South Africa, yet the second-largest contributor to the South African economy.
KZN is SA’s second largest economic contributor

According to Standard Bank 2016 review *(Feb 2017)*, KZN makes a contribution of 15.7% to the national GDP.

Figures showed that KwaZulu-Natal accounts for:

- 27% of the country’s agriculture sector;
- 22% of South African manufacturing;
- 13% of the value added in the country’s construction sector;
- Around 16% of the country’s electricity, gas and water output – placing it in second position to Gauteng’s 33%;
- 18% of the country’s retail & wholesale trade, catering & accommodation;
- An 23% stake of the nation’s transport, storage and communication facilities;
- 14% of the country’s finance, insurance, real estate and business activities; and
- At least 14% of South Africa’s community, social and personal services sector activity.

The factors outlined contributing to KZN’s position include:

- Manufacturing, trade, transport and the finance sector are key role players in KwaZulu-Natal’s economy. It is also important to note is that agriculture, manufacturing, trade and transport have a comparative advantage, as these sectors are much larger in size in the province’s economy than in the national economy.
- Its annual growth expectations are very similar to those anticipated for the national economy.
- The manufacturing sector, with its expected contribution of approximately 17% to the province’s economy, ranks it as its fourth largest sector.
- Of significance is the fact that this share of the manufacturing sector in KwaZulu-Natal exceeds the size of the manufacturing sector in all the other provinces, as well as in the national economy (12,4%).
- At a more detailed economic sector level, the province’s strong stance in manufacturing is reflected by the comparative advantage it has in eight of the ten manufacturing related sub-sectors.
- Many of the challenges faced by key sectors of the KwaZulu-Natal economy are similar to those experienced elsewhere in the country.
- However, the overall economic strength and diversification of the provincial economy will ensure that the province remains a key contributor to South Africa’s GDP.

Making a unique Economic Impact will require:

- An analytical approach used to estimate economic benefits from projects or programs in KZN
- Economic benefits determined by spending patterns, investments, and job creation
- Economic benefits are measured in terms of output, value added, jobs, household earnings, and taxes
- Measured benefits for a specific sub-region and time period
- Employment Impact : Number of jobs created
- Labour Income Impact : Payroll paid to employees plus entrepreneurs’ income
- Output Impact : Total value of goods and services produced
- Value Added Impact : Value of goods and services less the intermediary goods and represents a portion of output (GDP)
- Tax Impact : National and local tax revenues
- Direct Impact : The initial value of goods and services the organization purchases locally
- Indirect Impact : Jobs and production needed to produce goods and services required by organization
- Induced Impact : Change in local households spending due to increased earnings
In addition to conducting research and providing advisory services to entities in the public and private sectors on politics, policy and other related areas; a critical contribution will be to strengthening democracy and promoting an open society, our experts also participate and offer their perspectives in public discourses.

Possible goals of the Institute could include some/all of the following:

- To be the first point of reference on progressive ideas affecting KZN. KZN needs people with technical and intellectual capacity to inform decision-making and to lead society. MKI endeavours to be a well-known incubator of technical expertise and a source of advice to private and public entities.
- MKI aims to be an independent research institute that takes a long-term view on the strategic challenges facing KZN.
- MKI will focus on research, academia, policy-making and governance who saw the need to create a platform of engagement around strategic issues facing KZN. It is an entity that combines research and academic development, strategic reflection and intellectual discourse. It applies itself to issues such as economics, sociology, history, arts and culture and the logics of natural sciences.
- MKI seeks to combines research and rigorous discourse with an array of partners, and seeks to deepen debate and broaden avenues of enquiry on a plethora of issues, including economics, governance, history, art, culture and natural sciences.
- MKI endeavours to provide platforms for dialogue and forge partnerships for intellectual exploration that both bolster a fledgling democracy, and push the boundaries of limited expectation as a result of our fractured history.
- MKI combines research and rigorous discourse with an array of partners, the Institute seeks to deepen debate and broaden avenues of enquiry on a plethora of issues, including economics, governance, history, art, culture and natural sciences.
- MKI is predicated upon a long-held and deeply entrenched passion among Southern Africans to deliberate socio-political issues that have both a local impact and a global resonance.
- MKI provides a platform of engagement around strategic issues facing KZN. The Institute combines research and academic development, strategic reflection and intellectual discourse. It applies itself to issues such as economics, sociology, history, arts and culture and the logics of natural sciences.
- MKI combines research and rigorous discourse with an array of partners, the Institute seeks to deepen debate and broaden avenues of enquiry on a plethora of issues, including economics, governance, history, art, culture and natural sciences.
- MKI will provide platforms for dialogue and forge partnerships for intellectual exploration that both bolster a fledgling democracy, and push the boundaries of limited expectation of our fractured history.

Economic Goals:

- Facilitate revenue and employment growth in KZN’s regional hubs;
- As an embodiment of the K”KZN as a learning region”, significantly increase the participation rate of local learners (Students) as well as attract international students in the KZN region;
- Develop the available skills in the workforce;
- Attract new businesses and direct investment to the region;
- Increase the contribution to KZN’s GDP of tourist/business spending;
- Maximise the return on investment of KZN’s major events portfolio;
- Increase the economic contribution of events hosted in KZN-managed events and venues;
- Leverage the major infrastructural investments (SIPS) scheduled for the region; and
- Enhance KZN’s global reputation as a destination to visit, live, work, study and invest.
Facilitate opportunities for businesses operating in an environmentally sustainable manner.

MKI is constructed on these foundations, drawing lessons from the past and contributing to charting a course towards a future of economic prosperity for KZN. **What form should MKI take – a research institute, a think tank, etc?**

A **research institute** conjures up a variety of possibilities: independent, non-aligned, etc – these are questions that the authorities need to consider in the context of the agreed mandate and anticipated goals of the organization.

The concept of a ‘**think tank**’ is well known; more often as a research organization that undertakes public policy research and analysis and intended to influence policy dialogues and advocate policy solutions. Some are strictly non-partisan, researching policy issues without regard to partisan political outcomes, while others see one of their main functions as providing intellectual support to political parties and legislators. In addition, a think tank, policy institute, or research institute is an organisation that performs research and advocacy concerning topics such as social policy, political strategy, economics, military, technology, and culture.

In many developing countries, think tanks effectively engage with development actors to provide evidence-based contributions to processes that aim to achieve national, regional and international goals and visions. Basically, think tanks stimulate evidence-based policy debates and policy formulation, and they participate in the monitoring and evaluation of policy implementation programs, potentially leading to policy reviews. In doing this, think tanks create evidence-based awareness about past, present and future development trajectories. In the process of such awareness creation, they contribute to local-context-relevant customization of global development agendas such as the Sustainable Development Goals (SDG’s) and corresponding financing strategies. The outcomes of such engagements depend on a number of factors including relationship building in the research-to-policy-to-action spectrum, where context is a major factor.

Objectives will include inter alia to (A) **inform** policy makers, stakeholders, and the public at large about issues that are important for the global economy and for economic development. By doing this, one hopes to (B) **shape policy** by presenting evidence and rationale on what works and what doesn’t in economic development and economic policy. This requires two things - research and outreach.

To **inform**, one need to know something! So, one will try to ask interesting, policy relevant questions and then do one’s best to answer them by doing research and improving the understanding of what drives certain outcomes. The research process involves reading and number crunching, but also involves talking to people, testing ideas, collaborating, learning from different experiments, partnering with others to combine resources, etc. All of these inputs will end up with reports, papers, presentations, conferences, and other channels that put the ideas into a transferable format.

To **shape policy**, one also need to communicate one’s ideas to policymakers and participate in efforts that inform the policy-making process. It is important to note that this does not mean lobbying or advocating for specific legislation. Rather, it means informing participants in the policy-making process so that they can make informed decisions and, hopefully, effective policies. This ranges from direct participation in reports commissioned by development agencies, in working groups tasked by governments to identify key priority areas for development, in speeches and presentations given to key “influencers” or directly to policymakers, or in one’s own reports that are designed to support understanding of (or helping to design) a specific agenda like the UN’s Sustainable Development Goals, for example. Think tanks try to measure their “impact” in a variety
of quantitative and qualitative ways that include number of citations (how often one’s research is cited and by who), participation in panels or commissions, media interviews, etc.

But in general, think tanks focus on research that is focussed on public problems with recommendations on what can or should be done to solve them. So while the research is focussed, it will tend to be of a general nature suitable for policy development. This role is different from the scientific community, which is more interested in more distinct research of a more specific nature suitable for advancing scientific theory. Think tanks will refer to scientific information, but will also be interested in considering the political implications of the science as well. Think tanks are fairly common in developed economies, and increasingly in developing economies. But the breadth and depth of their interests and specializations, and the influence they have over policy-makers and private-sector leaders varies considerably.

Internationally, leading think tanks range from the Brookings Institute, Rand Corporation, Aspen Institute, Singapore Institute of International Affairs (SIIA), Konrad Adenauer Stiftung, Friedrich Ebert Stiftung, Chatham House, French Institute of International Relations (IFRI), Center for Strategic and International Studies (CSIS), Carnegie Endowment for International Peace, Bruegel, Woodrow Wilson International Center for Scholars, Fundacao Getulio Vargas (FGV), Council on Foreign Relations (CFR), Cato Institute, International Institute for Strategic Studies (IISS), etc.

Leading African think tanks include IMANI Centre for Policy and Education (Ghana), African Economic Research Consortium (Kenya), Council for Development and Social Science Research in Africa (CODESRIA), African Centre for the Constructive Resolution of Disputes (ACCORD), Food, Agriculture and Natural Resource Policy Analysis Network (FANRPAN).

Amongst the South African think tanks (however many of the older ones are steeped in legacies of the past) : South African Institute of International Affairs (SAIIA), Helen Suzman Foundation (HSF), Institute for Justice and Reconciliation (IJ&R), Centre for Development Enterprise (CDE), Free Market Foundation (FMF), SA Institute of Race Relations (SAIRR), Centre for Security Studies (ISS), Stellenbosch’s Bureau of Economic Research at (BER), UCT’s Development Policy Research Unit (DPRU), UDW’s erstwhile Institute for Socio-Economic Research (ISER), etc.

Amongst the newer think tanks are the Mapungubwe Institute for Strategic Reflection (MISTRA, Xubera Institute for Research & Development, Centre for Politics and Research,

A few points to consider in focusing the proposed think tank along an “economic development trajectory”:

- What is the background of the organizations’ existing personnel and within the associated institutional arrangements in both theoretical development economics and practical approaches, both successful and un-successful, used in the past? Should this be a constraint? Ideally not – as we propose a flexible structure in the following paragraphs that hypothetically yields the optimal staffing and capability arrangements.
- What are the possible limitations of the think tank’s approach? (Is it limited by political ties, for example?)
- How solid, and how creative is the basis for the think tank in its evaluation of both the current situation and the constraints and advantages prevalent?
- Can the think tank effectively hold out against political pressure? What are its vulnerabilities? Strengths?
- Will the think tank have cooperative relationships with academia, other think tanks, or governmental programs?
- What credibility will the think tank have with media and other key influencers? Does it seek to cultivate a narrative of building public awareness and political support for new initiatives?
I strongly recommend including successful entrepreneurs and a diverse group of business leaders (including gender, age, ethnicity diversity) in efforts at all levels. Their practical experience of economic limitations and constraints tempers theoretical recommendations.

Choosing the right organizations and individuals to lead an economic development effort — and doing everything transparently — helps increase effectiveness. But, as with most things in life, beware of anyone saying they have a “proven” solution. Every economic situation is unique, and if they come in with a cookie-cutter mentality, the project will be plagued.

Structure of the new organization
In the competitive landscape that dominates the 21st Century, new organizational structures that are replacing the traditional ones that dominated the landscape for decades with multiple management levels and large numbers of permanent staff working in clearly demarcated occupations. For organisations to thrive, they will need to be flexible and responsive to change, as these organisational models allow.

- The Shamrock Organisation consists of an inner core of fixed-term professional employees, supported by temporary or part-time persons (‘the contractual fringe’) who provide specific services needed on a contract basis.
- The Virtual Organisation is a temporary network of independent organisations and/or individuals collaborating in informal alliances towards a shared goal, and using a combination of information and communication technologies. The virtual organisation does not have a central office, an organisational chart or hierarchy. An ‘adhocracy’ is an example in which individuals with particular expertise get together on an ad hoc basis to work on a project. When the project is completed, the ‘entity’ disbands and the individuals may never work together again. [Many consulting business functions as an adhocracy, drawing expertise for specific projects into temporary associations based on the experience required for the projects.]

It is possibly moot that the MKI Board give consideration to having a core team that as a coordinators and intermediaries; those who disseminate, collate and manage teams drawn as per as assignment.

In this way, there is no need for a large permanent cohort, but a posse of flexible experts drawn from all possible areas, with a variety of expertise (ie. From professional organizations, academic institutions, etc) can be retained and/or engaged on an ad-hoc basis.

It is possibly the best way to harness the enormous potential of eminent and powerful resources (retired academics, development practitioners, planners, engineers, economists, LED-personnel, knowledge workers, etc) from a variety of sources, all imbued with a unique experiences and available on sort-term basis and without the concomitant burden of permanent staffing (and the challenges that brings – eg. office space, pension and medical benefits, labour law implications, financial implications, etc).

Further examination of Handy’s Shamrock organisational structure; it consists of three parts, or leaves: “A form of organisation based around a core of essential executives and workers supported by outside contractors and part-time help” – a typical “hub and spoke model”.

This model and variations of it are often used to explain the move to outsourcing non-core functions. In Handy’s analogy, the top leaf of the shamrock represents the core staff of the organisation. These people are likely to be highly trained professionals who make up the senior management; and will typically be strategists, knowledge core processors, et al.

The second leaf consists of the contractual fringe – individuals or other organisations – and may include domain experts, sector experts, etc – who provide services as required. These individuals operate within the broad framework set down by the core, but have a high level of discretionary
decision-making power to complete projects or deliver (generate new business and contact). Smart people are not to be easily defined as workers or as managers but as individuals, as specialists, as professionals or executives, or as leaders and that both they and the organisation also need to be obsessed with the pursuit of learning if they are going to keep up with the pace of change. Very often these kind of resources desire flexibility; and ideally MKI needs to have strategic access to such people. Eg. ICT or MIS, Marketing, training, etc. Thought must be given to synergy with academic and education institutions eg. funding of Chairs in relevant disciplines that will have value to the MKI mission.

The third leaf includes the flexible labour force. More than simply hired hands, in Handy’s model, these workers have to be sufficiently close to the organisation to feel a sense of commitment, which ensures that their work – although project-by-project, part-time or intermittent – is carried out to a high standard and seamlessly.

This could represent an ideal model for the envisaged “lite-MKI” structure going forward.

This flexible entity (MKI of the future) with the potential to be the:
- Catch-it-all entity that has unlimited access to resources on tap;
- over numerous domains
- serve every possible EDTEA-related issues in KZN – ranging from:
  - EDTEA Ministry – policies, white papers, position papers, advocacy positions, Tourism collateral, environmental research, public understanding of missions, etc
  - EDTEA MEC’s speeches, generation of new ideas, etc
  - Act as the common research platform for all the Provincial entities
  - Co-ordinate interaction within the provincial Clusters; develop their marketing literature
  - Liaise and interact with other provincial ministries to offer similar services – especially research and communications
  - Undertake strategic EDTEA-related strategic input for KZN Municipalities such as Investment Promotion, annual reports
  - Develop strategy and marketing collateral (multi-media, reports, marketing briefs, etc) for the Economic Development Agencies (EDA’s)

From a governance angle, MKI will constitute an advisory board that - inter alia - to:
- provide guidance on the broad direction of the Institute’s work by approving, monitoring and evaluating the strategic plans of the Institute
- contribute to the Institute’s broad strategic content
- exercise oversight on governance matters relating to the operations of the Institute, including approval of corporate governance principles as well as human resources and compensation policies
• act as the public face of the Institute on strategic governance matters
• contribute to building domestic and international partnerships
• receive reports from management and take strategic decisions on matters of governance
• exercise oversight with regard to the management of the funds of the Institute and, in this regard, approve investment policies, budgets and financial statements
• ensure appropriate systems to manage risks
• contribute to resource-mobilisation initiatives

However all of the reconfiguration of the MKI – must be co-located within the notion of developing KZN as a STEM-empowered region; one where innovation, entrepreneurship and prosperity are paramount.
STEM – An Overview

Given the global buzz with respect STEM education, exactly how can STEM play a role in assisting KZN and its people achieving the desired goals.

- **A transformative and empowerment agenda** that creates opportunities for the citizens of KZN and unlocks the KZN economy; primary (agriculture), secondary (manufacturing/processing) and tertiary (Services)
- Create **broad public awareness** of the changing world of work, the disruptive nature of the digital economy, the Fourth Industrial Revolution, and manufacturing and industrialisation challenges; adaptability and mobility; and equipping the stakeholders for the global challenges
- **Applied and Economic research** to unleash the potential of the economy; discover new opportunities; in oil & gas, maritime, ocean economy, tourism, aquaculture, agriculture & agro-processing, tourism, energy,
- **Collaboration** with the educational sector, the public and private (corporate) sector, organized business and social partners
- Develop **human Resources** equipped with STEM skills to implement the KZN Agenda for Sustainable Economic Growth, Radical Economic Transformation, Industrialisation (IPAP), Manufacturing, Empowerment, Job-creation & competiveness.
- Seeks to make KZN the leading education and training and research hub of the region
- The **enhanced supply of skills and qualifications** to increase the competitiveness of labour markets
- **Promote Youth Development** via programmes that promote innovation, entrepreneurship and sustainability via skills training in partnership with the various SETA’S, donor agencies, diplomatic-core, CSI funders, Operation Phakisa, Tooling Initiative, Foundry Network, Techno-parks, etc...

**Implementation of a STEM Strategy as an Economic catalyst**

In order to achieve strong economy and social development, a robust STEM and Innovation education strategy is crucial. It will have many elements- infrastructure, professionally trained mathematics and science teachers, innovative approaches in curriculum and its delivery, a strong public awareness programme for changing of attitude/mindset, knowledge and understanding and appreciation of science, technology and innovation as basic pillars of national development

**Critical points on STEM and economic development**
1. Science, Technology and Innovation (STI) power the economy
2. Absorption of STEM knowledge is necessary for making improvements
3. Nature of STEM curricula and its delivery will determine STEM awareness in society
4. Jobs in STEM fields have higher growth potential, earning power, and is likely to increase further
5. High level of mathematics and problem solving skills are in greater demand globally
6. Strong STEM education and innovative skills give competitive edge to a nation.
7. Decline in STEM knowledge capital reduces growth in basic science research which is essential for national growth.
8. STEM gap costs jobs, opportunities and money
9. GDP growth is linked to mathematics skills
10. Knowledge and skills are needed to solve tough problems of a nation; it requires selective gathering of evidence and evaluate data/information. These skills are inherently acquired in STEM education programmes.
11. Niche areas are necessary for national development - basically STI knowledge capital.
12. Success of economy, prosperity of people and their well-being depends upon cutting edge science, technology and innovation.
Now in the KZN context:

- KZN - the second largest economy in South Africa with a very progressive outlook towards new initiatives and has many economic projects e.g. Richards Bay IDZ, Dube Trade Port, Aerotropolis, Techno-hubs, Ship-building and ship-repair, Maritime Clusters, the Ocean Economy, Automotive Supply Park, Aquaculture, Green/Renewable economy, Renewable Energy, Chemical Parks, etc.
- The economy is still largely driven by agriculture and tourism; gainful employment is a major issue for the youth; as well as the re-training of the existing workforce as well as re-purposing of jobs.
- However a strong STEM-inspired thread can be catalytic e.g. A more scientific approach to farming without the difficulties of studying “high level science” understanding and implementing the applications thereof.
- The desired shift to Industrialization - developing a manufacturing economy; such growth is driven by innovation and participation of youth (and older stakeholders); followed by a vibrant service economy.
- Beneficiation - a seismic shift from exporting primary resources to continuous and sustained value-addition (e.g. conversion to value-added intermediate and/or consumer products) is the key to increased prosperity.
- Provide appropriate human resources for the pivotal role of driving these new challenges.
- A comprehensive approach to implementation of a well-defined STEM Learning Strategy - A Strategy that starts working with learners in pre-primary (ECD) primary, middle and high school itself when they need guidance the most and are open unlearning the old and re-learning the new will be apt. An action plan that involves the teachers, parents as well as the corporates and community to address the aspirational needs of its youth is imperative. By necessity, this strategy must be wholly inclusive of those who have dropped out of school, job-seekers, unemployed graduates (to enable greater and improved employability) as well as enhance the employability of the graduate cohort. The repository should ideally also be a resource to those seeking to re-purpose their inherent skills and knowledge, adjust their existing skillset as well as serve as a career-guidance resource for parents, teachers, learners, employers, etc.

STEM skills are increasingly important for the competitiveness of the KZN economy

- Skills Development in terms of Economic Development priorities for KZN is a growing imperative as the specific need for STEM skills become increasingly critical to retaining business competitiveness and attracting strategic industries and investments.
- South Africa under-performing internationally (WEF) compared to STEM strong countries
  - Participation by primary and secondary school learners in STEM related subjects is decreasing and performance is below many countries in terms of international comparisons.
  - There is a need to develop more engaging school curriculum and pedagogy to attract learners to STEM-aligned careers
  - Participation by university learners in STEM related disciplines is not keeping pace with the needs of the economy and is low compared to other like-economies.
- South Africa unlike many other comparable countries (OECD) lacks a national STEM skills strategy driven in concert with industry.
  - School – industry STEM initiatives are characterised by un-coordinated and non-systemic activity.
  - University – industry collaboration, including STEM fields, is low by international comparison.
- Financial assistance to STEM is thinly dispersed, non-systemic and does not contribute to a national approach.
- There is a need to increase the qualified STEM teaching workforce. Employers report significant difficulties recruiting technicians and trades workers with STEM skills. Those employers that promote STEM skills most commonly do so through work placements, work experience and internships.

**STEM Education and Training**
One needs a reliable pipeline of specialist STEM skills; but one also need informed workers, users and consumers who have the curiosity and imagination to be part of the broader STEM economy. This must be underpinned by lifetime engagement for all South Africans with STEM, beginning in childhood and constantly renewed as knowledge and technologies expand. The education, formal and informal, should prepare a skilled and dynamic STEM workforce, and lay the foundations for lifelong STEM literacy in the community.

In the instance of technology, real systemic change is required to cultivate a shift from consuming technology to creating with technology. The only way to achieve this is through STEM skills and prioritizing computational thinking, problem solving and innovation from a young age; enabling opportunities in whichever field students choose as a career path.

Work undertaken by the various global think-tanks and consultancies shows that STEM skills are increasingly important to the global workforce and that participation by university students in STEM disciplines is not keeping pace with the changing needs of the economy – particularly when compared to peer economies. The difficulty experienced in recruiting employees with STEM skills was reiterated by a survey commissioned (South African Chamber of Commerce and Industry (SACCI report 2015) by which some 20% of employers report a mismatch between the skills they require and those of applicants. The survey also found that some 50% of employers expect their need for STEM professionals to increase in the next 5 to 10 years. It was also found that less than 30% of respondents thought that the current school curriculum is adequate in preparing students with the skills they need for the future.

While the employment of ICT professionals has grown strongly over the 10 years to May 2014 (notwithstanding the decline in student numbers taking up ICT courses), the feedback from employers is that the vast majority of graduating students were not suitable to the advertised position. The South African Chamber of Commerce and Industry (SACCI report 2015) reinforced this gap – with 36% of business surveyed identifying the lack of tertiary qualifications relevant to the business and 34% the lack of employability skills and workplace experience a major barrier to ICT graduate employment. The mismatch between the needs of industry and tertiary graduate qualifications is a general one impacting the whole of the ICT industry but it is particularly playing out in new and dynamic areas of technology capability where course pedagogy is not keeping pace with rapid technology developments. The Report also highlighted the need for increased Industry support and targeted youth engagement programs that harness and encourage young people to develop STEM based skills and specifically, pursue ICT based careers. While parents saw the value of their children pursuing a digital career few felt that this was a career of interest to them.

Program investment, Industry engagement and education agility are necessary to strengthen the pipeline of STEM and specifically ICT skilled graduates. In the meantime the focus of local ICT companies (especially the multi-nationals) remains focused on retaining the skills they need to be competitive; retraining graduates to meet their requirements; and where all else fails, recruiting skills from overseas. Lack of skills translates to lack of capacity and capability which invariably impacts the ability of companies to focus efforts and resources on developing export capability.
Developing a holistic approach to STEM and education and training
Noting the education and training initiatives currently in play; however the view that long-term investment into a national cross-departmental STEM framework is required and that a national education strategy developed that incorporates all aspects of Science, Technology, Engineering and Mathematics. One also flags that one have a shortage of supportive programs, which require a holistic framework to leverage, measure and build upon best practice initiatives. An envisaged Industry STEM skills partnerships project will help to coordinate expansion of current/future activities.
Further, the advocacy of the creation of a strategic national STEM policy framework that is centrally driven and funded and includes both curriculum reform and new teaching standards. It should include decentralized program initiatives and partnerships and link STEM activities in schools, vocational and higher education with industry, business and STEM professionals and supported by world class university programs.

Interconnectivity of programs, disciplines and implementation is critical to the success of the STEM agenda. This needs to be supported by a sound STEM policy framework that includes career, program and education mapping to best build foundations for STEM success and amplification rather than duplication. At a practical level this means broadening initiatives such as National Science Week (NSW) to include a focus on all STEM disciplines. A design-thinking and user experience approach is needed to remove current segmentation and “silo-ing” of disciplines. Communication about STEM needs to be inclusive of all STEM disciplines and language describing STEM must be consistent.

The value of inquiry-based learning or project-based learning is critical in executing an effective STEM strategy and this needs to include a focus on real-world contexts or situations. The relevance, importance and opportunities STEM capabilities offer need to be clear to all young people not just high achievers.
Vision for a STEM-enabled KwaZulu-Natal Province

Preamble:
Science, Technology, Engineering and Mathematics (STEM) skills, knowledge and capability unlocks opportunities for all of us to flourish and grow as individuals, as communities and as a province. Every child in KZN, from the early years onwards, should experience the wonder and excitement of STEM, growing and building the skills and knowledge that they will need in life and in work.

STEM ignites our curiosity about and helps us enjoy and comprehend the natural and physical world around us. STEM skills and knowledge help us to understand, engage with and tackle important issues in society such as climate change and sustainability. STEM helps us be inquiring, productive, creative, inventive and enterprising as individuals and opens up high quality, rewarding, flexible and engaging jobs and careers for us all.

KZN’s economy needs a highly numerate, digitally skilled, capable, creative, entrepreneurial and empowered workforce with a global outlook. There is huge demand for STEM skills, knowledge and capability in the economy today and this demand is projected to grow. Numeracy and digital skills in particular are increasingly fundamental right across the labour market. The careers and occupations that rely on STEM are diverse and range from healthcare and medicine, animal health, engineering, life sciences, and construction to beauty, design, tourism, retail and financial services.

All children and young people need to develop the skills and confidence to use and understand mathematics, technology and science in their day-to-day lives, as well as in whatever career they choose. We also need to ensure there are opportunities for young people and our current workforce to access the STEM skills and knowledge they need in a developing and fast-changing labour market, and across careers that are becoming increasingly diverse and varied.

KZN has much to do if we are to meet the demands and challenges of our economy and build the society we want to see now and in the future.

STEM skills are increasingly important for the competitiveness of the KwaZulu-Natal (KZN) economy

- South Africa as a nation is under-performing internationally compared to STEM- strong countries.
- STEM skills are increasingly important to the KZN workforce.
- Participation by primary and secondary school learners in STEM-related subjects is decreasing
- There is a need to develop more engaging school curriculum and pedagogy to attract learners to STEM.
- There is a need to increase the qualified STEM teaching workforce and performance is below many countries in terms of international comparisons.
- Participation by university students in STEM related disciplines is not keeping pace with the needs of the economy and is low compared to other like-economies.
- Employers report significant difficulties recruiting technicians and trades workers with appropriate STEM skills.
- Those employers that promote STEM skills most commonly do so through work placements, work experience and internships.
- South Africa unlike many other comparable countries, still lacks a national STEM skills strategy driven in concert with the social partners i.e. organized commerce and industry and the unions.
- School – industry STEM initiatives are characterized by un-coordinated and non-systemic activity.
University – industry collaboration, including STEM fields, is low by international comparison.

National financial assistance to STEM is thinly dispersed, non-systemic and does not contribute to a national approach.

Factors fueling demand in STEM include:

- Technology explosion
- An aging and growing worldwide population
- Renewed focus on innovation
- Conservation and green energy
- Heightened security measures
- Adoption of nanotechnology

INVESTMENT INNOVATION INCLUSIVE GROWTH INTERNATIONALALISATION

- Education, skills and health
- Infrastructure and digital
- Business Investment
- Natural capital, resource efficiency and low carbon
- Communities, local assets and housing

- Business Innovation and entrepreneurship
- Workplace Innovation and digital
- Commercialization of research and development
- Public services

- Trade
- Investment
- International Connectivity
- Global outlook, influence and networks

- Fair Work
- Business Pledge
- Promoting equality and tackling Inequality
- Place and regional cohesion
Aim 1
To improve levels of STEM enthusiasm, skills and knowledge in order to raise attainment and aspirations in learning, life and work.

Aim 2
To encourage uptake of more specialist STEM skills required to gain employment in the growing STEM sectors of the economy through further study and training.
Alignment with NDP, KZN PGDP, ANC Policy, etc

The premise of a “Vision for a STEM-enabled Province - Science, Technology, Engineering and Mathematics: KwaZulu-Natal’s Future” is to articulate a plan of action, including for the specific initiatives required to execute the vision outlined in the National Development Plan 2030 and the KwaZulu-Natal Provincial Growth and Development Plan 2035 (KZN PGDP 2016-17).

In recent years, advanced nations across the world have placed a particular emphasis on improving the quality of education in Science, Technology, Engineering and Mathematics (STEM). This reflects the critical importance of STEM disciplines for modern society. They empower the citizens in so many important ways. Science and Mathematics provide answers to the fundamental questions of nature and enable us to understand the world around us. Expertise in STEM disciplines is necessary to drive the economic ambitions, support innovation and provide the foundations for future prosperity. Knowledge-based economies are particularly dependent on the quality and quantity of STEM graduates. Providing STEM Education of the highest quality is essential if KZN is to deliver on its ambitions to be a hub of technological creativity and an innovation leader.

The KZN Provincial Growth and Development Plan (KZN PGDP 2016-17) strategy (STRATEGIC GOAL 2: HUMAN RESOURCE DEVELOPMENT) speaks directly to the basis that a competent and literate “human resource capacity of KZN is relevant and responsive to the growth and development needs of the province.”

This goal is aligned to:

- **National Outcomes 1 (Education) and Outcome 5 (Skills Development).** National Outcome 1 (Education) which is aimed at improving the quality of teaching and learning through development, supply and effective utilisation of teachers; and through provision of adequate, quality infrastructure and Learning and Teaching Support Materials (LTSM); tracking learner performance, expanded access to Early Childhood Development (covered in Outcome 13) and improvement of the quality of Grade R; strengthening accountability and improving management at the school, community and district level; and partnerships for is aimed at education reform and improved quality.

- **National Outcome 5 (Skills Development)** seeks to create a credible institutional mechanism for labour market and skills planning; Increase access and success in programmes leading to intermediate and high level learning and occupationally directed programmes in needed areas and thereby expand the availability of intermediate level skills with a special focus on artisan skills. Education and skills development are critical success factors for economic growth and social stability.

The above highlights the critical importance of excellence in STEM Education to ensure the continuous development of a pipeline of talent to support the vision of the province (and the country) that will encompass local developmental agenda as well as potential Foreign Direct Investment (FDI) and an active ecosystem for indigenous start-ups.

The acquisition of knowledge and skills needed by a robust and forward looking economy will take place throughout the value chain of the education and training system. For example, the basic education sector must feed the human resource chain to ensure good linkages between economic growth and people development. Basic education is one of the elements that contribute towards the distribution of opportunity, especially in unequal societies like South Africa. Access to opportunity works as a leverage for levelling the playing-field as it provides tools for social mobility.
The strategic goal related to human resource development within the PGDS highlights the need to look at the whole education continuum i.e. early childhood development, school education, artisan and technical skills, community education and training, and professional education rendered at University level. The linkages in relation to this continuum must be emphasised. Opportunities to partner with the private sector also need further consideration. Best practices from both government- and private led education can be valuable contributions to strengthening interventions, this should also include engagement on farm schools and community colleges, engagements with tertiary institutions to reconsider the courses offered to meet the needs of KZN, as well as partnering with the private sector to expand internship programmes across sectors.

Strategic thinking must also be deployed towards incentives to attract professionals to different parts of the Province to support quality and equity issues. Nodal enhancement must be undertaken so that small towns are made attractive to potential professionals, so that rural schools, hospitals, municipalities and businesses are able to benefit from their quality expertise. Institutions of higher learning must be engaged in producing professionals ready for the social context of the Province. This means quality education related to the professional focus as well as socio-economic skills relevant to working with various communities in the Province.

GOAL 2: HUMAN RESOURCE DEVELOPMENT

The human resource capacity of the province is relevant and responsive to growth and development needs.

The KZN PGDP’s Goal Indicators include inter-alia:

- Reduction in skills shortage in key priority skills areas.
- TVET NC (V) graduation rate.
- Gross Enrolment Rate (GER) in higher education.
- The proportion of the unemployed who are unable to find employment or self-employment due to not having the appropriate education and/or skills
- Percentage of Grade 12 learners passing with Mathematics and Science.
- Performance in SACMEQ (Reading and Mathematics).

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<tr>
<th>Support skills alignment to economic growth</th>
<th>Enhance youth skills development and life-long learning</th>
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<tbody>
<tr>
<td><strong>Objectives</strong></td>
<td>The development of skills is sufficient and appropriate to service the economic growth and development needs of the province</td>
</tr>
<tr>
<td><strong>Primary Indicators</strong></td>
<td>The education and skills level of youth and adults is enhanced</td>
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- Number of NSC candidates taking Mathematics and Science
- Percentage of Grade 12 learners passing Mathematics at 50% or more in the NSC
- Percentage of Grade 12 learners passing Science at 50% or more in the NSC
- Number of full- and part-time learners in public TVET Colleges for NC(V), N courses and occupational programmes
- Number of youth on mentorships / internships / learnerships
- Number of Adult Education Training Centres that conform to government norms and standards
- Number of CET colleges established and throughput of the CET College sector across the Province, disaggregated by types of courses studied
- Learners graduating in fields of Education, and in Science, Engineering and Technology (SET)
- Proportion of learners graduating within 4 years of registering
- Number of PhD graduates
- Percentage of academic staff with PhD Qualifications
- Pass rate of TVET and CET colleges
- Percentage learners successfully placed in employment on graduation from TVET Colleges
- Number of artisans qualifying in scarce skills

### Interventions

- Improve skills development planning and implementation in the Province as detailed in the KZN HRD Strategy, and including skills plans for lead economic sectors per district municipality
- Revitalise and expand the TVET sector and develop CET Colleges
- Develop counselling and vocational guidance for out-of-school youth
- Skills development for the informal sector, township and rural economies focusing on enterprise education and technical skills
- Strengthen Provincial HRD Council to develop partnerships between the state HRD sector and the private sector
- Encourage the development of women professional and technical graduates and people with disabilities

- Expand and targeted skills development, capacity building and mentoring programmes for the SMMEs, Cooperatives, and persons in the informal economy
- Facilitate targeted support to meet youth skills development needs
- Preparation of district based HRD plans linked to IDPs, including the assessment and development of district needs based supply pipelines
- Monitor progress of education and training programmes prepared for delivery in community-based colleges
- Develop awareness campaigns regarding opportunities for learnerships, apprenticeships, mentorships and internships within the public and private sectors
- Maximise the enrolment of youth in TVET colleges and other post-school training institutions focusing on artisan development

### Extracts from the KZN PGDP:

A. At the Youth Development Summit in August 2014, the constituencies agreed that learnerships, apprenticeships and internships provide a useful vehicle for developing the country’s skills needs. It was agreed that more young unemployed people be recruited into learnerships, apprenticeships and internships to acquire the skills they need to become self-employed and improve access to employment opportunities. Targeted youth skills development interventions need to raise the quality of basic and higher education, re-engage drop-outs with the education system and provide an environment that cultivates academic, technical and vocational skills. These include measures to improve literacy and numeracy; increase the number of quality passes in maths and science, and encourage the National Curriculum to offer vocational education options for young South Africans in order to reduce drop-out rates after Grade 9.
B. In essence, the KZN Province recognises the disjuncture between the number of qualified women graduates and people with disabilities, and those taken up in the formal economy through employment and entrepreneurship measures. Province is therefore committed to expand the enrolment of young women and people with disabilities in TVET colleges, and promote their qualification in key areas to promote the production of professionals. Supporting measures will include the compilation of a database of qualified women and people with disabilities, and creation of partnerships between women entrepreneur and business forums, disability networks, and skills development entities. There is need for young girls and children with disabilities to study and perform well in Science, Engineering and Technology subjects, from the Foundation Phase. Educators’ attitudes, knowledge and skills required to develop appropriate teaching interventions for these subjects to young girls and children with disabilities needs to be enhanced.

C. In terms of ICT skills development, several initiatives have been implemented since 2008, with the Moses Kotane Institute (MKI) and more recently, the KZN Technology Hubs (i.e. Techno-innovation hubs) are being established in PMB, Newcastle, Port Shepstone (was launched in June 2016) and Richards Bay (was launched in July 2016). The above are substantial ICT infrastructure investment and; will stimulate economic growth in the area through science, research and technological innovations as well as assist greatly in improving ICT skills in the province. However in this review it is proposed that ICT skills development remains an intervention so to ensure one meet growing demand for ICT connectivity which have been established in Port Shepstone and Richards Bay respectively. The technology park for the Durban Dube Tradeport is currently underway and will consist of an Enterprise zone for both large and small companies, ICT Innovation Incubators and an ICT R&D Innovation Institute. In addition,

The release of the first official report on “Skills supply and demand in South Africa”; The Human Sciences Research Council (HSRC) led by Dr Vijay Reddy et al (2016) was commissioned by Department of Higher Education and Training (DHET) to study the dynamics of skills supply and demand in order to inform skills policy in South Africa.

The South African labour force is made up of 15 million employed and 7.5 million unemployed people. Three quarters of the employed and 90% of the unemployed are from the African population group. Unemployment is also particularly high amongst youth (15 to 34 years) and this is increasing as more young people join the labour force. The education level and skill base of the labour force is lower than that of many other productive economies. Of the employed population, 20% has a tertiary qualification, 32% has completed secondary education, and close to half of the workforce do not have a grade 12 certificate. Sixty percent of the unemployed has less than a grade 12 certificate. This translates to 11.75 million of the labour force with less than a grade 12 certificate.

The three main findings from the research are:

Firstly, on the economy and the demand for skills:
The South African economy has been characterised by low economic growth rates, leading to poor employment growth. This employment growth has not been sufficient to absorb the large numbers of youth coming onto the labour market for the first time. The end result is an escalating unemployment rates.

The sectors in which people work and the types of jobs available are changing. There is an absence of low-wage jobs in the manufacturing sector that could absorb the vast majority of unemployed who are looking for work. There has been a structural shift towards a service economy and a high
dependence on high-skilled financial services. The financial services sector contributes towards growing the country’s GDP, but offers negligible opportunities for employment growth. The only sector experiencing significant employment growth is the state sector and this is not sustainable.

There is a structural mismatch between labour demand and supply, in that the economy and labour market shows a demand for high skilled workers, but there is a surplus of low-skilled workers. The economy must respond to the twin challenge of participating in a globally competitive environment which requires a high skills base and a local context that creates low-wage jobs to absorb the large numbers who are unemployed or in vulnerable jobs. The economy should create more labour-intensive forms of growth in order to absorb the growing levels of people, particularly young people, as first time labour market entrants.

Secondly, on education and supply of skills:
A critical constraint for the post school education and training system and the labour market is the quality of basic education. Success in the school subjects of Languages, Mathematics and Science forms the basis for participation and success in technical subjects in post-school education and training institutions, and in the workplace. Even an economy based on a low skill trajectory will require a workforce that has completed their school leaving certificate and gained basic numeracy and literacy skills.

Presently, each year around 140 000 grade 12 learners complete the matriculation examination with a bachelor’s pass, and of these only around 50 000 learners pass Mathematics with a score higher than 50%. The pool of learners who can potentially access university and Science based TVET programmes is very small, in comparison to the skill demands in the country.

The university and TVET college sub-systems are the largest components of the post-school education and training system. In 2014, there were around 1.1 million learners in the university sector and 0.8 million learners in the TVET sector. Since 2010 the TVET sector has been expanding at an average rate of 23% per annum and the university sector has been expanding at an average rate of 2.1% per annum.

Completion rates at both universities and TVET colleges are less than desirable in that in 2014 there were 185 000 completers from the university sector, 21 000 NCV4 and 57 000 NATED 6 programme completers from the TVET sector.

Access to school, universities and TVET colleges has improved. However quality remains elusive leading to low progression through institutions as well as low completion rates from schools, TVET colleges, and universities.

The skills development focus should not only be on a small number of skilled people in the workplace, but also on the unemployed, the youth, low-skilled people, the marginalised, and those in vulnerable forms of employment, including the self-employed.

Thirdly, on the link between the tertiary education and the labour market destination
The data revealed that nearly half of the Higher Education graduates are employed in the community, social and personal services sector, which is dominated by the public sector. A high proportion of the Science and Engineering graduates, from both higher and technical and vocational education sectors, prefer to work in the financial services sector, as opposed to the manufacturing sector. SET qualifications are versatile and graduates will move into different fields of work. The implication for skills planning is that one needs a high number of SET graduates than needed by the SET occupations.
These positions offer graduates a good salary and conditions of service. Unfortunately this is distorting the labour market and not attracting graduates to the private sector. The private sector must review its human resource strategies to attract more graduates to the sector.

In conclusion
The dilemma facing policy makers is how to respond to these diverse sets of development and occupational pathways, and decide how resources should be targeted for inclusive skills development. These imperatives may seem paradoxical, but all are essential to achieve a more inclusive growth and development trajectory.

In examining the Academy of Science of South Africa (ASSAf) documents, the following scenario emerges:

Although the South African higher education sector overall has expanded significantly since 1994, the participation rates in higher education relative to the population remain extremely racially skewed. In 2009, the participation rate, that is, the total headcount enrolment as a percentage of the total population between the ages of 20–24, was only 13% for Black learners compared with 57% for White learners.

In addition, there is increasing concern about the poor retention and throughput rates of undergraduate learners. A recent Council on Higher Education (CHE) study in which the 2000 student intake to higher education was analysed provided compelling evidence that across the sector there is a high attrition rate at first year, a low overall completion rate and a very small group who complete in regulation time.

Within the Science, Technology, Engineering and Mathematics (STEM) fields, specifically, only 21% of learners in life and physical sciences completed a degree in 3 years, and in engineering only 32% of learners completed the degree in the regulation time of 4 years. Clearly the current structures and processes are not effective for the majority of learners, who, given the low participation rates in higher education (17% of the age cohort in 2009), are, in fact, the ‘cream of the crop’ of school-leavers. In relation to the underperformance of undergraduate learners, the level of preparation of first-year learners for university studies has long been a concern, with the interface between school and higher education often characterised in terms of a discontinuity or ‘articulation gap’. Over the last few decades, the predominant mode for responding to this gap has been the establishment by the higher education sector of what are currently termed ‘foundation programmes’ or ‘extended curriculum programmes’. The so-called ‘mainstream’ programmes have remained relatively unchanged over this period.

The Academy of Science of South Africa (ASSAf) (October 2010) focused attention on existing interventions, together with opportunities and imperatives for further mainstream responsiveness. To identify ways forward for STEM education in South African higher education institutions, it confirmed that weaknesses and inequities in the schooling system are not likely to be solved in the short term despite some pockets of excellence – a case to too little and poorly co-ordinated. What one sees as poor through-out and low pass-rates in higher education is rooted in weak Early Childhood Development (ECD) and primary and secondary school teaching and learning especially in the language and STEM fields. Whilst the post-school/higher education institutions share responsibility with other education sectors in overcoming the legacy of apartheid and building a better future for South Africa and its citizens; this is certainly not enough.

To summarise the key findings from the scholarly work presented by ASSAf and like-minded research institutes and the HSRC; as well as draw on other relevant science and engineering education research at the secondary–tertiary interface. AN attempt to synthesise, in areas where there is
currently sufficient evidence, a tentative consensus position (what do we know?) and highlight areas for future research and innovation (what do we still need to know).

It is important to locate concerns about the South African articulation gap within the international context of higher education. Although there are particular local features that can be traced to the impact of apartheid, the broader issues have strong international resonance. Higher education, traditionally catering to an elite group, has expanded dramatically in the second half of the 20th century around the world, and most countries now aspire to having the majority of their young people complete post-secondary education. At the same time, in many contexts the system has been arguably slow to respond to the implications of such massification, but in recent times there has been an increased focus on issues around teaching and learning in higher education. The debate around the ‘gap’ between schooling and higher education is not unique to South Africa. Here it needs also to be acknowledged that schooling is not only geared towards higher education preparation, but has an important, far broader, role in society in producing well-rounded individuals who can take up their places in a democracy and in the world of work.

Key concerns are that:

- The existing focus of the Department of Basic Education’s (DBE) MST is primarily on Mathematics, Science and Technology at the expense leaving out the 4th - leg of the STEM cohort - Engineering.
- The Dept. of Science and Technology (DST) uses the “SET” nomenclature – i.e. Science, Engineering and Technology – that assumes that Mathematics underpins the suite.
- The NDP 2030 does not articulate an action agenda. While the plan reflects on existing initiatives consistent with the strategic objectives and identifies potential areas where more could be done, it does not provide clear actions or a pathway to ensure those objectives are achieved.

Existing policy documents recognize that the number and quality of Masters and PhD degrees should be drastically increased. The National Planning Commission proposed that by 2030, over 25% of enrolments should be at postgraduate level and there should be more than 5,000 doctoral graduates per year - against 1,423 in 2010 – with an emphasis on those in the STEM fields.

However the translation of the above policies thus far displays a profound lack of specifics and omission of recommended actions raises serious concerns regarding the extent to which the government is genuine in its commitment to STEM capacity building.

Without committed investment in STEM capability development, South Africa simply cannot compete with the efforts of our global competitors.

The NDP (2012) also proposes increase of gross enrolments from 950,000 in 2010 to 1,620,000 in 2030.

The Plan admits that a ‘greater understanding within government is required to acknowledge the importance of science and technology and higher education in leading and shaping the future of modern nations’ (ibid). Given this acknowledgement, and despite recognizing that funding for higher education as proportion of GDP has declined from 0.76% in 2000 to 0.69% in 2009 (2011: 292), it is disappointing that, in a report bristling with targets, the Plan refrains from setting a target for increased GDP funding for higher education, noting only that ‘additional funding will be needed’ (2012: 293) to fund the targeted expansion in enrolments and research. It is becoming self-evident that without such a guaranteed increase in state revenue, attempts at expansion cannot succeed.
Field of study
Analysing the four major fields of study: Business and Commerce (B&C), Education (Edu), Humanities (Hum) and Science, Engineering and Technology (SET); one sees the enrolment patterns by field of study from 2008 to 2013. The lowest number of enrolments has been, and still is, in education. However, this is also the field with the highest growth rate in enrolments (39%) over that period.

Headcount enrolments by major field of study from 2008 to 2013 (ASSAF)

<table>
<thead>
<tr>
<th></th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>B&amp;C</td>
<td>234 588</td>
<td>238 256</td>
<td>278 845</td>
<td>288 487</td>
<td>281 299</td>
<td>279 954</td>
</tr>
<tr>
<td>Edu</td>
<td>124 689</td>
<td>137 467</td>
<td>145 416</td>
<td>164 999</td>
<td>168 608</td>
<td>172 991</td>
</tr>
<tr>
<td>Hum</td>
<td>215 250</td>
<td>228 854</td>
<td>234 206</td>
<td>220 326</td>
<td>212 184</td>
<td>247 131</td>
</tr>
<tr>
<td>SET</td>
<td>224 948</td>
<td>237 166</td>
<td>234 472</td>
<td>264 447</td>
<td>273 282</td>
<td>283 622</td>
</tr>
</tbody>
</table>

The graph shows a decrease in the proportion of humanities enrolments to other fields especially in 2011, which from the 2012 enrolments started to increase again. All fields have seen growth in terms of absolute numbers enrolled.

A close examination of the National Development 2030 Plan raises the following concerns:

An analysis of what the NDP reveals that those in the education, training and innovation domains will play crucial roles in the realization of the majority of the NDP goals.

The challenges in relation to the NDP goals can be summarised as follows:

- How will these goals be realised?
- How will one maintain the essence of the NDP in reality and make it a living document

The importance of the Plan cannot be underestimated; although education, training and innovation occupy less than 10% of the document, this proportion may not reflect the depth and consistency of the challenge. It was widely reported that the Commission members envisaged that the aims of the Plan to achieve – inter alia - overall growth and development, will depend to a very large degree on what these three areas are able to act and enablers and catalysts

However, whilst this thread do not emerge in the Plan itself, these sectors are the initiators of implementation and the engines for sustaining the development process. The Plan includes 14 objectives and 16 actions relating to education, training and innovation. The objectives are extremely wide ranging and often-times weak on detail. Spanning the improving of early childhood development and school performance levels, expanding the college system, producing over 30 000 artisans a year, producing a rather vague “well over” 5000 doctoral graduates a year by 2030 (the present number is about 1200), and “expanding science, technology and innovation outputs by increasing research and development spending by government” and industry.
The task at hand immediately presents a major challenge - a school system that is ineffective. Only 36% of Grade 12 learners who write maths pass with a mark above 40%, while the proportion that pass with a mark over 50% falls into single digits. The system is also highly unequal. Nearly 75% of the schools in the top quintile achieve pass rates close to 100%, while in many rural areas of South Africa pass rates are closer to 50% or 60%. Levels of quality are questionable and will remain so while it is possible to obtain a National Senior Certificate with qualifying marks of 30% or 40% in a number of subjects. The dismal competencies that learners achieve in science, mathematics and language, have to be vastly improved as they will be critical for future development. As long as these and similar challenges remain unresolved, many of the objectives set for education, training and innovation will be difficult to attain.

The challenge is greater for the fact that 35% of learners who enrol in Grade 1 do not make it through to Grade 12, with 50% of Grade 10 learners dropping out before writing the National Senior Certificate (NSC) examinations. The result is that almost 50% (3.2 million) of the 18–24 year olds in South Africa are not in employment, education or training – the so-called NEETS.

The NDP is silent in addressing and foregrounding this reality – which could turn out to be a major weakness. Noting that very little can be achieved without high-quality education, training, research and innovation. Take the case of health; one of the primary objectives to be achieved is an increase in male and female life expectancy at birth to 70 years – a task that involves a complex set of contributions from a wide spectrum of health-care specialists, engineers, agriculturalists and social workers, etc. Without the competent human resources to provide these services (educated and trained in universities and colleges), and without serious, intensive research and appropriate innovation, the changes needed will almost certainly not happen.
ANC’s Education, Health, Science and Technology discussion document

It is interesting to note that the ANC’s Education, Health, Science and Technology discussion document - released in advance of the ANC’s 5th National Policy Conference slated for 30 June – 5 July 2017; peripherally makes mention of:

4.3 SCIENCE, TECHNOLOGY AND INNOVATION

4.3.4 Reports on the implementation of policy and specific projects and programmes:

4.3.4.9 To ensure that there is research on education issues to inform policy, thirteen (13) research chairs have been established through the South African Research Chairs Initiative (SARChI). These are focusing on mathematics education, numeracy education; integrated studies of learning languages, mathematics and science; teacher education, higher education and human development, and work-integrated learning. Science education is an integral component in encouraging the exploration of science, technology, engineering, mathematics and innovation (STEM) as a career. Focused initiatives cater for teacher training and learner engagement opportunities;

4.4 BASIC EDUCATION

4.4.4 Report on the implementation of policy and specific projects and programmes

4.4.4.37 On economic transformation: Conference could recommend that an updated Science Technology Engineering and Mathematics (STEM) strategy to develop be developed and implemented in order to feed national human resource development goals. Conference should undertake a radical review and transformation of the means of assessing what learners can and should do and know at national and provincial levels, and ensure that this is integrated with classroom- and school-level systems for improving feedback and teaching for better learning outcomes

What is ideally required – nay demanded – is a holistic approach to STEM. While it is noted in particular, the importance of technology in an increasingly digitally driven global economy, one should fully appreciate that all the STEM disciplines – science, engineering, technology and mathematics are critical to KZN’s (and South Africa’s) workforce capability of the future.

Given the recently announcement (Engineering News 04 April 2017) – that the Moses Kotane Institute (MKI) recently revised its mandate to be more responsive to addressing the issues around shortage of skills in Science, Technology, Engineering and Mathematics; which necessitates that it deploys various strategies to expand its reach.

The response addresses each of the four themes of the strategy and which have deliberately offered a broad range of specific actions that one hope will be considered by MKI Board in taking forward an actionable STEM agenda. Hire Intelligence is committed to supporting a provincial STEM agenda and assisting the MKI Board execute an effective STEM program supported by milestones and a measurement framework to monitor progress.
Excerpts from the resolutions of the ANC Economic Transformation commissions from the July 2017 conference: an overall approach on economic transformation

At the end of the conference, The ANC re-affirmed the 15 Pillars adopted at Polokwane ie.:

1. Creating **decent work** is the primary focus of economic policy.
2. Accelerating **shared economic growth** by overcoming obstacles to growth and intervening to promote equity.
3. A comprehensive and clear **rural development strategy**.
4. Reversing **apartheid settlement patterns** in both urban and rural areas.
5. Expanding the opportunities for sustainable livelihoods, through **support for cooperatives and micro-enterprises**.
6. Programmes that directly absorbs the unemployed, including **public works programmes**.
7. Expanding the **social wage** with universal and subsidised access to basic social services.
8. Investing in priority **skills and education**, and improving the performance of South African learners in **mathematics and science**.
9. Using **South Africa’s natural resources** in a manner that benefits the nation as a whole.
10. Ensuring **energy security** and promoting clean and renewable sources of energy supply.
11. **Integration of the economies of Southern Africa** and building stronger economic linkages across the continent as a whole.
12. Building the **capacity of the democratic developmental state and implement programme of economic transformation**.

The conference further reaffirms the **6 elements** adopted at the National Conference in Mangaung ie.:

1. Adoption of the **National Development Plan** and affirming the jobs drivers of the New Growth Path and IPAP, the infrastructure development plan and localisation
2. **Minerals**: beneficiation, equitable state-share of mineral wealth, mine safety/social plan and skills/R&D investment
3. **Youth, small business and cooperatives**, including a state bank and support for worker rights.
4. **Rural development and land reform**: addressing the need to conduct a land audit, addressing a willing-buyer-willing-seller, land tenure system, food security, rural development and reopening restitution of land.
5. **Sustainable and transformative macro-economic policy** biased towards job creation and the extension of services to increase equality and economic inclusion.

**Radical socio-economic transformation** requires fundamentally changing the structure of South Africa’s economy from an exporter of raw materials, to one which is based on beneficiation of raw materials (minerals and agriculture) and enhanced manufacturing, in which our people’s full potential can be realized.

In addition to ensuring increased economic participation by black people in the commanding heights of the economy, radical economic transformation must have a mass character.

**Immediate tasks of the movement in the economy:**

1. **Growth**: to reignite economic growth particularly as South Africa has entered a recession and recognizing economic growth is a necessary condition for the successful implementation of radical socio-economic transformation.
2. **Employment**: Since the dawning of democracy South Africa has created millions of new employment opportunities, yet unemployment has continued to rise because of the significant numbers of our people who, previously excluded, are now entering the labour
market. It is critically important that new decent employment opportunities are created particularly for the youth.

3. Building an effective and corruption free developmental state is imperative if we are to build a more equal and prosperous society.

Reigniting growth
1. South Africa must act urgently to reignite economic growth. This requires government to act to inspire popular confidence and the private sector to recommit to investment for growth. This requires the movement to engage in an active stance of cooperation and contestation with private capital to reshape and rebuild the South African economy.

2. Active steps to achieve this goal include:
   a. Articulating a radical programme to unlock new opportunities for our people to participate in investment, growth and employment creation.
   b. Isolating and rooting out corrupt elements that are eroding government’s credibility.
   c. Stabilise the governance and finances of state owned companies.
   d. Ensuring a measured and balanced path of macroeconomic management.
   e. Working to avoid further downgrades to South Africa’s credit rating and regain an investment grade.
   f. Acting to root out uncompetitive structures and conduct.

3. It is recommended that the NDP should be reviewed and that every five years it should be recalibrated in order to ensure that its implementation is improved.

Land Redistribution
1. Government’s approach to land reform is based on three pillars: tenure for farmworkers, restitution, and redistribution. The programme of land redistribution has been inadequate. Not enough productive land has been transferred into the hands of black farmers and producers. Support programmes for new farmers have also been ineffective.

2. In addition it was agreed to:
   a. Ensure effective programmes to increase training and support measures that will ensure the success of beneficiaries of land reform. This must include access to water rights and access to inputs like fertilisers, veterinary services, farming equipment and broadband as well as more certainty with regard to access to markets.

Economic concentration
1. The high levels of concentration of ownership in many sectors of our economy is dysfunctional to growth, entry of black South Africans in the economy and effective competition.
Strengthening broad-based Black Economic Empowerment

1. The broad-based BEE programme should be reviewed with a view to implementation of radical socio-economic transformation
2. State procurement should enhanced as an empowerment lever as it represents a significant market for businesses, large and small, and should be viewed as a key instrument for empowering emerging black businesses.
3. The PPPFA should be significantly amended to fully realize all objectives set out in s217 of the Constitution. Set asides must be further strengthened so that they work more effectively in promoting black businesses, including small and medium enterprises and the domestic manufacturing sector. This will ensure that we preserve existing industrial capacity and jobs.
4. Government should intensify the use of state concessions as a policy tool for economic development and transformation, including in minerals, petroleum, fishing, spectrum, land, water, energy etc.
5. There should be increased levels of black ownership and control across all economic sectors and legislation, charters and codes should not extend the definition of black beneficiaries to persons naturalized after 1994.
6. A worker empowerment component should be introduced in the policy framework to massify share-ownership among workers and to provide for worker representatives sitting on the boards of companies.

Manufacturing

Manufacturing continues to be a major sector of South Africa’s economy, providing a significant base of skilled employment opportunities. Through its Industrial Policy Action Plan (IPAP), government seeks to transform the structure of South Africa’s manufacturing base through creating new levels of dynamism and competitiveness in the sector.

In addition:

1. A renewed emphasis must be placed on localisation, particularly linked to procurement by government and state-owned companies.
2. There should be clear consequences for non-compliance by public entities of our policies on localisation.
3. There should be increased designation of products that are locally produced.
4. Improved efficiencies in South Africa’s transport and logistics networks are required.
5. The black industrialist programme should be strengthened and support programmes should be developed for other sectors.

Skills revolution

1. The challenges of new technology and the 4th industrial revolution require a revolutionary approach to training and skills development.
2. Initiatives that accelerate the placement of youth – on a massive scale – in employment that generates skills and experience should be intensified.

Improving the industrial and economic impact of public expenditure

1. Infrastructure spending remains a lever through which industrial development and economic growth can be sustained.
2. The infrastructure programme should actively support youth employment, localization, black industrialists and other developmental goals.
3. The procurement institutions must be strengthened to ensure a close monitoring of adherence to our revised preferential procurement regulations.
4. The most potent way to build and strengthen backward and forward industrial linkages in our economy is through local procurement. This will improve our trade balance and in
ensuring that fiscal policy has an increased multiplier impact on economic growth, employment and long term development.

**Beneficiation and building high value-added value-chains**

1. New measures to inwardly orient those components of mining and upstream production such as petrochemicals and basic iron and steel, which are crucial for metals fabrication, capital goods production especially engineering activities, need to be put in place in support of a coherent strategy of industrial development based on raw minerals beneficiation.
2. To ensure that beneficiation is effectively introduced, a concessional pricing regime should be introduced where mining companies are required to make a portion of mineral output available at pricing below the market price to domestic manufacturers in order to promote local production.

**Small businesses and co-operatives**

1. Government measures to support small business and cooperatives need to be scaled up to ensure their impact is felt across the economy.
2. The stimulation and protection of township-based economic activities is also key in this regard. Access, affordability and stability of credit extension for these firms is important for them to acquire inputs, upgrade their capital base and for them to extend trade credit to their customers.
3. Youth employment must be prioritised, including through effective public employment programmes, internships, job placement, youth set-asides, procurement from youth-owned enterprises and youth entrepreneurship programmes.
4. Effective use and resourcing of the National Youth Development Agency is important as it offers support services to young people, especially those in rural areas and in working class urban communities. Youth support will be incorporated as one of the areas in the scorecards for firms from which government procures goods and services.

**Operational issues**

A number of operational and sector issues were identified in the Commissions. Some of these need to be finalized and implemented prior to the December 2017 National Conference. Others contain levels of detail that would not be appropriate in a broad policy framework or are purely operational and transactional.

It is proposed that these be referred to the NEC to finalise and operationalise prior to December 2017.

These include the following:

1. Proposals to strengthen the tourism sector
2. Finalising the fishing quotas and ensure they are given effect to immediately.
3. Ensuring the National Empowerment Fund is effectively capitalized and able to operate within a developmental mandate.
4. A marine-policy that ensures the use of South African ships as part of our trade with the rest of the world.
How does KZN achieve STEM Excellence?

A framework for action
There are many voices in the STEM debate. What’s clear is that no single group can solve the problem on its own. Business, government and educators need to plan and work together to create the STEM workforce KZN needs.

Business must play a leading role
KZN businesses already have an important role in building an innovation ecosystem through providing venture capital and R&D. But they also have a role to play when it comes to STEM education. After all, they will be the ones fighting for STEM talent if one could continue down the path of flat growth. Here’s how they can help.

Engage, influence and connect
Driving change through the education system is challenging. And in the case of STEM it needs to begin with a clear, shared understanding and belief in the importance of the challenge and the innovation outcomes one is striving for. This starts with more open discussions between business and education leaders.

Business also has the opportunity to better connect with learners. This can be done by profiling emerging STEM careers, talking about workforce needs, offering workforce and internship experiences and breaking down the stereotypes and barriers that still remain today. It’s not new, but scope exists for a much more coordinated approach to engaging with the potential STEM workforce.

In terms of policy reform, business is well placed to help move the agenda forward through thought leadership and advocacy. In particular, they can provide data and insights to help governments make evidence based policy decisions.

Innovate
Advances in technology have the potential to disrupt education in the same ways they are disrupting entire industries. Business is at the forefront of this change. How can they bring those skills to the table and combine it with the deep knowledge of the educators, to unearth new solutions in the challenge of educating to innovate?

Scale
While the importance of STEM has gained increasing prominence of late, the issue is not new. Many long-standing initiatives are in play and new ones are emerging. The challenge is not a lack of solutions but of identifying and scaling the solutions that can achieve rapid and national level change.
Perhaps the most important role for business is to apply its expertise in growth and expansion, and in particular in adapting solutions to new markets.

The skills that business brings to the table include: evaluating initiatives likely to succeed, developing rapid scale solutions and mobilising resources to make change happen.

This is not just about identifying philanthropic programs for businesses to support. It’s about creating an Eco-system of high potential commercial, semi-commercial and philanthropic solutions – both within and external to the education system.
Why STEM?
Some 75% of the fastest growing occupations today require science, technology, engineering and mathematics (STEM) skills and knowledge. South Africa is one of the few OECD countries without a science or technology strategy. This is unfortunately reflected in the low ranking in terms of Global Competitiveness (WCI), World Economic Forum (WEF) and the TIMMS review. Most other countries have realized that such an approach is essential to remaining competitive in a world reliant on science and science-trained people. Worse still must specifically address education to bring it up from the Position 142 out of 144 countries by the TIMMS.

South Africa is not producing enough school leavers who are competent in maths and science. This is a fact borne out by international assessments such as the Trends in International Mathematics and Science Study (TIMMS) and the World Economic Forum’s Global Competitiveness Report. These show that South Africa is not making much headway when it comes to maths and science. The 2016 Global Competitiveness Report ranked South Africa last among 140 countries for maths and science. This places it behind poorer African countries like Mozambique and Malawi.

In 2016 there was a marginal improvement in the maths pass rate, from 49.1% the previous year to 51.1%. The country is moving at a glacial pace in an area that demands urgent attention. After all, science and maths are key to any country’s economic development and its competitiveness in the global economy. The TIMMS study ranks Singapore, Hong Kong, South Korea and Japan among its top maths and science performers. It’s no coincidence that these countries feature among the top 20 on the Global Innovation Index. Good quality education fuels an economy. South Africa needs to increase its supply of science and technology university graduates, which at the moment constitute the bulk of scarce skills outlined by the department of higher education and training.

But instead of chasing improved results, the government is lowering the bar for maths at school level. At the end of 2016 it set 20% as a passing mark for pupils in grades 7, 8 and 9. This lends credence to the common view of maths as a subject only the “gifted” can comprehend. It’s time to place a premium on maths and to ensure that pupils – especially those from poorer backgrounds – receive the necessary support to excel at maths. This is critical if South Africa is to produce the human capital needed to drive economic growth and create new industries in the future.

How maths and science boost economies
Maths and science are a gateway to new industries. Mastery of them endows an economy with the human capital needed to ride the technological wave. In his work on the industries of the future, Alec Ross, who advised Hillary Clinton on innovation during her term as US secretary of state, points out that sectors such as robotics, advanced life sciences, codification of money, big data and cybersecurity – all of which require mastery of technology and mathematical skills – are the pillars of the fourth industrial revolution. Simply put, this “revolution” is the age of technology that’s already upon us.

More importantly, a grasp of maths and science boosts confidence and expands career possibilities for pupils. This ultimately gives them an edge in the labour market. Many students drop out of maths not by choice but because they’re frustrated by a lack of adequate support.

But succeeding in maths, or in any area of skill, isn’t entirely a matter of genetic endowment. Psychologist Anders Ericsson, in his book Peak, draws on three decades of research to prove why natural talent and other innate factors have less of an impact than what he calls deliberate or purposeful practice. He contends that “a number of successful efforts have shown that pretty much any child can learn math if it is taught in the right way.”
South Africa should be focusing on how to teach maths in the right way rather than buying into the myth that it is an impossible subject. The current approach is robbing the economy of critical human capital.

Radical interventions
Some may argue, though, that any improvement or shift is impossible in an education system that’s plagued by weak infrastructure, a lack of teacher development and support and too few qualified maths and science teachers. Even if the numbers of teachers in these subjects were to increase, it’s crucial that the quality of education rises too. Radical interventions are needed now or South Africa will never become a global player in the fourth industrial revolution.

The country must develop new teacher training methods and nurture a supportive environment for teachers. Innovative teaching tools should be introduced in the early phases to demystify maths and science for young pupils. If these subjects are more fun to learn, more pupils may be drawn to them as future career options. Taking these steps will give South Africa a better chance in the future to harness the talent of its youth to powering the economy, and improve its global competitiveness.

The World Economic Forum (WEF) Global Competitiveness Report 2015 – 2016 ranked South Africa last in terms of its quality of math and science education. The country also performed poorly in the quality of the education system ranking – 138th out of 140 countries. The Global Competitiveness Report presents the rankings of the Global Competitiveness Index (GCI). The GCI is based on 12 pillars that provide a picture of the competitiveness landscape in countries around the world at different stages of economic development. The report contains detailed profiles highlighting competitive strengths and weaknesses for each of the 140 economies featured. The report showed that South Africa climbed seven places to reach number 49 out of 140 countries. This improvement was largely thanks to the increased uptake of ICTs – especially higher Internet bandwidth – and improvements in innovation.

South Africa’s education rankings
The fifth pillar is higher education and training, and in this category South Africa performed poorly.
- Quality of math and science education – 140 out of 140 countries
- Quality of the education system – 138 out of 140 countries
- Internet access in schools – 119 out of 140 countries
- Tertiary education enrolment – 93 out of 140 countries

There were some positive indicators, including the quality of management schools and secondary education enrolment.
- Secondary education enrolment – 12 out of 140 countries
- Extent of staff training – 19 out of 140 countries
- Quality of management schools – 24 out of 140 countries
- Availability of specialised training services – 41 out of 140 countries

The report stated that South Africa’s quality of education is a problem, where higher secondary enrolment rates will not be enough to create the skills needed for a competitive economy.

How the ranking works
It should be noted that some of the rankings were not based on testing the performance of learners, but rather on opinions of business leaders.
The WEF used an Executive Opinion Survey for its education quality scores. As part of this survey, local business leaders were asked:
• In one’s country, how would one assess the quality of math and science education in schools?
• How well does the educational system in one’s country meet the needs of a competitive economy?

While countries such as the US, UK, Singapore, China, Brazil and India are investing heavily in building their STEM capability precisely because they regard these disciplines necessary to future economic and social wellbeing, South Africa’s performance is lagging behind many of the comparable peers

• Singapore has nearly 50% of STEM degrees as a percentage of the total
• 41% of all degrees awarded by Chinese institutions in 2011 were in a STEM subject (almost twice the proportion in the UK and three times the rate in America)

In their 2015 World in 2050 report, PwC predicts that Australia’s economy will drop 10 places in world rankings by 2050 from its current rank of 19. This will take Australia out of the G20 and behind countries such as Bangladesh, Egypt, Iran, Pakistan, Philippines and Thailand. In PwC’s opinion, this slump is based on an assessment that Australia has under invested in non-resources areas of the economy, with STEM education identified as a key example of under investment. Unfortunately neither can the HSRC, STATS SA or the Ministries of Basic Education, Higher Education or Science & Technology provide any comparable statistics.

STEM underpins a differentiated and readily adaptable economy that is globally competitive and will enable all global citizens to benefit from the opportunities that follow.

An education in STEM fosters a range of generic and quantitative skills and ways of thinking that enable individuals to see and grasp opportunities. These capabilities—including deep knowledge of a subject, creativity, problem solving, and critical thinking and communication skills—are relevant to an increasingly wide range of occupations. They will be part of the foundation of adaptive and nimble workplaces of the future.

STEM skills are critical to the management and success of R&D projects as well as the day-to-day operations of competitive firms.

Strong performance in STEM is also critical to education and training sector. Getting the basics right in areas such as education is critical if one is to create an environment conducive to tech-savvy innovation, entrepreneurship and business growth – essential to KZN’s potential international competitiveness.

**Why 'T' for Technology?**

Digital skills are more than just being able to use computers and applications. They involve the ability to design, build or program computer applications to help create new products and services. Digital skills use what is described as “computational and design thinking, the ability to understand how digital technology can be used to do new and innovative things.

By strengthening digital skills in the school system, KZN/SA will give young people core capabilities in logic and critical thinking. These skills will improve their job prospects and one will improve the provincial/national innovation capability for the future. It is important that young people not only know “how to use” technology, but they also know “how it works”, and how it can be used to create new content and applications.
Digital skills are increasingly important in most occupations. Digital skills are essential to jobs in industries as diverse as manufacturing, professional services and public utilities, the creative industries, mining and agriculture. It is expected that digital skills will help future workers manage the disruption in their employment and transition to new occupations that are more productive and better paid...

**Competiveness**
**The importance of innovation and STEM to KwaZulu-Natal’s competitiveness**
To sustain the level of prosperity KZN has enjoyed (and expects), productivity growth is imperative. However, this is only possible if one’s remains, indeed improve, the global competitiveness. In the current global digital economy this translates to both the ability to participate and effectively compete in the global market as well as the ability to compete locally to develop and retain skilled employees.

Competing in a global economy driven by data, digital technologies and innovation requires an appropriately skilled workforce. Using the typical global indicators (economic growth, GDP, productivity, etc.), the South African economy can be compared with Australia (although having approximately half of the population) - analysis by PwC shows that 44% (5.1 million) of Australia’s current jobs are at high risk of being affected by computerization and technology over the next 20 years. One cannot simply be sure that these same jobs will exist tomorrow. However, one can educate workers to be more innovative and creative.

**STEM education is important not as an end in itself, but as a means to develop the foundations to support innovation:** skills that promote inquiry, critical thinking and analytical skills, enable interpretation of data, learn from hands-on experimentation, identify connections between different disciplines, persist in problem solving (even at the risk of failure), work collaboratively and strengthen research skills.

While greater investment in ‘inputs’ can provide shorter term growth in national income, over the longer term innovation coupled with strong STEM foundations is the primary driver of sustained higher economic growth and living standards. At an international level a more comprehensive view of innovation has emerged, and has led to educational interventions aimed to foster creativity and thinking skills, as well as non-disciplinary entrepreneurial capacities, in a wide number of contexts and for all learners, irrespective of their field of study.

Countries that lead in STEM such as Germany and Sweden also rank high on innovation. Germany which ranks third in the OECD in terms of STEM graduates and Sweden which has around 90% of learners attending highly digitally-equipped schools and supports national STEM focused training for teachers, are both recognized for their high performance innovation capabilities.

**STEM skills are essential for the future economic and social well-being for the nation.** However the participation in STEM skills at secondary school and university are unacceptably low; and virtually non-existent at ECD and Primary school level. The shortfall in STEM, including digital skills limits innovative capability and productivity improvement.

**Strengthening education for innovation is paramount to KZN’s competitiveness and prosperity.** Education policies (a national competence) can increase national innovation capacity by equipping more people with the skills required to contribute to innovation and by inspiring talented young people to enter innovation-related occupations. However the national Government (via the NDP, KZN-PGDP and the DBE) response fails to provide a clear road map as to how this is achieved within the innovation agenda.
At an international level a more comprehensive view of innovation has emerged, and has led to educational interventions aimed to foster creativity and thinking skills, as well as non-disciplinary entrepreneurial capacities, in a wide number of contexts and for all learners, irrespective of their field of study.

Referencing the envisaged role of the KZN Techno-hubs and SEZ development; to make this initiative relevant to developing KZN’s STEM capability however, there needs to be clear actions to ensure the STEM agenda is integrated with the strategic operations of the Techno-Hubs.

While the MKI Board must develop appropriate mechanisms to drive innovation, the link between the focus of these programmes and progressing the STEM agenda needs to be more overt.

Given the increasing role of technology and STEM skills generally in facilitating innovation consideration of the appropriate membership of the proposed/envisaged MKI STEM Advisory Board must include broad STEM expertise and in particular knowledge of digital and emerging technology.
The Application of STEM for Economic Development
Promoting Innovation and Critical Thinking through STEM-focused post-school (vocational & higher education)

- This will entail the acquisition of lifelong skills, application of theoretical frameworks, practical skills, attitudes and knowledge relating to workplace competence. This will demand that one rethinks the continuum of sustainable personal development - quality education is required to be: (a) an integral part of general education; (b) a means of preparing for occupational fields and for effective participation in the world of work; (c) an aspect of lifelong learning and a preparation for responsible citizenship; (d) an instrument for promoting sustainable development; (e) a method of facilitating poverty alleviation.

- One of the most intractable problems facing KZN is youth unemployment. In the KZN economy, there are more people willing to work than the number of jobs available. If the economic conditions continue to decline, cyclical unemployment will continue to increase. Hence the need for the encouragement of self-employment, entrepreneurship and innovation.

- Engineering and other STEM fields are areas of great concern and great demand for employers. It needs support from the various agencies - not limited to the HSRC, CSIR, etc. including the Ministries of Science, & Technology, Labour, Energy and Mineral Resources, Health and both Basic Education and Higher Education working in tandem to empower youth to pursue STEM-related fields. Improving the skilled pool of STEM-literate workers will be attractive to Foreign Direct Investors (FDI) looking to set up without the added cost of having to find multi-skilled pool of human resources - as they would already be available in abundance.

- Globally education is acknowledged as a means of transforming and empowering citizens within a country with requisite skills, knowledge and, attitudes to enable them to become productive members of the society. Innovations and advances in STEM are end products of critical thinking and problem solving.

- The primary role of education is its contribution to longer-run economic growth (Töfﬂer 1995) it has a big role to play in the success of the National Developmental Plan (NDP) in terms of the quality of jobs and productivity growth Promote Innovation and Critical thinking through STEM-focused education and training initiatives.

- Critical Thinking: one is almost always dealing with thinking. Thinking is the way that the mind makes sense of the world. There is no way to understand anything except through thinking. Innovation and creativity are end products of critical thinkers. (Wood 2002)
AN IDEAL SITUATION: STEM EDUCATION IN THE SCHOOL SYSTEM

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Are our skills strategies failing the workforce of the future?

The world of work of 2030 and beyond will be significantly different from the workplace most of us know today. Therefore, it is crucial for business leaders to understand the major shifts to ensure that they have the skills planning and other strategies in place that will enable them to survive the turbulence of the next 5 to 10 years. Similarly, the government, the Sector Education and Training Authorities (SETA’s) and other policy makers must rethink the skills strategies that are failing to prepare the current and future workforce for the Fourth Industrial Revolution. Projections by authoritative organisations clearly indicate that South Africa’s education and training system is not preparing the workforce for the “exponential pace of change (that is) disrupting every industry in every country (and) impacting every aspect of how we work and how we live, creating threats and opportunities”. (Morgan, 2016)

These exponential disruptions will not affect all industries and occupations to the same extent or at the same pace. However, ignoring the impact of the Fourth Industrial Revolution is as short-sighted as believing 5 years ago that the internet and electronic communication would have little impact on our work and lives. There are areas in which our skills development strategies are failing to prepare the workforce for the changes that we will experience in the next five years. The article:

- Explains the future world of work, the nature of the disruptive technologies of the Fourth Industrial Revolution and their impact on the work environment;
- Identifies some changes needed in the occupation-directed skills development system; and
- Concludes with a description of the new skills that are required by the workforce of 2020.

Our skills strategies are failing the future workforce

The main concerns about the post-school education and training (PSET) that should prepare people for the world of work are that:

- Many occupational qualifications are preparing the workforce for occupations that will no longer exist in five years’ time, or – if they do exist – will be radically different.
- The process of developing qualifications does not keep pace with the rapidly changing world of work, so many qualifications are outdated by the time the first cohort of students graduate.
- The school and post-school systems are not equipping people with the skills they will need to succeed in the work environment that will be significantly transformed by disruptive technologies.
- The SETA grants and public funding do not incentivise employers to support the kind of training that is essential to prepare the workforce for 2020 and beyond.
- Education and training is primarily focused on training people for JOBS – not for WORK, and are not making a significant impact in creating entrepreneurs.
- The obsession with training for credits on the National Qualifications Framework (NQF) and points on the B-BBEE Scorecard means that training is not primarily focused on developing the skills organisations need to “relentlessly and continuously innovate”. (World Economic Forum (WEF), 2016a)

Whilst these broad generalisations that do not apply to all training or all organisations, they are nevertheless prevalent in our post-school skills development system.
The benefit of leadership on STEM
As digital technologies continue to disrupt, and as KZN looks for new avenues of growth, a growing number of businesses will be facing a STEM skills deficit. Business therefore needs to be part of a collective effort to create the scale of change required. Those that engage now will be those that reap the rewards.

STEM School Definition
STEM stands for Science, Technology, Engineering, and Mathematics, and these schools separate themselves from traditional learning in that they integrate all of these subjects into a cohesive learning environment where learners can apply what they study to real-world functions. Typically, STEM curriculum spans elementary schools, middle schools, and high schools. While the idea of boosting science fields has persisted for decades, including the creation of the National Science Foundation (NSF) in 1950, the rise of STEM education especially started to boom during the early 2000s.

Kinds of STEM Schools (American)
While these science- and technology-driven schools exist in many forms (including STEM magnet schools and STEM charter schools), the National Research Council of the National Academies identified three kinds of STEM schools:

- **Selective schools**
  Selective STEM schools enrol a small number of learners with interest in STEM areas. Typically, these schools are elite public schools, and a written exam is required in order to be admitted.

- **Inclusive schools**
  Despite providing a similar STEM experience as selective schools, inclusive schools are open to all learners and also focus on more marginalized groups, like low-income families, women, and underrepresented ethnic groups.

- **STEM-Focused CTE Schools**
  At STEM-focused Career and technical education (CTE) schools, STEM subjects can be fused with regional career technical centres and career-focused high schools and academics. While very few of these schools focus on engineering, they do address other fields like auto-technology and financial management.

The push to educate America’s youth in the ways of science and technology hopes to put learners in jobs rather than unemployment lines and strengthen a nation that’s statistically shown to be falling behind in these fields.

STEM in the Workplace
The entire STEM imperative must be inculcated into every workplace; if KZN is to reap the benefits of a holistic STEM Culture – must transcend each and every workplace. I.e. Every workplace becomes a STEM-repository – both in terms of STEM knowledge and practice.
International context:
In a seminal work by Jonathan Rothwell: “The Hidden STEM Economy”, his finds that “workers in STEM (science, technology, engineering, and mathematics) fields play a direct role in driving economic growth. Yet, because of how the STEM economy has been defined, policymakers have mainly focused on supporting workers with at least a Bachelor’s degree, overlooking a strong potential workforce of those with less than a bachelor’s degree. An analysis of the occupational requirements for STEM knowledge finds that:

- As of 2011, 26 million U.S. jobs—20 percent of all jobs—require a high level of knowledge in any one STEM field. STEM jobs have doubled as a share of all jobs since the Industrial Revolution, from less than 10 percent in 1850 to 20 percent in 2010.
- Half of all STEM jobs are available to workers without a four-year college degree, and these jobs pay $53,000 on average—a wage 10 percent higher than jobs with similar educational requirements. Half of all STEM jobs are in manufacturing, health care, or construction industries. Installation, maintenance, and repair occupations constitute 12 percent of all STEM jobs, one of the largest occupational categories. Other blue-collar or technical jobs in fields such as construction and production also frequently demand STEM knowledge.
- STEM jobs that require at least a bachelor’s degree are highly clustered in certain metropolitan areas, while sub-bachelor’s STEM jobs are prevalent in every large metropolitan area. Of large metro areas, San Jose, CA, and Washington, D.C., have the most STEM-based economies, but Baton Rouge, LA, Birmingham, AL, and Wichita, KS, have among the largest share of STEM jobs in fields that do not require four-year college degrees. These sub-bachelor’s STEM jobs pay relatively high wages in every large metropolitan area.
- More STEM-oriented metropolitan economies perform strongly on a wide variety of economic indicators, from innovation to employment. Job growth, employment rates, patenting, wages, and exports are all higher in more STEM-based economies. The presence of sub-bachelor’s degree STEM workers helps boost innovation measures one-fourth to one-half as much as bachelor’s degree STEM workers, holding other factors constant. Concentrations of these jobs are also associated with less income inequality.

“There must be a stream of new scientific knowledge to turn the wheels of private and public enterprise. There must be plenty of men and women trained in science and technology for upon them depend both the creation of new knowledge and its application to practical purposes.” Vannevar Bush

Innovation—primarily through the invention, development, and profusion of new technologies—is the fundamental source of economic progress, and inventive activity is strongly associated with economic growth in metropolitan areas and nationally. Technological innovation, in turn, usually requires the expertise of specialists with knowledge in fields of science, technology, engineering, and mathematics (STEM). The notion that scientific and technical knowledge are important to living standards is embodied in the Constitution, which explicitly gave government the role to “promote the progress of science and useful arts” by granting patents to inventors. The government’s explicit commitment to provide funding to enhance the STEM labour supply and promote research can be traced to Vannevar Bush, who helped initiate the National Science Foundation (NSF) with his 1945 report to President Roosevelt. Since then, reports from the NSF have emphasized the need for STEM education.

More recently, national leaders from both major political parties have acknowledged the importance of STEM education. In 2006, President George W. Bush launched the American Competitiveness Initiative to improve STEM education and increase the supply of working scientists. Likewise, President Obama frequently mentions the importance of STEM education in his speeches. He also created the “Educate to Innovate” campaign to boost STEM education, and signed into law a
reauthorization of the Bush-era America Competes Act, which embodies many of the same goals as the Bush administration’s STEM priorities.

In “Rising Above the Gathering Storm”, a National Academy of Sciences book, the authors emphasize PhD training in science and even K-12 (pre-primary to matric) preparation, but they offer no assessment of vocational or practical training in science and technology. Notwithstanding the economic importance of professional STEM workers, high-skilled blue-collar and technical STEM workers have made, and continue to make, outsized contributions to innovation. Blue-collar machinists and manufacturers were more likely to file a patent during the Industrial Revolution than workers in professional occupations. US industrialization coincided with a “democratization of invention” beyond professional workers and researchers. In 1957, one economist criticized the National Academy of Sciences for overemphasizing PhD researchers, when evidence suggested that they were the minority of inventors, and that roughly half of patent holders had not even completed a college degree. At the same time, between the late nineteenth century and the 1950s, wages for manufacturing workers grew faster than wages for professional workers.

The economy has obviously changed since then. Formal education in a science or technology field is more important than ever to providing the skills required to invent. One recent survey found that 94 percent of U.S. patent inventors between 2000 and 2003 held a university degree, including 45 percent with a PhD. Of those, 95 percent of their highest degrees were in STEM fields, including more than half in engineering. Still, most innovators—inventors or entrepreneurs—do not have a PhD, and the vast majority is employed outside of academia.

The STEM economy draws from high schools, workshops, technical and vocational schools, and colleges. Workers today are less likely to be directly involved in invention, but they are critical to the implementation of new ideas, and advise researchers on feasibility of design options, cost estimates, and other practical aspects of technological development. Skilled technicians produce, install, and repair the products and production machines patented by professional researchers, allowing firms to reach their markets, reduce product defects, create process innovations, and enhance productivity. These technicians also develop and maintain the nation’s energy supply, electrical grid, and infrastructure. Conventional wisdom holds that high-skilled, blue-collar jobs are rapidly disappearing from the economy as a result of either displacement by machines or foreign competition. But the reality is more complex. High-skilled jobs in manufacturing and construction make up an increasingly large share of total employment, as middle-skilled jobs in those fields wane. Moreover, workers at existing STEM jobs tend to be older and will need to be replaced.

More high-STEM workers (those high in any one field) are health care practitioners and technicians than any other broad category. Even in less technical professional fields such as management and finance, many workers are required to have high levels of STEM knowledge.

A few examples illuminate some of these non-traditional blue-collar STEM occupations. High-STEM installation, maintenance, and repair jobs include a wide array of skilled occupations: automotive service technicians and mechanics, first-line supervisors, industrial machinery mechanics, HVAC mechanics and installers, telecommunications equipment installers and repairers, aircraft mechanics, computer and office machine repairers, heavy equipment mechanics, and electrical repairers. These jobs all score very highly on engineering and technology skills, and they are often at least in the middle, if not the high, end on other STEM fields.

In the construction and extraction trades, most occupations qualify as high-STEM, and some even as super-STEM: construction and building inspectors, electricians, and elevator installers and repairers. These and other STEM-based construction jobs tend to depend highly on engineering and technology. Finally, there are different production jobs that qualify as high-STEM; examples of which
include: water and wastewater treatment plant and system operators, tool and die makers, chemical plant and system operators, stationary engineers and boiler operators, computer numerically controlled machine tool programmers, and plant and system operators. These jobs tend to depend highly on appropriate science and engineering backgrounds.

Distribution across Industries

Jobs requiring high-level STEM knowledge can be found in every sector of the economy, although there are large differences in the demand for STEM knowledge across sectors. Utilities, professional services, construction, mining, and manufacturing are the five most STEM-intensive sectors. Generally utility sector workers are required to have a cross-cutting, high level of STEM knowledge, and a high-level STEM knowledge in at least one field. The construction industry also has a high share of workers with high-level STEM knowledge; cross-cutting knowledge is a huge advantage. For buildings and infrastructure to be safe and durable, the construction industry demands a considerable level of skill in engineering, physics, and mathematics. At the low end of the STEM scale are sectors such as accommodation and food services, arts, entertainment and recreation, and retail, where advanced STEM knowledge is generally not important.

In 2009, President Barack Obama launched the Educate to Innovate campaign, with the goal of getting high schoolers at the top of the pack in terms of science and math in the United States. In recent years, American learners have fallen behind when it comes to STEM classes. In 2011, only 45 percent of U.S. high school graduates were proficient enough in math(ematics) to complete college work, with only 30 percent competent in science.

But the history of the focus on science in schools dates back to the 1940s, when then American President Franklin D. Roosevelt directed the Director of the Office of Scientific Research and Development asking for the application of scientific knowledge to carry over beyond wartime problems. “The diffusion of such knowledge should help us stimulate new enterprises, provide jobs for the returning servicemen and other workers, and make possible great strides for the improvement of the national well-being.”

Decades after the fact, Roosevelt’s letter highlights many of the same ideas prevalent today, with the former president proposing a program for discovering and developing scientific talent among American youth. This is the fundamental mission behind STEM schools and education.

After a sustained period of economic prosperity, South Africa – and therefore KwaZulu-Natal is facing some tough challenges. Slowing growth, declining real wages, falling productivity, and the end of the mining boom, to name a few. At the same time, businesses are coming to terms with the massive disruptive impact that digital technologies are having on business models, supply chains and customer behaviour.

As per the recent editions of the World Economic Forum Global Competitiveness Reports – South Africa is lagging behind in the education and competitiveness indicators. These changes are putting major pressure on the workforce, and the companies that rely on it. Building on cutting edge work undertaken at Oxford University, new analysis by PwC shows that 44 per cent (5.1 million) of current Australian jobs are at high risk of being affected by computerisation and technology over the next 20 years. One chooses Ireland and Australia as a comparative example as it mirrors a range of developmental indicators as per global developmental organizations such as OECD, WEF, UNIDO, etc.)

In order to realise the potential for innovation, KwaZulu-Natal needs an appropriately skilled workforce; a workforce fit for the future. Businesses competing in a global economy driven by data, digital technologies and innovation will need more employees trained in science, technology, engineering and mathematics (STEM). Research indicates that 75 per cent of the fastest growing occupations now require these skills. (Becker, K. and Park, K., Journal of STEM Education Volume 12 – Issue 5 & 6, July-September 2011)
Interestingly enough, based on a number of key STEM indicators; both the participation and graduation rates ex the tertiary sector (post-school) is relatively flat; the number of Grade 12 learners studying STEM subjects is declining and businesses are struggling to find STEM employees. The benefits of a stronger commitment to STEM are many. It would help meet workforce needs, better equip workers with vital skills for the future and drive innovation and productivity. It would also deliver economic growth.

The Australian economy finds that shifting just 1 per cent of the workforce into STEM roles would add $57.4 billion (ZAR 750 billion) to GDP (nett present value over 20 years). The case for growing the STEM workforce and outlines some of the benefits and impacts for businesses specifically and the economy broadly. And it calls on business, to take a leading role alongside government and the education sector in order to deliver the STEM outcome, KZN needs to remain a competitive, innovative and prosperous region.

The need to act

The leadership of KZN is alert to the fact that the good times can’t go on forever. In the face of economic challenges and a digital revolution that’s reshaping business and the workforce, one need to act.

The economic challenges are significant - As a comparative study to the KZN economy, Australia’s recent economic history is truly impressive. The twenty four-year period from 1991 to 2015 is one of the longest continuous economic expansions of any developed country. (Garnaut, R; ‘Dog Days: Australia After the Boom’, 2013). The prosperity during this period was underpinned by two key factors. One was the economic reforms of the 1990s, which drove productivity growth and created the foundation for long-term economic success. The other was the China-led surge in demand for commodities during the 2000s, which saw Gross Domestic Product (GDP) grow by 44 per cent. (Minifie, J. (2013). ‘The Mining Boom: Impacts and Prospects’).

But in the wake of the Global Financial Crisis (GFC) and the end of the commodity boom, Australia has become something of a victim of its own success. While the first ten years of growth were fuelled by genuine innovation and hard-won reforms such as trade liberalisation and a national competition policy, growth in the second decade was largely good luck. Australia now face significant economic challenges that are both circumstantial and structural: slower GDP growth, declining real incomes, low productivity growth, declining employment, sluggish global growth and rising shortfalls in tax revenue.

Governments are finding it difficult to fund the services one expect – good schools, a strong health system, effective public infrastructure and a safety net for those that need it the most. Unless there’s substantial action towards addressing these fiscal pressures, Australians can expect to see their standard of living deteriorate over the coming decades. This represents an inflexion point. The opportunity to move towards a more innovative, productive and sustainable economy is in front of us and is needed to respond.

Digital is disrupting everything

Inextricably woven into the fabric of the economic future is the impact of digital disruption, arguably the most significant mega-trend of the 21st century. Digital technologies are radically changing the way one lives, consumes and works.

For example:

• **Machine learning**, which allows computers to make intelligent decisions by processing massive amounts of data, will be a source of major productivity gains. This will have

- **3D printing** stands to potentially disrupt traditional supply chains by lowering the cost of ‘where’ and ‘how’ manufacturing is done. An estimated 41 per cent of air cargo and 37 per cent of ocean cargo are threatened by 3D printing. (Strategy & Commercial Transportation Trends: 3D printing; 2015)

- **Crowdsourcing**, enabled by online social networks, is creating a new human resource model by allowing companies to engage with a globally distributed workforce to complete tasks on demand and at scale.

Businesses and institutions alike are working hard to adapt. How does one respond to these changes will go a long way to determining the effectiveness of businesses and the prosperity and well-being of society.

**Jobs are at risk**

One of the major implications of digital disruption for KZN is the impact it will have on the workforce. Many of the jobs people work in today simply won’t exist in the next decade, either entirely, or at the same number. Building on cutting edge work undertaken at Oxford University, (Carl Frey and Michael Osborne), The Future of employment: How susceptible are jobs to computerisation; Oxford University, 2013) shows that 44 per cent (5.1 million) of current jobs are at high risk of being affected by computerisation and technology over the next 20 years. By ‘high risk’ one means there’s a greater than 70 per cent chance the job could be automated by technology. Frey and Osborne do not specify a specific timeline rather that “occupations are potentially automatable over some unspecified number of years, perhaps a decade or two”

Jobs most likely to be affected are those where computer learning systems or robotics are able to perform simple and routine tasks faster and more accurately than humans. These typically include unskilled or low-skilled activities in offices, factories and shops. For example: data entry, operating a checkout, book-keeping, doing simple office administration and operating machinery. This is not to say that jobs will no longer exist or that industries would disappears, rather it is indicative of where major impacts are likely to occur give the pace of technological development. Rather it is a continuation of a trend we are currently seeing in examples such as automated check-out systems replacing routine transactions; however, customer service still being performed by people.)

The impact on the workforce will be significant not only for employees but also for businesses, which are already struggling to find appropriately skilled talent.

<table>
<thead>
<tr>
<th>Jobs most at risk from computerisation and technology in next 20 years</th>
<th>Probability of being automated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accounting clerks/bookkeepers</td>
<td>97.5%</td>
</tr>
<tr>
<td>Checkout operators/cashiers</td>
<td>96.9%</td>
</tr>
<tr>
<td>General office administration workers</td>
<td>96.1%</td>
</tr>
<tr>
<td>Wood machinists</td>
<td>93.4%</td>
</tr>
<tr>
<td>Financial and insurance administration workers</td>
<td>93.1%</td>
</tr>
<tr>
<td>Farm, forestry and garden workers</td>
<td>92.5%</td>
</tr>
<tr>
<td>Personal assistants and secretaries</td>
<td>92.4%</td>
</tr>
<tr>
<td>Sales administration workers</td>
<td>91.1%</td>
</tr>
<tr>
<td>Keyboard operators</td>
<td>87.1%</td>
</tr>
<tr>
<td>Hospitality administration and support workers</td>
<td>85.5%</td>
</tr>
<tr>
<td>Sales assistants and salespersons</td>
<td>85.2%</td>
</tr>
</tbody>
</table>
Real estate sales agents 85.2%
Factory process workers 84.6%
Fabrication trades workers 84.3%
Receptionists 83.9%
Clerical and office Support workers 83.8%
Printing trades workers 82.9%
Mobile plant operators 82.8%
Food preparation assistants 82.5%
Food process workers 82.2%
Glaziers, plasterers and tilers 81.4%
Food trades workers 80.7%
Automobile, bus and rail drivers 80.5%
Machine operators 80.1%

Derived and adapted from Oxford University study, PwC analysis

A workforce for the future
As the world looks towards new sources of growth in a rapidly changing global economy, one needs to start building a workforce fit for the future. But what does the workforce of the future look like? And where should one be focusing attention on? Identifying jobs that have a low risk of being automated is a good place to start. Modelling shows that the jobs most likely to endure over the next couple of decades are ones that require high levels of social intelligence, technical ability and creative intelligence. This includes doctors and nurses, teachers, engineers, and information communication and technology (ICT) professionals, and managers.

<table>
<thead>
<tr>
<th>Jobs least at risk from computerisation and technology in next 20 years</th>
<th>Probability of being automated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical practitioners</td>
<td>0.4%</td>
</tr>
<tr>
<td>Education, health and welfare managers</td>
<td>0.7%</td>
</tr>
<tr>
<td>Midwives and nurses</td>
<td>0.9%</td>
</tr>
<tr>
<td>Advertising, Public Relations and sales managers</td>
<td>1.5%</td>
</tr>
<tr>
<td>Database and systems administrators, and ICT Security Specialists</td>
<td>3.0%</td>
</tr>
<tr>
<td>Education professionals</td>
<td>3.3%</td>
</tr>
<tr>
<td>ICT managers</td>
<td>3.5%</td>
</tr>
<tr>
<td>Tertiary-level teachers</td>
<td>3.6%</td>
</tr>
<tr>
<td>School teachers</td>
<td>4.0%</td>
</tr>
<tr>
<td>Engineering professionals</td>
<td>4.2%</td>
</tr>
<tr>
<td>Legal professionals</td>
<td>6.5%</td>
</tr>
<tr>
<td>Social and welfare workers</td>
<td>6.8%</td>
</tr>
<tr>
<td>Accommodation and hospitality managers</td>
<td>7.2%</td>
</tr>
<tr>
<td>Construction, distribution and production managers</td>
<td>8.2%</td>
</tr>
<tr>
<td>Child carers</td>
<td>8.4%</td>
</tr>
<tr>
<td>ICT network and support professionals</td>
<td>9.7%</td>
</tr>
</tbody>
</table>

Derived and adapted from Oxford University study, PwC analysis

But what about the jobs one don’t yet know one’s need, the jobs of the future? The rapidly changing nature of technology and global competition makes it difficult to predict precisely what these will be. What do know?, is that technology and innovation, which are transforming the economy whether one like it or not, are key to solving both the workforce and growth challenge.
Against the backdrop of the OECD recently rating Australia as only ‘average’ in its competency and capacity to innovate. (OECD, OECD Science, Technology and Industry Outlook 2012) the political, business and social leadership need to figure out a strategy to overcome this quickly. This is no different from the challenges one faces in South Africa and in particular KZN. Hence, in order to realise the potential, KZN needs a workforce that is technologically savvy and able to innovate. And one of the best ways to do this is by improving capabilities in STEM.

The Critical role of Stem
A STEM education underpins innovation and plays a critical role in economic and business growth. But South Africa (as per WEF) is lagging on key indicators of STEM. In order to realise the potential for innovation, KZN needs an appropriately skilled workforce. Businesses competing in a global economy driven by data, digital technologies and innovation will need more STEM-trained employees. Research indicates that 75 per cent of the fastest growing occupations now require STEM skills, (Becker, K. and Park, K; Effects of integrative approaches among STEM subjects on learners’ learning’; Sept 2013) and over 70 per cent of Australian employers identify STEM employees as being among the most innovative. (Prinsley, R. & Baranyai, K.; ‘STEM Skills in the Workforce: what do employers want’; 2015). There will also be a growing need for the broad skills that STEM fosters. Critical thinking and problem solving, analytic capabilities, curiosity and imagination have all been identified as critical ‘survival skills’ in the workplace of the future. (Ellen Kumata, Tony Wager’s Seven Survival; 2014)

What counts as STEM?
There is no universally agreed definition of what counts as a STEM education or field of occupation. It’s generally considered to include an education in the fields of:

- Natural and physical sciences
- Information technology
- Engineering and related technologies
- Mathematics.

From an economic view however, one should include:

- Architecture and building
- Agriculture, environmental and related studies
- Health.

STEM underpins innovation
Countries that lead in STEM education also rank high on innovation. Germany, for example, ranks third in the OECD in terms of graduates in STEM fields, compared to the US which ranks 33rd. (The Brookings Institute; 2015), Skills and Innovation Strategies to Strengthen U.S. Manufacturing Lessons from Germany).

In 2011 Germany produced 53 patents per 1000 researchers, while the US produced 39. (The Brookings Institute (2015), Skills and Innovation Strategies to Strengthen U.S. Manufacturing Lessons from Germany)

Sweden, which has a reputation for successfully commercializing innovative research, including seat belts, pacemakers and Skype, has a STEM-focused education system. 90 per cent of Swedish learners attend highly digitally equipped schools and each year several thousand teachers attend national STEM-focused training centres.

In 2012, the US the Obama administration announced over $240 million in new private-sector commitments to inspire and prepare more learners – especially those from underrepresented
groups – to excel in STEM fields. The “Educate to Innovate” campaign has to date resulted in over $1 billion in financial and in-kind support for STEM programs.

By developing the right infrastructure and teaching capabilities, these countries are growing a workforce of the future that has the core skills and competencies for driving innovation.

**Leading businesses participate:**

- **Cisco** this year announced a five-year, $31 million program to increase the pool of talent with STEM skills in US, Ireland, Australia, New Zealand, India and Germany.
- **BHP Billiton** last year launched a $28.8 million CSIRO education program aimed at increasing interest and achievement among indigenous Australian learners in STEM related professions. More recently they have announced a further $22 million commitment over five years to encourage girls to study maths.
- **Microsoft** has just announced its commitment to being part of the fabric of the community and would offer training workshops and support STEM education starting with India, Malaysia and K

**Can we be doing much better?**

Despite these and other positive initiatives, South Africa overall is lagging behind many of its OECD peers on a number of key indicators for STEM.

Globally the final school year (Grade/Year 12) participation in STEM subjects is declining. Over the twenty-year period from 1992 to 2012, there was a fall in participation of 11 per cent for intermediate mathematics. Research suggests that the divergence is explained largely due to a preference among year 12 learners for selecting non-calculus based course work; 2012) 10 per cent for biology, 5 per cent for chemistry and 7 per cent for physics. (John Kennedy, Terry Lyons and Frances Quinn; The Continuing Decline of Science and Mathematics Enrolments in Australian High Schools, 2012).

Enrolments and completions in university STEM courses have remained flat over the period 2001 to 2013. Non-STEM, on the other hand, has grown steadily.

In 2012 in the highly innovative manufacturing nation of Singapore, 52 per cent of university graduates were from a STEM-related course. In South Africa and Australia the proportion was just 11 and 16 per cent respectively.

While these results are a concern, it’s important to recognise that education is one of a number of ways to boost STEM skills. Alternatively, businesses could reskill current employees or bring talent in from overseas. In fact, it has been argued that at the global level, there’s no shortage of STEM skills. Rather, there’s just a location mismatch. For example, there may be a shortage of electrical engineers in the UK but a large and growing supply in India.

What is clear, however, is that the countries with a strong track record in innovation also tend to have a strong commitment to STEM education and as a result a strong pipeline of STEM workers.

**The benefits of growing STEM**

Growing STEM would help businesses meet workforce needs, better equip workers with vital skills for the future and drive innovation and productivity. It would also deliver economic growth and higher wages for STEM workers.
KZN needs to grow its STEM workforce. The shift away from mining-led growth to knowledge, services and construction is well underway. For example, the services industries account for the majority of the Australian economy. The vast majority of the SIPS (Strategic Infrastructure Projects) are infrastructure related; and South Africa expects to spend over R185 billion in new infrastructure projects over the next five years. The demand for engineers and construction managers alone will be significant. But what is an appropriate STEM target across the whole economy? If one looks to countries considered to be leaders in STEM, to see what they consider reasonable targets for accelerated workforce growth.

According to the European Centre for the Development of Vocational Training, demand for STEM skills in Germany could potentially be as high as 7.6 per cent more than forecast. (European Centre for the Development of Vocational Training; Forecasting skill demand and supply, 2014)

As an example if Australia were to target a similar growth trajectory to compete with STEM leaders like Germany, 126,327 Australian workers – or 1 per cent of the current workforce – would need to move into more STEM occupations by 2035. (According to PwC baseline modelling), by 2035 Australia’s workforce is expected to grow from 11 million workers to over 15 million. During that time the ‘baseline’ STEM workforce will continue to grow from 760,000 workers to over 1 million workers. To meet the accelerated target, one will need an additional 126,327 people working in STEM occupations in addition to the baseline. This equates to approximately 1.1% of the current Australian workforce.)

This means that over and above the current expected number of graduates, one would need to train: an additional 20,500 new engineers, 17,500 business and system analysts and programmers, 13,500 construction, distribution and production managers, 12,000 natural and physical scientists, 9,500 architects, designers, planners and surveyors, and 53,000 workers in other STEM fields. To put these numbers in perspective, in 2014 the University of Melbourne’s Faculty of Science had 6,500 graduate and undergraduate learners enrolled. (University of Melbourne: Faculty of Science, 2015)

Possibly local universities would need at least another dedicated science faculty of comparable size to reach the STEM target.

The table following shows the 10 STEM jobs that would grow the most if Australia met the accelerated STEM target. Assuming a throughput of +6,300 learners per year over the next 20 years (eg 6,300 x 20 = 126,000) (PwC – Australian workplace report 2015)

<table>
<thead>
<tr>
<th>Job</th>
<th>Percentage growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering professionals</td>
<td>11.7%</td>
</tr>
<tr>
<td>Business and systems analysts, and programmers</td>
<td>9.5%</td>
</tr>
<tr>
<td>ICT network and support professionals</td>
<td>9.0%</td>
</tr>
<tr>
<td>Database and systems administrators, and ICT security specialists</td>
<td>8.2%</td>
</tr>
<tr>
<td>Natural and physical science professionals</td>
<td>8.0%</td>
</tr>
<tr>
<td>ICT and telecommunications technicians</td>
<td>7.1%</td>
</tr>
<tr>
<td>ICT managers</td>
<td>6.8%</td>
</tr>
<tr>
<td>Architects, designers, planners and surveyors</td>
<td>6.2%</td>
</tr>
<tr>
<td>Building and engineering technicians</td>
<td>5.1%</td>
</tr>
<tr>
<td>Construction, distribution and production managers</td>
<td>4.1%</td>
</tr>
</tbody>
</table>

Source: PwC
More STEM workers would deliver an economic boost
Growing KZN’s STEM workforce would also deliver a sustained boost to the economy. This is because higher skill workers create more valuable goods and provide more valuable services than lower skilled workers. They can then sell these at higher real prices and command higher wages for doing so.

Modelling by PwC shows that if Australia were to develop a STEM workforce in line with other leading STEM countries, it would generate, in present value terms, an additional $57.4 billion (ZAR 750bn) in GDP over the next 20 years. That’s roughly equivalent to South Africa’s motor vehicles and parts industry, and almost twice as big as the aircraft manufacturing industry. While the benefit of this boost would be felt right across the economy, some industries stand to gain more than others. The professional, scientific and technical services industry would see the biggest gain with an additional $21 billion (net present value) of output.

The benefit for the mining industry would be marginal given that the mining construction boom is now over and operations are not as heavily reliant on STEM occupations.

<table>
<thead>
<tr>
<th>Benefit to key industries as a result of increasing the STEM workforce</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
</tr>
<tr>
<td>Professional, scientific and technical services</td>
</tr>
<tr>
<td>Information media and telecommunications</td>
</tr>
<tr>
<td>Financial and insurance services</td>
</tr>
<tr>
<td>Construction</td>
</tr>
<tr>
<td>Electricity, gas, water and waste services</td>
</tr>
<tr>
<td>Manufacturing</td>
</tr>
<tr>
<td>Wholesale trade</td>
</tr>
<tr>
<td>Rental, hiring and real estate services</td>
</tr>
<tr>
<td>Retail trade</td>
</tr>
<tr>
<td>Administrative and support services</td>
</tr>
<tr>
<td>Transport, postal and warehousing</td>
</tr>
<tr>
<td>Public administration and safety</td>
</tr>
<tr>
<td>Arts and recreation services</td>
</tr>
<tr>
<td>Mining</td>
</tr>
</tbody>
</table>

Source : PwC

Real wages growth for key STEM jobs
A stronger STEM workforce will also have a positive impact on wages growth. STEM occupations tend to be relatively higher paying, reflecting higher productivity; expanding the STEM workforce will result in a growth in higher paying jobs. Engineers could expect to see an almost 2 per cent increase over and above baseline growth each year, with business and systems analysts and programmers enjoying 1.4 per cent annualised growth in wages above baseline.

KZN stands to gain significant benefits by building the STEM workforce. But this will be no mean feat. Industries and institutions will need to create new STEM roles; workers will need to be re-skilled and redeployed.
The Fourth Industrial Revolution

The Future World of Work
The future world of work is unknown and unpredictable, as confirmed by the University of Oxford report: *The Future Is Not What It Used to Be.* (Manyika, 2016) We have entered “The Age of Unreason” as described by Charles Handy, considered to be one of the current greatest business minds. He warns that in the 21st century change has become discontinuous and no longer follows a rational and predictable pattern: “The only prediction that will hold true is that no predictions will hold true...” (Handy, 1989: 257). Mark Shuttleworth is quoted as saying “Technology and society are evolving so fast that you can’t rely on tradition and tried and tested techniques to teach you how to perform in the future”. (Shuttleworth, 2000)

Disruptive Technologies
Major changes in the world of work are brought about by ‘disruptive technologies’, labelled as such because they significantly disrupt the global economy, how businesses operate and the way we work and live “... the acceleration of innovation and the velocity of disruption (brought about by these technologies) are hard to comprehend or anticipate and these drivers constitute a source of constant surprise, even for the best connected and most well informed. Indeed, across all industries, there is clear evidence that the technologies that underpin the Fourth Industrial Revolution are having a major impact on businesses.” (WEF, 2016a)

Examples of these disruptive technologies are: (McKinsey Global Institute, 2013)
- Advanced robotics: increasingly capable robots or robotic tools with enhanced ‘senses,’ dexterity and intelligence can take on tasks once thought too delicate or uneconomical to automate;
- The ‘internet of things’: the network of physical devices, vehicles, buildings and other objects embedded with electronics, software, sensors, actuators and network connectivity that enable them to collect and exchange data;
- Artificial intelligence exhibited by machines that work and react like humans and are capable of speech recognition, visual perception, decision-making, problem solving and learning;
- Devices and physical systems that store energy for later use that could make electric vehicles cost competitive and bring electricity to remote areas of developing countries; and
- Drones, cloud technology, nanotechnology, virtual reality, software-based digital therapies, next-generation genomics, 3D printing and driverless vehicles.

These disruptive technologies are already playing a critical role - General Electric has designed robots that can climb and maintain wind turbines. A 3D printer in the Netherlands is building a footbridge over a canal by using long robotic arms and lasers to melt the metal powder – without the help of human hands, girders or concrete foundations. Self-driving robots can deliver parcels and groceries anywhere within a 3-mile radius using less energy than most light bulbs. Ford is already road testing driverless cars, and the head of Ford predicts that in the future driving with a steering wheel will be “as antiquated as wanting to ride a horse”. (The Edge Foundation, 2016) On 25 August 2016 Singapore launched a trial and “became the first country in the world to have on-demand driverless taxis – a new technology that is touted to disrupt the transport industry”. (http://www.straitstimes.com)

Technology has catapulted us into the Fourth Industrial Revolution:

“The First Industrial Revolution used water and steam power to mechanize production. The Second used electric power to create mass production. The Third (the digital revolution) used electronics and information technology to automate production. ... (The Fourth is) characterized by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres. When compared with previous industrial revolutions, the Fourth is evolving at an exponential rather than a linear pace. Moreover, it is disrupting
almost every industry in every country. And the breadth and depth of these changes herald the transformation of entire systems of production, management, and governance. ... The bottom line, however, is the same: business leaders and senior executives need to understand their changing environment, challenge the assumptions of their operating teams, and relentlessly and continuously innovate.” (WEF, 2016a)

The world stands on the brink of a technological revolution that will fundamentally alter the way its population will live, work, and relate to one another. In its scale, scope, and complexity, the transformation will be unlike anything humankind has experienced before. One does not yet know just how it will unfold, but one thing is clear: the response to it must be integrated and comprehensive, involving all stakeholders of the global polity, from the public and private sectors to academia and civil society.

The First Industrial Revolution used water and steam power to mechanize production. The Second used electric power to create mass production. The Third used electronics and information technology to automate production. Now a Fourth Industrial Revolution is building on the Third, the digital revolution that has been occurring since the middle of the last century. It is characterized by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres.

There are three reasons why today’s transformations represent not merely a prolongation of the Third Industrial Revolution but rather the arrival of a Fourth and distinct one: velocity, scope, and systems impact. The speed of current breakthroughs has no historical precedent. When compared with previous industrial revolutions, the Fourth is evolving at an exponential rather than a linear pace. Moreover, it is disrupting almost every industry in every country. And the breadth and depth of these changes herald the transformation of entire systems of production, management, and governance.

The possibilities of billions of people connected by mobile devices, with unprecedented processing power, storage capacity, and access to knowledge, are unlimited. And these possibilities will be multiplied by emerging technology breakthroughs in fields such as artificial intelligence, robotics, the Internet of Things, autonomous vehicles, 3-D printing, nanotechnology, biotechnology, materials science, energy storage, and quantum computing.

Already, artificial intelligence is all around us, from self-driving cars and drones to virtual assistants and software that translate or invest. Impressive progress has been made in AI in recent years, driven by exponential increases in computing power and by the availability of vast amounts of data, from software used to discover new drugs to algorithms used to predict one’s cultural interests. Digital fabrication technologies, meanwhile, are interacting with the biological world on a daily basis. Engineers, designers, and architects are combining computational design, additive manufacturing, materials engineering, and synthetic biology to pioneer a symbiosis between microorganisms, one’s bodies, the products one consumes, and even the buildings one inhabits.

Challenges and opportunities
Like the revolutions that preceded it, the Fourth Industrial Revolution has the potential to raise global income levels and improve the quality of life for populations around the world. To date, those who have gained the most from it have been consumers able to afford and access the digital world; technology has made possible new products and services that increase the efficiency and pleasure of one’s personal lives. Ordering a cab, booking a flight, buying a product, making a payment, listening to music, watching a film, or playing a game—any of these can now be done remotely.
In the future, technological innovation will also lead to a supply-side miracle, with long-term gains in efficiency and productivity. Transportation and communication costs will drop, logistics and global supply chains will become more effective, and the cost of trade will diminish, all of which will open new markets and drive economic growth.

At the same time, as the economists Brynjolfsson and McAfee have pointed out, the revolution could yield greater inequality, particularly in its potential to disrupt labour markets. As automation substitutes for labour across the entire economy, the net displacement of workers by machines might exacerbate the gap between returns to capital and returns to labour. On the other hand, it is also possible that the displacement of workers by technology will, in aggregate, result in a net increase in safe and rewarding jobs.

Unfortunately one cannot predict which scenario is likely to emerge, and history suggests that the outcome is likely to be some combination of the two. However, in the future, talent, more than capital, will represent the critical factor of production. This will give rise to a job market increasingly segregated into “low-skill/low-pay” and “high-skill/high-pay” segments, which in turn will lead to a possible increase in social tensions.

In addition to being a key economic concern, inequality represents the greatest societal concern associated with the Fourth Industrial Revolution. The largest beneficiaries of innovation tend to be the providers of intellectual and physical capital - the innovators, shareholders, and investors - which explains the rising gap in wealth between those dependent on capital versus labour.

Technology is therefore one of the main reasons why incomes have stagnated, or even decreased, for a majority of the population in high-income countries: the demand for highly skilled workers has increased while the demand for workers with less education and lower skills has decreased. The result is a job market with a strong demand at the high and low ends, but a hollowing out of the middle.

This helps explain why so many workers are disillusioned and fearful that their own real incomes and those of their children will continue to stagnate. It also helps explain why middle classes around the world are increasingly experiencing a pervasive sense of dissatisfaction and unfairness. A winner-takes-all economy that offers only limited access to the middle class is a recipe for democratic malaise and derealization.

Discontent can also be fuelled by the pervasiveness of digital technologies and the dynamics of information sharing typified by social media. More than 30 percent of the global population (Brooking Institute Bulletin, May 2017) now uses social media platforms to connect, learn, and share information.

In an ideal world, these interactions would provide an opportunity for cross-cultural understanding and cohesion. However, they can also create and propagate unrealistic expectations as to what constitutes success for an individual or a group, as well as offer opportunities for extreme ideas and ideologies to spread.

The impact on business
Many global CEOs and senior business executives agree that the acceleration of innovation and the velocity of disruption (WEF 2016) are hard to comprehend or anticipate and that these drivers constitute a source of constant surprise, even for the best connected and most well informed. Indeed, across all industries, there is clear evidence that the technologies that underpin the Fourth Industrial Revolution are having a major impact on businesses.
On the supply side, many industries are seeing the introduction of new technologies that create entirely new ways of serving existing needs and significantly disrupt existing industry value chains. Disruption is also flowing from agile, innovative competitors who, thanks to access to global digital platforms for research, development, marketing, sales, and distribution, can oust well-established incumbents faster than ever by improving the quality, speed, or price at which value is delivered.

Major shifts on the demand side are also occurring, as growing transparency, consumer engagement, and new patterns of consumer behaviour (increasingly built upon access to mobile networks and data) force companies to adapt the way they design, market, and deliver products and services.

A key trend is the development of technology-enabled platforms that combine both demand and supply to disrupt existing industry structures, such as those one see within the “sharing” or “on demand” economy. These technology platforms, rendered easy to use by the smartphone, convene people, assets, and data—thus creating entirely new ways of consuming goods and services in the process. In addition, they lower the barriers for businesses and individuals to create wealth, altering the personal and professional environments of workers. These new platform businesses are rapidly multiplying into many new services, ranging from laundry to shopping, from chores to parking, from massages to travel.

On the whole, there are four main effects that the Fourth Industrial Revolution has on business—on customer expectations, on product enhancement, on collaborative innovation, and on organizational forms. Whether consumers or businesses, customers are increasingly at the epicentre of the economy, which is all about improving how customers are served. Physical products and services, moreover, can now be enhanced with digital capabilities that increase their value. New technologies make assets more durable and resilient, while data and analytics are transforming how they are maintained. A world of customer experiences, data-based services, and asset performance through analytics, meanwhile, requires new forms of collaboration, particularly given the speed at which innovation and disruption are taking place. And the emergence of global platforms and other new business models, finally, means that talent, culture, and organizational forms will have to be rethought.

Overall, the inexorable shift from simple digitization (the Third Industrial Revolution) to innovation based on combinations of technologies (the Fourth Industrial Revolution) is forcing companies to re-examine the way they do business. The bottom line, however, is the same: business leaders and senior executives need to understand their changing environment, challenge the assumptions of their operating teams, and relentlessly and continuously innovate.

The impact on government
As the physical, digital, and biological worlds continue to converge, new technologies and platforms will increasingly enable citizens to engage with governments, voice their opinions, coordinate their efforts, and even circumvent the supervision of public authorities. Simultaneously, governments will gain new technological powers to increase their control over populations, based on pervasive surveillance systems and the ability to control digital infrastructure. On the whole, however, governments will increasingly face pressure to change their current approach to public engagement and policymaking, as their central role of conducting policy diminishes owing to new sources of competition and the redistribution and decentralization of power that new technologies make possible.
Ultimately, the ability of government systems and public authorities to adapt will determine their survival. If they prove capable of embracing a world of disruptive change, subjecting their structures to the levels of transparency and efficiency that will enable them to maintain their competitive edge, they will endure. If they cannot evolve, they will face increasing trouble.

This will be particularly true in the realm of regulation. Current systems of public policy and decision-making evolved alongside the Second Industrial Revolution, when decision-makers had time to study a specific issue and develop the necessary response or appropriate regulatory framework. The whole process was designed to be linear and mechanistic, following a strict “top down” approach.

Given the Fourth Industrial Revolution’s rapid pace of change and broad impacts, legislators and regulators are being challenged to an unprecedented degree and for the most part are proving unable to cope.

How, then, can they preserve the interest of the consumers and the public at large while continuing to support innovation and technological development? By embracing “agile” governance, just as the private sector has increasingly adopted agile responses to software development and business operations more generally. This means regulators must continuously adapt to a new, fast-changing environment, reinventing themselves so they can truly understand what it is they are regulating. To do so, governments and regulatory agencies will need to collaborate closely with business and civil society.

As this process takes place and new technologies such as autonomous or biological weapons become easier to use, individuals and small groups will increasingly join states in being capable of causing mass harm. This new vulnerability will lead to new fears. But at the same time, advances in technology will create the potential to reduce the scale or impact of violence, through the development of new modes of protection, for example, or greater precision in targeting.

The impact on people

According to Klaus Schwab (WEF Founder) - “The Fourth Industrial Revolution, finally, will change not only what one can do but also who we are. It will affect our identity and all the issues associated with it: our sense of privacy, our notions of ownership, our consumption patterns, the time we devote to work and leisure, and how we develop our careers, cultivate our skills, meet people, and nurture relationships. It is already changing our health and leading to a “quantified” self, and sooner than we think it may lead to human augmentation. The list is endless because it is bound only by our imagination.”

The moot question remains: the inexorable integration of technology in our lives could diminish some of our quintessential human capacities, such as compassion and cooperation. Our relationship with our smartphones is a case in point. Constant connection may deprive us of one of life’s most important assets: the time to pause, reflect, and engage in meaningful conversation.

One of the greatest individual challenges posed by new information technologies is privacy. We instinctively understand why it is so essential, yet the tracking and sharing of information about us is a crucial part of the new connectivity. Debates about fundamental issues such as the impact on our inner lives of the loss of control over our data will only intensify in the years ahead. Similarly, the revolutions occurring in biotechnology and Artificial Intelligence (AI), which are redefining what it means to be human by pushing back the current thresholds of life span, health, cognition, and capabilities, will compel us to redefine our moral and ethical boundaries.
**Shaping the future**

Neither technology nor the disruption that comes with it is an exogenous force over which humans have no control. All of us are responsible for guiding its evolution, in the decisions we make on a daily basis as citizens, consumers, and investors. We should thus grasp the opportunity and power we have to shape the Fourth Industrial Revolution and direct it toward a future that reflects our common objectives and values.

To do this, however, we must develop a comprehensive and globally shared view of how technology is affecting our lives and reshaping our economic, social, cultural, and human environments. There has never been a time of greater promise, or one of greater potential peril. Today’s decision-makers, however, are too often trapped in traditional, linear thinking, or too absorbed by the multiple crises demanding their attention, to think strategically about the forces of disruption and innovation shaping our future.

In the end, it all comes down to people and values. We need to shape a future that works for all of us by putting people first and empowering them. In its most pessimistic, dehumanized form, the Fourth Industrial Revolution may indeed have the potential to “robotize” humanity and thus to deprive us of our heart and soul. But as a complement to the best parts of human nature—creativity, empathy, stewardship—it can also lift humanity into a new collective and moral consciousness based on a shared sense of destiny. It is incumbent on us all to make sure the latter prevails.

**What role will education play in the Fourth Industrial Revolution?**

The Fourth Industrial Revolution urges us to think creatively about the manufacturing process, value chain, distribution and customer service processes. In the meanwhile, the future of education emphasizes the immense need to look beyond these areas and strategically utilize the “Internet of Things” to prepare the coming workforce for the challenges ahead.

Currently our post-school system (i.e. Universities, Universities of Technologies and the TVET Colleges) do not really emphasize their role in shaping future technology by being the test-beds for innovation and educating future generations (obviously with a select few institutions). Traditional education has contributed greatly to the current levels of industrial evolution and technological advancement.

However, in order for post-school/higher education to deliver future generations with the right set of skills and knowledge; an imperative question has to be asked regarding how higher education institutes would be affected by the Fourth Industrial Revolution and how the delivery of education will be transformed.

There are different opportunities available that will shape the role which can be undertaken by higher education in the Fourth Industrial Revolution. Combining the strength of the traditional higher education with the increasing trend of blended learning integrating e-learning, digital learning, and MOOCs represents necessary steps to scale quality education.

**A mix between traditional education and MOOCs**

At times where the boundaries between the internet, physical world and people are becoming more blurred by each passing day, the need for education in general and higher education in particular to be “campus-based” is diminishing. Currently, education is being connected to mobile devices through applications in the cloud and is no longer limited to knowledge but extended to skills acquisition. With the expansion in networking services nationally and globally, physical boundaries are no longer barriers to education.
Massive Open Online Courses (MOOCs) are a potentially disruptive innovation. The number is increasing exponentially across the globe, making learning more accessible to people. According to “By the Numbers: MOOCs in 2015” (www.class-central.com/report/mooc-2015-stats), the number of participants has doubled in 2015 from 16-18 million students to 35 million students across all MOOC providers; even universities are digitizing some of their courses. However, one can’t overlook the importance of direct and face-to-face interaction between the learners and teachers as an influential part of a quality education. Therefore, a mix between MOOCs, which are gaining more and more popularity, and traditional ways of delivering education is extremely vital for meeting the global job markets’ needs.

One of the main issues facing MOOCs is related to accreditation and trust in the associated credential. On the other hand, higher education institutions are trusted and have had a long experience in accreditation. The future mix between MOOCs and traditional education can provide higher education institutes the opportunity to expand services to offer credentials using the experiences of the lecturers and teachers. One of the main services universities offer is the provision of certification for students upon the completion of their studies. Nonetheless, there are many students whose education is disrupted whether because of war, conflicts, or a lack of financial resources. The higher education community might address this great challenge by creating micro certificates recognizing the level of knowledge or skills acquired by the sum of a person’s education until the moment of its interruption.

Global identity
As individuals gain education from different universities, work at diverse and global organizations and participate actively with different initiatives, his/her identity is no longer tied to one organization. Creating identities based on every institution one learns from or organization one works at could be very confusing and overwhelming; which raise the question of “What is our identity and where can we find it?” The trust placed in Higher Education institutions could be the driver for Higher Education to be leading the creation of a global identity that is portable across universities and organizations. Higher Education is not proprietary nor limited to one ideology; its openness and long history of trust makes it eligible to act as a custodian for protecting this identity and continuously create environment for knowledge and skill attainment.

Education for the Individual (Customized Learning)
Data analysis and automation help companies not only to survive but also to thrive in the future. Similarly, Higher Education institutions are embracing data mining in order to gain better understanding of student performance and deliver “Education for the Individual” that is tailored to meet the demand of the job markets while considering the students’ needs. Alan Blinder, (a former Vice President at the US Federal Reserve Bank and an economist at Princeton University, argued in “Education of the Third Industrial Revolution” that for students to adapt to the information age, a great focus should be of the type of education students receive rather than the quantity they receive. Education is increasingly becoming “just in time” rather than “just in case”; it is more about what one needs to know for a certain time than compiling knowledge that may never be needed. Data regarding student performance, behaviour, development, and interaction inside classrooms and on the online platforms of MOOCs as well as data from smart campus would create diverse and fast-changing data. The ability of Higher Education institutions to integrate this information into smart data would result in intelligent decisions in regards to the delivery of customized education and personalized learning experience for students.

The challenges ahead
Altering higher education is more necessary than ever before. However, the challenges ahead have to be considered in order to ensure effective and immediate transformation. With the reduced
public financial support for higher education; universities need to think strategically regarding methods to utilize their experience in credentials, trust and identity to offer new services. Furthermore, higher education leadership needs to be less risk averse especially in this world of disruptive change. It is no longer an option to keep doing things the old way; innovation and accepting change are now prerequisite for survival.

Inequality would still be a concern for digital higher education since more than 4 billion people are still offline without access to the internet according to a study (McKinsey 2017). Most of those people are marginalized families who live in developing countries with no access to an affordable education.

Although digital higher education can be more affordable compared to other education options, higher education institutions need to consider the best ways to reaching underserved populations where education can serve as a strong empowerment and change tool.

Risk, privacy and security are other challenges facing higher education. Collaboration, integration and aligning security process are key words for scaling higher education efforts and bringing sustainability.

During the World Engineering Education Forum 2015, Professor Sabina Jeschke from RWTH Aachen University said “the complexity of the systems developed to meet the demands of the fourth industrial revolution necessitate interdisciplinary and collaboration as a precondition for innovation.”

This is the time to ask whether the global higher education community will only react to how the business world is shaping the Fourth Industrial Revolution or if it will be among the key players of shaping the Fourth Industrial revolution! Furthermore, the annual meeting of the World Economic Forum happening in Davos, 2016 is the place to investigate and explore further the previously mentioned question and challenges.

**How can we prepare for the next wave of innovation?**

The relationship between minds and machine is at the heart of innovation. Its history has been marked by critical moments that changed the nature of the bond forever —, many of which brought fundamental disruptions in our global economy as well. One need only think of the changes brought about by the use of tools for agriculture or the Internet to appreciate the scale of the impact, for example.

Today, we stand at the verge of another wave, characterised by the digitisation of our economies, our knowledge and our lives. The transformative potential of such a transition could be just as game changing as the previous waves of innovation, if not more so. This transition will also bring about a new evolution in the links between minds and machines.

A smooth transition will also require us to address the concerns associated with the new phase of the minds-machines relationship. Our minds now rely much more on machines for productivity at the same time that machines are developing a mind of their own. We are also getting to a point where our minds can influence not just mechanical machines but biological machines as well (eg DNA, cells). Some concerns associated with these tensions are old and often exaggerated (eg “automation will take our jobs”); others are new and relate to tipping-point dynamics, such as Elon Musk’s arguments about artificial intelligence or how far we should go with human enhancement. These are complex issues for which there are no easy answers; they will require careful consideration if we are to make a successful transition.
The relationship between minds and machines is probably one of the most defining characteristics of human evolution — certainly one of the most powerful in terms of the evolution of the speed and form of economic growth.

It is interesting in the way in which the relationship between minds and machines is fraught with contradictions. There’s always an element of hope mixed with fear. Whilst humans generally love to use the machines to use them to do things that we don’t like doing, but at the same time we have this instinctive fear that machines might somehow replace us, replace workers and not work in our interest.

These concerns were probably less important during the first wave of this evolution — agriculture — but one can see it very clearly in the case of the Industrial Revolution. In both cases, however, no comparison was being made between the mind and the machine. The demarcation line between the two was very clear.

What is happening now with this current wave of evolution is that this line becomes to some extent blurred. With the development of big data mining, computing and eventually artificial intelligence — and to some extent robotics — we’re also looking at the possibility of machines taking over a number of intellectual tasks.

As an example an Economist looks at global economic data, now aided and abetted by super computers can sift through tons of economic data and come up with economic forecasts for any number of variables.

So, all of a sudden there have machines expanding into a different realm of activity. What’s distinctive and interesting about this phase of evolution is that it’s leading us to ask ourselves more insightful and complicated questions about what it is that makes humans special. This is not just a philosophical question, it’s an economic one. It amounts to asking, “What is the best division of labour between minds and machines in this third phase of revolution where machines can take over more and more intelligent and intellectual activities?”

Once one starts making industrial machines and supply chains more intelligent through data and sensors, what one gets is a more efficient and productive economy, leading to more economic growth and more jobs. These productivity gains, in a sense, are not dissimilar to the previous wave [Industrial Revolution] but the difference is that now we will have software helping us predict when and what will go wrong with any piece of equipment, where to intervene before an outage occurs, how to plan around it and thus eliminate outages or stoppages in production.

The most powerful characteristic of this new wave of relationships, however, is the global brain. This is probably where one has the greatest interaction and cooperation between minds and machines. And this is because on top of having humans leverage the computing power of machines, we are also now leveraging the ability that machines have to put humans in contact with each other. In terms of software development this has been going on for a while.

The incredible progress in advanced manufacturing techniques. This is another form of the evolution of this new phase of mind and machine interaction, and it has a different kind of power. These techniques allow one — that allows anyone to be the engineer, the scientist, the thinking brain of the machine — to start figuring out completely new products that are smart by design rather than smartened by having sensors added on top of them. I think this is another area where we will see enormous progress over the next 20 years. The rise of industrial machines and supply chains more intelligent through data and sensors, what one gets is a more efficient and productive economy,
In many ways we are just at beginning of this new innovation wave
Getting to the top of the current wave of innovation is going to take longer, because it is a much more complex an evolution than the Industrial Revolution.

We started decades ago with creation of computers, but I think it’s going to take probably another 50-100 years before we reach the top of this wave. That is not to say that the next 5, 10 years will not see anything meaningful — they will — but some of the innovations including 3D printing and 4D printing, are really at the beginning in terms of interesting applications. This is going to be a long and productive ride.

In terms of what needs to happen to get there, there are different things. An obvious one is infrastructure investments — both in physical and digital infrastructure. However, it will be much more important to invest in education.

Prior to the crisis, there was a widespread feeling — especially in advanced economies — that it didn’t matter what one studied, one would get a great job and be employed in a high-paying job for the rest of one’s life. As machines become more powerful on the information data intelligence front, however, it is becoming clearer that we need to better understand what skills humans need to have the best possible compatibility with the machines.

This means raising the bar on STEM (science, technology, engineering and mathematics) qualifications, but it also means focusing formal and informal education systems on creativity, flexibility and adaptability. In other words, to engage in this new phase of innovation, minds need to come first, then machines.

Some countries will be left behind — at least temporarily. There will be countries that underestimate the importance and the potential of this shift, and they won’t move fast enough. And because this technological shift is so powerful, if one falls behind and accumulates a delay, one would pay a higher price to catch up. **KZN cannot afford to be in his category.**

There is a big debate on whether these innovations will favour advanced economies or emerging economies. Some argue that the advantage will be squarely on the side of advanced economies. Whilst the US and India are leading the way; China, with its new “Made in China 2025” plan is also going to be racing for pole position.

I think there are a few insights and they go back to the role of policy. Examining the different approaches in the US and India compared to China, the US and India are pretty much distributed. There is some effort at the top research labs or government organisations to go in the right direction. There are many important initiatives, but other than that, one doesn’t really have a full, constant government strategy that sets the pursuit of the current wave of innovation as a priority.

In the case of China, where the economic system is completely different, there is clearly a very structured and determined effort on the part of the government to make the Industrial Internet a priority for investment. The advantage, in the case of China, is its tremendous focus on the education. An examination of the statistics on how many Chinese students graduate in science and engineering, it is over 40% compared to about 15% in the US and about 26% in India.

Whilst one can argue about the quality of scientific and engineering education there, but a difference of such a magnitude is nevertheless quite staggering. If one believes that skills and education are at the top of the priority list, it makes for a compelling observation.
Another insight is the difference in how these countries foster innovation. In China, there is a strong effort to gradually move their resources away from the underperforming state-run enterprises and towards companies that can innovate and advance [state-run or not]. There is also a lot of effort spent on trying to create areas where companies and individuals can experiment.

In the USA, by contrast, one has the opposite tactic. It’s taken for granted that there is a lot of innovation and experimentation going on, and one spends most of the time from a policy perspective trying to figure out the right way of leveraging that and refinancing it. India takes the middle ground.

The most interesting insight from the comparison between the above approaches is the observation that innovation never stops. As a country, one should never think that one will be able to produce enough innovation, enough activity. One should always be thinking in terms of: “How do I foster more of this?”

Going through this new wave of innovation will require one to make choices about how we interact with machines, some of which may be difficult and/or irreversible. Which are the tipping points one should pay the most attention to if we are to ride this wave of innovation successfully? When one start thinking in terms of the tipping points and the relationship of man and machines, the most promising and sensitive area will be healthcare. For example, as we make more progress in using new waves of technology to generate better health outcomes, we will inevitably come across new ways of augmenting human capabilities.

One tipping point here is whether or not we’ll reach a stage where concerns over artificially engineering human capacities become so strong that it forces policymakers and businesses to turn research the other way. This will be a critical moment and, in a sense, it is the other side of the blurry line (where minds become more like machines).

When one starts thinking in terms of the tipping points and the relationship of man and machines, arguably the most promising and sensitive area will be healthcare. In thinking of these long-term trends and trying to understand what is going to shape them and how to best respond to change,

**Isaac Asimov’s “I, Robot”** is a seminal work because when discussing great innovations, one is struck by how a lot of how one reacts is constrained by the fact that human nature has not changed very much. Asimov’s stories encapsulate the interaction between unchanging human nature and these tremendous innovations. One needs to understand both and keep both in mind if one wants to understand how this interaction between minds and machines is going to play out.

**Walter Isaacson’s “The Innovators,”** is also fascinating. Its talks to what guides the innovation process in terms of the innovators’ mind-set — what pushes them in a certain direction — and how that interacts with business creation and business models. This is very useful in thinking about the economic and business implications of all the technological innovations that one is seeing around us today.

Once the Industrial Internet becomes the norm, where will the next disruption come from? If it succeeds, however, it will have created so much capability in terms of production and wealth creation that the focus will shift to: “How does one improve institutions in a global way? How do the KZN EDTEA create a situation where the wealth created by new technologies can be spread in a way that is more sustainable while consistent with economic incentives?”
Implications of the Fourth Industrial Revolution for skills development

Key questions that we need to consider on how this revolution impacts on skills development are:

- What assumptions about skills development are preventing us from preparing the workforce for the workplace that will be exponentially disrupted by new technology?
- How do we need to reconceptualise training for occupations if some occupations will disappear or be significantly changed by the time learners’ graduate?
- How do we prepare the workforce for multiple career changes that cut across occupational boundaries?
- What skills sets will the current and future workforce need to thrive in the unpredictable ‘Age of Unreason’?
- What should we be ‘teaching’ if we cannot transfer everything that is known, and if what is taught becomes outdated within a year or two?
- How do we equip people with the skills they will need to use technology that hasn’t even been conceptualised yet?
- What do we need to do differently to create more entrepreneurs for a world of declining formal employment?

Technology-driven changes in organisations and employment

Disruptive technologies are already having a significant impact on the nature of work and organisations. These changes will also have a massive impact on society, contributing to large-scale job losses for workers who are not equipped with the right skills, as well as personal trauma and social unrest as employees struggle to cope with the uncertainty and instability of the new work environment.

Changes in the nature of work and occupations

The changes accompanying the Fourth Industrial Revolution that are impacting on how and where we work, and the occupations in which we work, will become more widespread.

- **New jobs will emerge** that we cannot even imagine now. We are already grappling to understand new occupations such as the Director of Intellectual Capital, Ethical Hacker, Cybrarian, Cyber Lawyer, Information Security Auditor and occupations created by e-commerce.
- **Existing occupations will disappear.** Travel and estate agents, postmen, lecturers, publishers of textbooks and many other occupations have had to fundamentally change their business models or find new ways of earning a living. If a librarian returned to work after five years in a coma, she wouldn’t be able to do her job.
- A large part of the workforce is moving into **jobs of short duration**, which require workers to be more flexible and multi-skilled.
- We are beginning to see the **end of the fixed job description**. More jobs have only the core functions clearly described, with employees having to figure the rest out as they continuously adapt to new technology and the changing work context.
- More work will be done by **cross-functional project teams** working together in temporary relationships, and collaborating through virtual communication across time zones, space and organisational boundaries.
- **The ‘office’ won’t be the place you go to work.** Less people will need to drive to a building to work office hours; they will join the new workforce whose ‘office’ is where they can interact through a device that is connected to the internet.

Changing organisational structures

New types of organisations are emerging as they adapt to new ways of working in the technology-driven environment. Except for the predominantly traditional organisations, more temporary structures are evolving, changing size, shape and their relationship to the workforce more.
organically as they respond to change. We are already seeing the more flexible organisational models that Charles Handy, and others wrote about in the late 1990’s. Below are examples of new structures that are replacing the traditional ones that dominated the landscape for decades with multiple management levels and large numbers of permanent staff working in clearly demarcated occupations? For organisations to thrive, they will need to be flexible and responsive to change, as these organisational models allow.

- The **Shamrock Organisation** consists of an inner core of fixed-term professional employees, supported by temporary or part-time persons (‘the contractual fringe’) who provide specific services needed on a contract basis.
- The **Virtual Organisation** is a temporary network of independent organisations and/or individuals collaborating in informal alliances towards a shared goal, and using a combination of information and communication technologies. The virtual organisation does not have a central office, an organisational chart or hierarchy. An ‘adhocracy’ is an example in which individuals with particular expertise get together on an ad hoc basis to work on a project. When the project is completed, the ‘entity’ disbands and the individuals may never work together again. [Many consulting business functions as an adhocracy, drawing expertise for specific projects into temporary associations based on the experience required for the projects.]

**Changes in employer-employee relationships**

These emerging organisational structures inevitably result in a significant shift in employment patterns, with less permanent employer-employee relationships. We have seen the end of one-job-for-a-lifetime with one employer, moving up the ladder to a senior position in the same occupation, and then retiring with a pension. A 2015 study of the International Labour Organization (ILO) confirmed that:

“**Fewer than 45 per cent of wage and salaried workers are employed on a full-time, permanent basis and even that share appears to be declining. This means that nearly six out of ten wage and salaried workers worldwide are in either part-time or temporary forms of wage and salaried employment. Women are disproportionately represented among those in temporary and part-time forms of wage and salaried employment.”** (ILO, 2015)

This coincides with the trend among new entrants into the workforce who are more mobile and less interested in tying themselves to one organisation for their entire working life. They change jobs more frequently and move comfortably across occupational boundaries. My daughter made six career changes across different occupations before turning 40, while my sister has been a primary school teacher for her entire working life. In the emerging world of work most people will work in multiple occupational roles throughout their working lives and these roles will rarely be directly related to the qualification they had on entering the workforce.

**The job loss crisis**

We will be seeing more and more news headlines like “**Nearly 60 000 in SA face jobs axe**” ([www.fin24.com](http://www.fin24.com) of 26 April 2016). Job losses are the reality of the future workplace, no matter how many labour unions or political parties strike against it. Clem Sunter (2015) confirms this trend:

“We have been saying for years that the world of work has changed forever and we are never going back to the mass employment conditions of the last century. Technology has driven a shaft through many jobs, companies are cutting back on their permanent work-forces by sub-contracting all their non-core activities to others and we now have the concept of on-demand employment where you are hired for a specific time to do a specific job”.

A 2016 World Bank Development Report found that 67% of jobs in South Africa are at risk from automation, 85% in Ethiopia, 69% in India, 65% in Nigeria, 35% in the UK, and 47% in the USA.
A Financial Times article, Artificial Intelligence and Robotics, reports on a factory in China where nine robots do the work of 140 full-time workers. The article quotes a Hong Kong economist who states that “industrial laggards in parts of Asia and Africa face a ‘race against the machines’ as they struggle to create sufficient manufacturing jobs before they are wiped out by the gathering robot army in China and beyond”. (Bland, 2016)

Challenges and barriers to future-directed workforce planning

Organisations need to adapt their workforce planning strategies to ensure that they equip their employees to be productive in the new world of work. Key question to consider are:

- What jobs will there be in each industry in 2020 and which jobs will have disappeared or have been radically altered?
- What full-time and temporary workers will organisations need in 2020 and what range of skills should they have?
- How should we prepare the workforce for productive partnerships with machines?

The WEF (2016b) studied the “measures and strategies for adapting to the top trends and disruptions expected to affect (industries) over the coming years ... as well as the biggest perceived barriers to successfully carrying out these measures and the perceived degree of preparedness prevalent across the industry”. The WEF identified the following main barriers for South Africa:

- Insufficient understanding of disruptive changes (68%);
- Workforce strategy not aligned to innovation strategy (44%); and
- Resource constraints (52%).

The first two are particularly significant barriers to adopting future-directed skills strategies.

Are we training people for a world that no longer exists?

In view of what we understand about the disruptive changes that will result from the Fourth Industrial Revolution, we need to consider whether our education and training is preparing the workforce for a world that won’t exist in 2020. Clem Sunter (2015) has strong views on this: “... schools and universities are still preparing their students for the market that prevailed fifty years ago. They have not woken up to the changing reality of business and the fact that technology has disrupted all of their cherished academic assumptions about what you should be taught to be a success in life”.

This disturbing trend is confirmed in university enrolment in subjects relevant to the technological revolution. The Department of Higher Education and Training report for 2014 indicates that of the total of 969 165 university students less than a third (only 287 221) were enrolled in Science, Engineering and Technology (SET) – and this figure includes students with major subjects in Engineering as well as Health, Life, Physical, Computer and Mathematical Sciences. (DHET, 2016)

“We are currently preparing students for jobs that don’t yet exist, using technologies that haven’t been invented, in order to solve problems we don’t even know are problems yet. ... The amount of new technical information is doubling every 2 years. By 2010 it (was) predicted to double every 72 hours. For students starting a 4-year technical degree this means that half of what they learn in their first year of study will be outdated by their third year of study.” (Rose: https://www.youtube.com/watch?v=XVQ1UJFQawk)

Changes required in South Africa’s occupation-directed skills development system

Clem Sunter (2016) warns that “One of my problems about the conversations at the moment between business and Government is that they’re not recognising this flag of the total change in the nature of work.” I believe that the changes described thus far raise ‘flags’ for changes that are
required in the occupation-directed skills development system in order to prepare the workforce for the continuous change, complexity and turbulence of the ‘Age of Unreason’.

There are four areas in which the system is failing to prepare the workforce for 2030 are highlighted below.

1. **Occupation-based qualifications model:** The Quality Council for Trades and Occupations (QCTO) adopted a model in which qualifications are developed for occupations that are registered on the Organising Framework for Occupations (OFO). The 2015 OFO includes almost 1500 occupations, including Accountant, Judge, Librarian, History Teacher, Railway Assistant and Ticket Collector, as well as all the trades – even the occupation of an ‘Escort’ who “Provides clients with social companionship or sexual services”. (The 2015 OFO list is available from [http://www.dhet.gov.za](http://www.dhet.gov.za))

   - However, we know that there will be significant changes in occupations, so we run the risk of occupational qualifications being outdated by the time student’s graduate, or that the occupations no longer exist when the graduates enter the workforce. We can foresee that the OFO will find it difficult to keep track of all the new occupations that will emerge, change fundamentally or disappear in the rapidly changing workplace.
   - We also recognise that people’s relationships to occupations are far more fluid now than they were 20 years ago. People now move flexibly between occupations that sometimes have no relationship to their qualifications, which often simply gave them entry into the world of work. We will have to prepare the workforce to move more easily across occupations if they want to remain relevant – rather than training them for very specific occupations on the OFO, such as a Nurse (Aged Care) or Nurse (Mental Health).
   - A pertinent example is four separate occupational qualifications that were recently registered for bus, train, truck and taxi drivers. In terms of the QCTO model, separate qualifications are likely to be developed for the drivers of boats, forklifts and other types of vehicles that are distinct occupations on the OFO. What is most interesting about these examples, is that they were developed at a time when driverless vehicles were being tested by most motor manufacturers, and factories were already buying self-driving freight carriers and autonomous forklift trucks to reduce manpower.

   I am not suggesting that we will all soon switch to driverless vehicles; but the example does illustrate the point that qualifications should be developed to prepare learners for the changing world of work.

   “Multiple careers will be commonplace and lifelong learning to prepare for occupational change will see major growth. To take advantage of this well-experienced and still vital workforce, organizations will have to rethink the traditional career paths in organizations, creating more diversity and flexibility.” (IFTF, 2011)

2. **The development of occupational qualifications** is a lengthy, consultative process involving multiple stakeholders (and costing around R250 000 or more per qualification), followed by a quality assurance process and culminating in the registration on the NQF about two to three years after commencement. The first learners will therefore complete the qualification about four to five years after the initial design.

   - As indicated previously, the acquired skills might no longer be relevant to the changes that have occurred in the occupation; that is if the occupation still exists.
   - *Business @ the speed of thought: Succeeding in the Digital Economy*, the title of Bill Gates’ 1999 book captures the tempo of change in the new world of work. Therefore, we cannot assume that the occupational qualifications will still be relevant five years after registration. We will have to develop quicker mechanisms and less cumbersome...
models for preparing the workforce for the future – either in addition to, or in place of the current occupational qualifications model.

3. **Learning for credits on the NQF**: The South African Qualifications Authority (SAQA) and the SETAs succeeded in promoting the value of programmes that enable learners to gain credits for qualifications or unit standards registered on the NQF – and I support the need for credit-bearing programmes. However, we now have a national obsession with credits, resulting in the misconception that all credit-bearing programmes have intrinsic value – and that other programmes have no value at all. So many employers believe that they shouldn’t implement any programmes that are not credit-bearing; and this misconception is fuelled by SETAs that, as a rule, don’t fund these programmes.

- The new workplace will require more short interventions that were put together quickly to develop the specific skills workers require to use unfamiliar disruptive technologies, in order to be fully functional in performing completely new tasks, and to work on innovative projects that are conceptualised ‘on-the-run’. This type of intervention will be critical for success – even for survival – in the Fourth Industrial Revolution.
- The National Skills Development Strategy (NSDS) as well as SETA funding priorities and discretionary grant structures must make provision for these skills interventions if the government and SETAs are serious about sector competitiveness, creating more work opportunities, investment and economic growth.
- Similarly, employers (particularly HR Managers and CFOs) will have to change policies that restrict training spend to credit-bearing programmes for skills development.

4. **The NSDS, B-BBEE Scorecard and SETA funding priorities** are – understandably – focused on the upliftment of previously disadvantaged groups who were denied quality education that restricts their access to employment in occupations where qualifications are required. However, companies that want to survive and thrive in the Fourth Industrial Revolution cannot adopt skills development strategies that are focused primarily on B-BBEE points and SETA grants.

- In our pursuit of NSDS/SETA targets and B-BBEE points, we could be failing to equip the workforce with the high level skills needed to engage innovatively with unpredictable and discontinuous change and adapt quickly to work processes transformed by disruptive technologies.
- Some companies are implementing learnerships simply to improve their BEE rating – irrespective of whether the programmes address identified organisational skills needs or the specific needs of learners. Unfortunately, many learnerships implemented today are based on qualifications that were developed 5 or more years ago, and most were automatically re-registered without any revision – so they might not even be relevant to the changing workplace.
- A lesson we should learn from the ‘Pareto principle’ is that 20% of invested input is responsible for 80% of the results obtained. In an organisational context, this is often interpreted to indicate that 20% of the workforce is responsible for 80% of the results achieved by the entire organisation. Therefore, it is critically important for organisations to ensure that the 20% of the workforce – which is probably the highly skilled, optimal performers – are skilled to higher levels because they will be the ones who ensure that the organisation survives and thrives in the turbulence of the next five years and beyond. ([http://www.investopedia.com/terms/p/paretoprinciple.asp](http://www.investopedia.com/terms/p/paretoprinciple.asp))

**Going beyond NQF credits and BEE points**

Coupled with the need for qualifications or the value of credit-bearing programmes; the imperative for Black Economic Empowerment will not prepare the workforce for the emerging world of work.
Such programmes must be supplemented by programmes that fall outside the NQF; programmes that develop the skills workers need to adapt quickly to new work requirements and work collaboratively in virtual teams, performing a range of functions that cut across occupational boundaries. These skills will enable organisations to “relentlessly and continuously innovate”. If an organisation wants to survive and prosper, a substantial portion of your staff development must be outside the parameters of the NQF, SETA grants and the B-BBEE Scorecard in order to develop the skills required by the workforce of 2030.

What are the new skills required by the workforce of 2030?
The experts quoted in this article confirm that many of the current occupations will disappear, others will grow and jobs that don’t exist yet will become quite common by 2030. The WEF (2016c) predicts that more than 35% of the skills considered important in today’s workforce will have changed within five years. “What is certain is that the future workforce will need to align its skillset to keep pace.”

The Institute for the Future describes ten skills that will be essential for the workplace of 2030:
1. Sense-making: the ability to determine the deeper meaning or significance of what is being expressed;
2. Social intelligence: the ability to connect to others in a deep and direct way, to sense and stimulate reactions and desired interactions;
3. Novel and adaptive thinking: proficiency in coming up with solutions and responses beyond that which is rote or rule-based;
4. Cross-cultural competency: the ability to operate effectively in different cultural settings;
5. Computational thinking: the ability to translate vast amounts of data into abstract concepts and to understand data-based reasoning in order to make sense of this information;
6. New-media literacy: the ability to critically assess and develop content that uses new media forms, and to leverage these media for persuasive communication;
7. Trans-disciplinarity: i.e. literacy in and the ability to understand concepts across multiple disciplines: “Many of today’s global problems are just too complex to be solved by one specialized discipline (think global warming or overpopulation). These multifaceted problems require trans-disciplinary solutions. While throughout the 20th century, ever-greater specialization was encouraged, the next century will see trans-disciplinary approaches take centre stage”;
8. Design mind-set: “recognizing the kind of thinking that different tasks require, and making adjustments to their work environments that enhance their ability to accomplish these tasks”;
9. Cognitive load management: “the ability to discriminate and filter information for importance, and to understand how to maximize cognitive functioning using a variety of tools and techniques”; and
10. Virtual collaboration: the ability to work productively and drive engagement as a member of a virtual team.
Preparing for a new partnership with machines

Technological literacy and technical entrepreneurial skills will be essential “use technology to create and capture value”. (The Edge Foundation, 2016)

“We are on the cusp of a major transformation in our relationships with our tools. Over the next decade, new smart machines will enter offices, factories, and homes in numbers we have never seen before. They will become integral to production, teaching, combat, medicine, security, and virtually every domain of our lives. As these machines replace humans in some tasks, and augment them in others, their largest impact may be less obvious: their very presence among us will force us to confront important questions.

- What are humans uniquely good at?
- What is our comparative advantage?
- And what is our place alongside these machines?

In some areas, a new generation of automated systems will replace humans, freeing us up to do the things we are good at and actually enjoy. In other domains, the machines will become our collaborators, augmenting our own skills and abilities. ... We will be entering into a new kind of partnership with machines that will build on our mutual strengths, resulting in a new level of human-machine collaboration and co-dependence.” (Institute for the Future (IFTF), 2011)

Entrepreneurship and adaptable lifelong learning

Two other skills that are essential for the future workforce and economic growth are entrepreneurship and lifelong learning. Clem Sunter (2015) advocates “opening the floodgates of entrepreneurship in this country”. He stressed that we must prepare people to create their own work instead of preparing them for the job market:

“Schools don’t have entrepreneurial programmes so they’re still training kids for the job market that existed in the 70’s and 80’s. I find it incredible that educational institutions like business schools, universities, primary and secondary schools, haven’t seen this flag of the changing nature of work. ... I believe that today, eighty percent of the jobs in the world are being created in small businesses (with less than 100 employees), either independently or in the kind of ‘Uber’ network. ... If you want to bring the unemployment rate down from 25 to 10%, you’re going to have to create millions of new businesses, which can each create 10 to 20 jobs in a business rather than creating 100,000 to 200,000 jobs in a big business.” (Sunter, 2016)

- However, there is no provision for entrepreneurship in NSDS III (covering 2011 to 2016), in the 2015 DHET proposals on the new landscape, and no dedicated SETA grants for entrepreneurship programmes.
- One also need to rethink the current assumption that having a qualification in entrepreneurship or compiling a good business plan will guarantee entrepreneurial success.

China has already opened these floodgates, "embracing mass innovation and entrepreneurship to seize the opportunities of the new development paradigm by nurturing an environment that encourages new ideas, tolerates mistakes, and supports new businesses”. (http://www.china.org.cn/business/2016-06/28/content_38761716.htm: Innovation, entrepreneurship drives 4th industrial revolution)

The IFTF stresses the need for workers of the future to be adaptable, lifelong learners.

“To be successful in the next decade, individuals will need to demonstrate foresight in navigating a rapidly shifting landscape of organizational forms and skill requirements. They will increasingly be called upon to continually reassess the skills they need, and quickly put together the right resources to develop and update these.”
Eric Hoffer’s warning is now more relevant than ever: “In a time of drastic change it is the learners who inherit the future. The learned usually find themselves equipped to live in a world that no longer exists.” (Hoffer, 1973) Charles Darwin taught us that it is not the strongest of the species that survive, nor the more intelligent, but the ones most responsive to change.

**Lifelong learning does not mean continuously attending courses to get credits on the NQF!** It requires pursuing formal and informal learning opportunities throughout life. It is learning that is flexible, diverse and available at different times and in different places, aimed at the continuous development and improvement of the knowledge and skills needed for employment and personal fulfilment.

**Conclusion**

Employers, SETAs, government and policy makers must heed the warnings of the WEF, ILO, Clem Sunter and other experts on the impact of the Fourth Industrial Revolution, and recognise the urgent need to review South Africa’s strategies for preparing the workforce for this revolution. The review will have to initiate substantial changes to strategies and programmes for equipping the workforce for the unpredictable and disruptive technology-driven world of work that we will be entering within the next five years.

We must also heed the warning of the futurist Joel Barker (1989) against relying on our past successes when confronted by paradigm shifts:

“When a paradigm shifts, everyone goes back to zero. It doesn’t matter how good you are at the old paradigm. With the new one you go back to zero. Your past success guarantees nothing in the future, if the rules change. If you’re not careful, your successful past will block your vision into the future, and that is why you must develop an openness to new ideas, a willingness to explore a different way of doing things, because only through that kind of tolerance can you keep open your door to the future.”
The Relevance of Science in Economic Development

“The most important thing is to invest in basic sciences. Those who try to skip this step fail.” Klaus Jaffe

Let us consider the relevance of science in (economic) development. Scientific knowledge and technical expertise promote the wealth of nations, and the following points are worth noting.

A. scientific productivity of a country correlates more strongly with gross national income per capita than its technological sophistication;
B. science is important for economic growth among developed economies, whereas technical complexity is more important for the economic development of poorer countries;
C. scientific productivity of countries correlates more strongly with present and future wealth than indices reflecting its financial, social, economic, or technological sophistication; and
D. Middle-income countries with higher relative productivity in basic sciences such as physics and chemistry have the highest economic growth in the following five years compared to countries with a higher relative productivity in applied sciences.

We live in age of science and technology. Scientific inventions and modern day technologies have completely changed the human life and paving the way for our future. Science and Technology has added greatly to our material comforts. It has also quickened the tempo of life. It has given man/woman an altogether new social and political outlook. Hence in this age the study of science is a necessity.

Without such study a modern man is like a bullock cart lumbering behind a motorized vehicle. It should begin in the developmental stage of a child’s life – with the training of observation; and closely followed through in early childhood development (ECD), pre-school, primary and high schools.

The study of science should begin early in life. The first steps should be to teach children the habit of observation. The child is always interested in trees, in flowers, in birds, in insects, in all the things that he sees around him/her. One’s curiosity in this regard should be fostered and developed. This can be done easily and naturally if teaching be related to those material objects that one is always seeing.

Knowledge of Technology should be imparted naturally in the form of answers to enquiring and intelligent questions. At the initial stage, more can be taught in this way than mechanically through books and expositions.

And pass on to experiments: After a pre-school course of this kind, exposure to science and technology should be gradually introduced. Here also practice, demonstration, actual experiments should precede the study of theories. It is only after the mind is well trained with the help of examples and experiments that the explanations of theories should be attempted. Unfortunately in South Africa, the reverse method is largely followed; which means wastage of time. A learner passes out by mere memory work, and as memory becomes faint, his knowledge becomes nebular, leaving him in his original state of ignorance.

Its influences on the Mind: The study of science and technology has an educative influence on the mind, and is of far-reaching importance. It makes one a lover of truth. It creates realistic attitude to life. It is also the enemy of superstition – which presents a challenge in some of more traditional societies. A scientist depends on his powers of observation, reason for his knowledge of truth. By
applying his reason to observed facts before believing in anything, he acquires patience and
diligence. One thus lays the foundation of true knowledge.

The study of science and technology acts as a perpetual urge to acquire knowledge. It deepens one’s
sense of the mystery of creation. The more one know of the secrets of nature, the more one realized
how much remains unknown. Today scientists speak of the wonder of nature with a thrill of
emotion. One is learning as much of the secrets of the atoms in space as of the molecular cells in
living organism. So a modern curriculum of studies must include the study of science and
technology, because the modern man needs a scientific mind in approaching the problems of life

Economies in the early stages of development are usually disturbed by large changes in growth rates
more than are the advanced economies, but the effects of contemporary globalism eventually spare
no national economy regardless of size; therefore, it is imperative for governments and business
organizations everywhere to prepare as much as possible for the sudden changes following major
events such as the financial meltdown of 2008 or the more recent Arab Spring. The fact that the
business world of today is in a state of constant and rapid flux is of no surprise to educated or
enlightened individuals. Sustainable success in this hectic environment is highly dependent on
visionary business and government leaders who can effectively instil a sense of purpose in people to
prevent complacency.

Modern societies can amass large amounts of productive knowledge because they distribute bits
and pieces of it among its many members. But to make use of it, this knowledge has to be put back
together through organizations and markets. Thus, individual specialization begets diversity at the
national and global level. The most prosperous modern societies are wiser, not because their citizens
are individually brilliant, but because these societies hold a diversity of know-how and because they
are able to recombine it to create a larger variety of smarter and better products.

Knowledge and wealth have been recognized to be related since ancient times. Napoleon is quoted
as saying that “there cannot be a great nation without great mathematics”. Yet how this relationship
works in the modern world is still a sensitive political issue. There is no doubt that scientific and
technological research affects economic development. Scientific development and the wealth of
nations are closely linked. Scientific development was shown to correlate with tolerance and
openness of a society, reflecting the fact that attitudes favouring science are related to valuation of
empirical facts over personal convictions, which lay at the base of modern scientific progress. The
existing statistical analysis (Jaffe et al) correlating scientific productivity with economic
development, found that increases in economic development preceded that of scientific
development, suggesting that the role of science was rather allowing sustained long term economic
development but not triggering its.

The experts agree that science and technology are decisively important tools for the advancement of
women and minorities. They believe that strategic involvement in the applications of science and
technology will lead to beneficial and productive uses. It is widely accepted that science and
technology are particularly useful in four critical areas: education and training, economy (also linked
with poverty), health, and communications/media. It is also critical to note that the Internet is the
one technology that most clearly appears to be embraced by both the developed and developing
countries.

These results open new questions. Do certain areas of science promote economic development
more than others? Are more applied sciences better in advancing economic development than
more general basic sciences?
Middle-income countries that focus on basic sciences, such as physics and chemistry, grow their economies faster than nations that invest in applied sciences, such as medicine or psychology, according to a paper by Venezuelan researchers (Jaffe K, Caicedo M, Manzanares M, Gil M, Rios A, Florez A, et al. (2013) Productivity in Physical and Chemical Science Predicts the Future Economic Growth of Developing Countries Better than Other Popular Indices. PLoS ONE 8(6): e66239. https://doi.org/10.1371/journal.pone.0066239).

“They say that "investing in basic scientific research seem[s] to be the best way a middle-income country can foment fast economic growth". Instead, they believe that investment in basic sciences — as indicated by the proportion of published articles in these fields — reveals a rational, decision-making atmosphere within a country and among its leaders, as well as promoting economic growth.

- Productivity in basic sciences correlates with economic growth, but does not directly cause it
- Scientific productivity is a better wealth growth predictor than many other competitiveness indices
- But benefits of investment in science should be weighed against investment in other development projects

Klaus Jaffe, lead author of the paper and coordinator of the Centre for Strategic Studies of Simón Bolívar University in Venezuela, tells SciDev.Net (http://www.scidev.net/global/r-d/news/basic-science-linked-to-faster-economic-growth.html) that the correlation between scientific productivity and economic growth "has always been suspected, but there has been very little evidence that supports this idea. One has been observing that poor or middle-income countries were growing at a different pace than the developed ones and one wanted to know why."

The study, published in PLOS One (is a peer-reviewed open access scientific journal published by the Public Library of Science (PLOS) - 12 June 2017), set out to investigate if some areas of science promote development more than others, and if applied sciences are better at advancing economic development than basic sciences. The researchers examined the correlation between World Bank data on the growth of GDP (gross domestic product) per capita and the proportion of scientific publications in different scientific fields. They found scientific productivity in basic science, including physics, chemistry and material sciences, correlated strongly with countries’ economic growth over the following five years. Further preferential investment in technology, without investment in basic sciences, achieved little economic development, the say. "Thus, technology without science is unlikely to be sustainable."

They also discovered that scientific productivity was a much better predictor of economic wealth and the Human Development Index — a composite of life expectancy, education and income indices used to rank countries’ development — than other commonly used indices, such as indices of competitiveness or globalisation. "The results of the paper demonstrate that the most important thing [for sustainable development] is to invest in basic sciences. Those who try to skip this step fail," says Jaffe. Looking ahead, the ranking of scientific productivity in 2010 showed that countries with the greatest focus on physics were "among the fastest growing economies in 2012. Regrettably, no country from Africa or Latin America is on this list.

Jaffe says that "the situation is different in every nation. Most countries of Africa, for example, are trying to build the infrastructure they need to be able to do proper research. In addition, this competes with trying to find solutions to everyday problems to guarantee people's subsistence."

Douglas Gollin, professor of development economics at the University of Oxford, United Kingdom, says research is needed to analyse what type of investment brings the greatest benefits. "One would want to compare the returns from basic science research with the returns from more applied
research on agriculture or health," he says. "One should also compare the returns with other investments in public goods: in infrastructure, primary healthcare, primary and secondary education and so on. Of all the things that the government can invest in, is this one that generates the greatest improvement in public welfare?"

Scientific productivity of middle income countries correlates stronger with present and future wealth than indices reflecting its financial, social, economic or technological sophistication. One identifies the contribution of the relative productivity of different scientific disciplines in predicting the future economic growth of a nation. Results show that rich and poor countries differ in the relative proportion of their scientific output in the different disciplines: countries with higher relative productivity in basic sciences such as physics and chemistry had the highest economic growth in the following five years compared to countries with a higher relative productivity in applied sciences such as medicine and pharmacy. Results suggest that the economies of middle income countries that focus their academic efforts in selected areas of applied knowledge grow slower than countries which invest in general basic sciences.

The present analysis allows drawing the following conclusions.
1. For historical periods with no global financial catastrophes, the economic growth of middle income countries can be predicted with high accuracy by looking at their relative academic productivity in physical sciences and engineering.
2. Academic productivity is a much better predictor of future economic growth than economic complexity as measured in. Scientific productivity is more accurate in predicting economic growth and wealth, than economic complexity. If one accept that “science is the mother of technology”, i.e. supports technological development, then science affects other aspects of live such as services, governability, rational thinking, attitudes, etc. and of the economy besides technological development.
3. No country with exclusive preferential investment in technology, without investment in basic science, achieved relatively high economic development. Thus, technology without science is unlikely to be sustainable.
4. The effect on the economy of scientific development is long term. It can be observed in 5 years' time. This time period is very short in terms of the process by which science creates new technology. Thus, one might be measuring the effect of science in preparing new technology leaders and in instilling rational thinking in the leaders of a country rather than the production of novel technology in middle income countries.

This study excluded countries with low scientific productivity, which include all poor countries. Previous studies showed that the correlation between science and wealth of a country appears only after a threshold of economic development has been reached and that a rapid increase in scientific productivity was normally observed after a previous increase in economic development. On the other hand, the relative effort to support academic activity in rich countries seems to be close to the maximum tolerated by society. Rich countries have completed their scientific and industrial revolution in the past and focus now on other aspects of the wellbeing of their citizens, as they have to manage low economic growth. This would explain the low correlations found between scientific publications and future economic growth in rich countries.

Jeffry Sachs (2005; The end of Poverty. Penguin Press 416 pp) recommended health, energy, agriculture, climate and ecology as the areas of science where investments were most likely to promote economic growth. Significantly, countries that knowingly or unknowingly complied with Sachs's recommendations achieved very poor economic growth. It is investment in hard sciences and basic sciences, such as physics and chemistry that correlate strongest with economic growth.
This is in agreement with more recent empirical explorations in economics (Azoulay P, Graff-Zivin J, Sampat B (2011) The diffusion of scientific knowledge across time and space: Evidence from professional transitions for the superstars of medicine. National Bureau of Economic Research Working Paper #16683) that revealed an intricate network of reciprocal relationships between knowledge, services, environment and finance. Azoulay et al propose that scientific development works in an analogous way, affecting multiple aspects of the economy and in turn being affected by many of these aspects producing positive feedback cycles.

Hirschman (Hirschman A (1958) The Strategy of Economic Development. New Haven, Conn.: Yale University press) postulated the high development theory, as the view that development is a virtuous circle driven by external economies – i.e. modernization breeds modernization. Some countries, according to this view, remain underdeveloped because they have failed to get this virtuous circle going, and thus remain stuck in a low level trap. The data in the aforementioned paper would support the proposition that investing in basic scientific research seem to be the best way a middle income country can foment fast economic growth, triggering Hirschman’s virtuous cycle. This proposition is also used by Lin (Lin JY (1995) The Needham Puzzle: Why the Industrial Revolution did not originate in China. Economic Development and Cultural Change 43: 269–292) to solve the Needham Puzzle: “Why the Industrial Revolution did not originate in China?” The scientific revolution needs a profound conceptual revolution which is achieved by the development of basic natural sciences.

It is in the nature of science that Scientists search for the truth in the unknown, which is so vast and complex that predictions will always be constrained by one’s ignorance of the future. The renowned historian of science Karl Popper described the state of knowledge this way: "Knowledge can only be finite, while ignorance must necessarily be infinite." Indeed, it is hard to predict the future, but it is hoped that with insight one can ask the right questions, gain new knowledge, and develop new technologies. In this process of scientific research it is essential that one understand the culture of science and its foundations - inherent continuity, uncertainty, and unmanageability.

SCIENCE AND ITS METHODOLOGY
Since the beginning of human civilization, science and technology has progressed in a continuous process. Fire must have been an exciting new technology for the first humans and to this day one is continuing research to fully answer the question, “What is fire?”

But the search for new knowledge is based on rational thinking, which is fundamental for progress and for making new discoveries. One doubts whether there was (or now is) a civilization that reached a high level of achievement without simultaneously nurturing Science and Technology (S&T) and employing the rational thinking characteristic of the culture of science. After all, we are Homo sapiens, the species characterized by an enlarged brain capacity. Science is an education process that allows the educated and creative minds to question, experiment or observe in an attempt to find answers, and then try to identify a set of unifying principles, concepts, and laws that embraces all phenomena of nature.

The aim is to better understand the universe and gain new knowledge that will enlighten humanity by unveiling mysteries of how nature works. In the process one may make new discoveries and inventions that change the way one thinks and/or create new technologies that transform society. The sharp division of science into pure and applied branches is not natural. Some believe in this division and wish to emphasize only "what is relevant" for the prosperity of the society. But that is not the way science works, as scientists themselves in their quest for new knowledge do not know what is relevant. And if they knew ahead of time it would not be new knowledge. Scientific research is not manageable in the usual sense of the word.
Most S&T advances are governed by a structure of a connected triad - basic research, technology development, and the involvement of society. In this cycle, both pure and applied science become an integral part of a successful endeavour. Take the case of cloning, a current subject of significant relevance to the definition of species. Cloning began as a laboratory experiment on the genetic material of the cells, DNA. But these experimental achievements would not have been possible without scientific research and advances over a half century of development in many areas: the discovery of the genetic code, molecular structure of DNA, recombinant DNA, and other related studies.

REVOLUTIONARY PARADIGMS
Cycles of this type ultimately lead to the development of new concepts and new tools or techniques. Some historians of science make a division between the two. The late influential historian and philosopher of science, Thomas Kuhn, favoured concept-driven research as a paradigm over tool-driven research. In fact new tools and techniques drive scientific research as much as new concepts, and both are part of the progress of science.

Gravity, relativity, and quantum mechanics are concepts that have changed the way one thinks. With these concepts one can describe phenomena of nature and understand their fundamentals - objects attract each other depending on their masses and the distance between them (gravity); objects that are massive or move at very high speed do not follow Newton's classical laws of mechanics (relativity), and objects of microscopic size also do not follow the laws of Newton (quantum mechanics). But these concepts and rules need to be tested experimentally and the phenomena have to be observed and studied. Moreover, in most cases the concepts and rules develop as a result of experimentation and observations that are made possible with new tools and techniques. In fact, one may argue that techniques for experimentation and observation are prerequisite for the development of concepts. Of course, these techniques must be used creatively in order to develop new paradigms and concepts.

Resolution of time is not a property of the microscope or the telescope, and to study ephemeral phenomena of matter one needed new developments. The integration of new techniques and concepts led to the development of the "femtoscope," which brings to vision the motion of atoms in real time. In so doing one is able to uncover the underlying fundamentals of the dynamics in simple and complex systems; and examine the forces responsible for the diverse molecular functions in diseases such as cancer, in the sense of taste, and in the elementary mechanism for food digestion. In the microscopic world - the quantum world - the motion of atoms call be observed only with an 'artificial eye' having a speed one million million times faster than the naked eye, which responds in a fraction of a second. Microscopic motion is ephemeral and ultra-short in duration and the need a telescope that not only brings their very far world up close for observation, but also freezes them in time so that one can take snapshots. Ultrafast laser optics is the essential element of this "femtosecond telescope".

FUTURE FRONTIERS
With these reflections on the culture and progress of science, what does one expect for S&T in the twenty-first century? One sees three major frontiers that through the triad of basic research, technology development, and the involvement of society will be rich in new paradigms and have direct impact on human life.

Matter - the scale of the very small – man is on the way to being able to manipulate matter at its smallest, most fundamental limits, both in time, on the femtosecond scale, and in length, on the nano-scale. Just think about these new scales of time and space in the world of the very small. If
one’s heart beats once a second, now one can see the beats of atoms in a femtosecond, in a millionth of a billionth of a second - a femtosecond is to a minute as a minute is to the age of the universe.

Similarly, one can study matter on the nanometre scale and resolve the atoms in their structures - the size of the atom to the size of the earth is like the size of the earth to the whole universe. The opportunity is huge for acquiring new knowledge and for creating new forms of “matter.” The manipulation of matter to produce new sources of energy (photovoltaic / photosynthetic, etc.) should become a major undertaking. The interface of matter’s micro- and nano-networks, designed to produce artificial intelligence, to one’s life organs, such as the brain, will be another frontier that could alter the boundaries and meaning of species.

The universe - the scale of the very big. In this century, one may have colonies on the moon, and one may have second homes on other planets and maybe even in other solar systems. Just think of the scales of the world of the very big. The universe is about 12 billion years old, and at the speed of light (300,000 km/s), the universe's limit of distance is 100 billion trillion kilometres - certainly enough space for the six billion people on earth today, even multiplying by ten or by one million for the future! The opportunities involving outer space and information technology are unlimited. On the planet, through ‘virtual walls’, which in principle will provide any information one needs, education and intelligence in all societies will be redefined.

Life - the scale in between. In the first year of this century, the sequencing of the human genome was completed. One now has a genetic map that describes every human on planet Earth. Just think, three billion letters have been deciphered and read into one’s book of life. The history of biology has changed from the classification of living organisms (Darwin’s theory), to the world of cells (Leeuwenhoek-Hooke microscope), to now the molecular world (Watson and Crick’s DNA) with revolutionary ideas in genetic engineering. Soon one might see a nano-scale motor entering the cell to do work. Medicine and human health will certainly enter a new age.

The scope of opportunities is wide ranging and the promise in these new and other areas of science for new discoveries and new technological developments are becoming a reality. However a few cautionary general remarks. First, in the new mode of research in the twenty-first century, one should not become professional technical experts in narrow areas of specialization. In this regard, multidisciplinary science may help, but should not be at the expense of depth and scholarship. Second, the mix of science and business by scientists is a concern that in this century may have a detrimental impact on the culture of science and commitment to scholarship. Academia should remain the place for free exchange, motivated primarily by the search for new knowledge and education of students. Third, the support of research should be granted for the best ideas and the best people, not for strategic- or mission-oriented, and managed, research. James B. Conant, the renowned educator and scientist and former President of Harvard University, in a 1945 letter to The New York Times commented: “There is only one proven method of assisting the advancement of pure science - that of picking men [and women] of genius, backing them heavily, and leaving them to direct themselves.”

THE WORLD OF THE HAVE-NOTS
For the developing nations, there are barriers for progress, but there is absolutely no way out of investing in science education and science development. A look at global S&T is illuminating. The total number of scientific papers published worldwide over the past five years is 3.5 million. The European Union's share is 37%; the United States, 34%; Asia Pacific nations, 21%. The United States contributes 30% to 40% to the world economy and the strong correlation between the advanced state of S & T and the advanced state of the nation is clear. Asian Pacific countries are showing
exponential growth in S&T papers and this too explains their increased position in the world economy. Other correlations of gross domestic product (GDP), health status, life expectancy, and illiteracy show the critical role of science education and scientific research in the global positioning of nations. The lack of a solid science and technology base is not always a result of poor capital or human resources. It sometimes stems from a lack of appreciation of the critical role of S & T in development, an incoherent methodology for establishing such a base, and an absence of a coherent policy addressing national needs, and human and capital resources.

Some countries consider scientific progress to be a luxury, as measured against other demanding concerns. Others believe that the base can be built by buying technology from developed countries. These beliefs translate into poor or, at most, modest advances that are based on the efforts of individuals, not institutional teamwork.

These issues point to three essential ingredients for progress. First is the building of human resources by eliminating illiteracy, ensuring active participation of women in society, and reforming education. Second is to rethink national constitutions, allowing for freedom of thought, minimizing bureaucracy, developing a merit system, and creating a credible - and enforceable - legal code. Third is the building of a science base. The foundations of a science base are investment in special education for the gifted, the establishment of centres of excellence, and the chance to apply knowledge in the industrial and economic markets of the country and, eventually, the world. This must go hand-in-hand with a plan for general education at schools and universities. With such a vision, a scientific culture will emerge that enhances a country's ability to follow and discuss complex problems, rationally and collectively. Scientific thinking becomes essential to the fabric of the society. Developing countries need centres of excellence, not only for research and development, but also for training experts in advancing technologies and so reducing the brain drain experienced by many such countries. It is important that these centres are not just exercises in public relations:

They should be limited to a few areas of Science and technology in the Twenty-First Century research in order to build confidence and recognition. In the coming fifty years, knowledge-based and skill-based societies will have the lion's share of the world market and high status. Without S&T how can the have-nots participate in current world issues such as stem-cell research, cloning, human genome sequencing, artificial intelligence, manipulation of matter, molecular medicine, and cosmology? Without S&T how can they actively contribute to the world market in technologies such microelectronics, information and communication, new materials, and the revolutionary biotechnologies?

The challenges require a new system of education and a new outlook on technologies. Technologies fall into three categories, those that are 'simple' but relevant to services, solving domestic problems of everyday life, from traffic lights to desalination of water; those that are 'innovative', which make participation in the world market possible, such as microelectronics; and those that are ‘frontier’, which are concerned with research into the unknown, representing an investment in the future. To be effective, a new system of education and research and development in the first two categories are required and, at the least, there must be serious engagement with the issues of the third, frontier category - where the world is going to be.

KZN – as a developing economy and region - must address these issues with a new action plan and serious commitment. If humanity’s quest is progress and prosperity, one will need to weave the rational scientific approach, which is basic to the definition as Homo sapiens, into the fabric of the civilization; if one does so, the future is bright. Surely, science and technology will then become the real spaceship for the successful voyage of posterity.
The Role of Science and Technology in the Developing World of the 21st Century

Developments in science and technology are fundamentally altering the way people live, connect, communicate and transact, with profound effects on economic development. To promote technical advance, developing countries should (and must) invest in quality education for youth, and continuous skills training (and re-training) for workers and managers.

Science and technology are key drivers to development, because technological and scientific revolutions underpin economic advances, improvements in health systems, education and infrastructure.

The technological revolutions of the 21st century are emerging from entirely new sectors, based on micro-processors, tele-communications, bio-technology and nano-technology. Products are transforming business practices across the economy, as well as the lives of all who have access to their effects. The most remarkable breakthroughs will come from the interaction of insights and applications arising when these technologies converge.

Through breakthroughs in health services and education, these technologies have the power to better the lives of poor people in developing countries. Eradicating malaria, a scourge of the African continent for centuries, is now possible. Cures for other diseases which are endemic in developing countries are also now possible, allowing people with debilitating conditions to live healthy and productive lives.

Access and application are critical. Service and technology are the differentiators between countries that are able to tackle poverty effectively by growing and developing their economies, and those that are not. The extent to which developing economies emerge as economic powerhouses depends on their ability to grasp and apply insights from science and technology and use them creatively.

Innovation is the primary driver of technological growth and drives higher living standards.

As an engine of growth, the potential of technology is endless, and still largely untapped in Africa and other developing world regions across the globe. Less developed countries not only lack skilled labour and capital, but also use these less efficiently. Inputs account for less than half of the differences in per capita income across nations. The rest is due to the inability to adopt and adapt technologies to raise productivity.

Computing for example, through unlocking infrastructure backlogs and managing integrated supply chains, can transform economic performance by enabling affordable and accessible services in education and healthcare. The combination of computers and the Internet, and mobile devices and the “cloud”, has transformed human experience, empowering individuals through access to knowledge and markets, changing the relationship between citizens and those in authority, as well as allowing new communities to emerge in virtual worlds that span the globe.

According to the United Nations International Telecommunications Union (UN-ITU), by the end of 2010 there were an estimated 5.3 billion mobile cellular subscriptions worldwide, including 940 million subscriptions to 3g services. About 90 percent of the world’s population can access mobile networks, with three-quarters of mobile subscribers living in developing economies. Cellular technology has allowed Africa to leapfrog the age of fixed line telephony, bringing affordable access to millions of people.

However, the continued and equitable expansion of Information Communication Technology (ICT) depends on electricity. The real divide over the next 20 years will be between those who have access to reliable electricity to power these devices and those who do not.
Other technologies under development are interventions for cognitive enhancement, proton cancer therapy and genetic engineering. Revolutionary inventions include small underground nuclear power units called nuclear batteries that will be ultra-safe and maintenance-free; new types of photovoltaics that will make electricity from sunlight cheaper than that from coal; and myriad nanotechnologies, some of which lower the cost and increase the reliability of many products – even in the poorest areas of the developing world.

Managing technological revolutions poses challenges. Certain innovations and discoveries will raise fraught bio-ethical issues, as genetic modification of food crops and cloning of human embryos has already done. There is a risk that their cost, particularly in the early stages of development, will worsen the present inequality by limiting access to wealthy individuals. This already happens in health care in certain G7 countries, where the demand for very high-cost diagnostic equipment and surgical interventions enabling longevity and better quality of life for older wealthy people overstretches public health care budgets, and lowers service quality in poor neighbourhoods. Finally, resource-intensive technologies, focused on satisfying high consumption demand, like holidays abroad in coastal resorts, wilderness areas, or iconic cities, increase carbon emissions and environmental damage.

To promote technological advances, developing countries should invest in quality education for youth, continuous skills training for workers and managers, and should ensure that knowledge is shared as widely as possible across society.

In a world in which the Internet makes information ubiquitous, what counts is the ability to use knowledge intelligently. Knowledge is the systemically integrated information that allows a citizen, a worker, a manager, or a finance minister to act purposefully and intelligently in a complex and demanding world. The only form of investment that allows for increasing returns is in building the stocks and flows of knowledge that a country or organization needs, an in encouraging new insights and techniques.

Adopting appropriate technologies leads directly to higher productivity, which is the key to growth. In societies that have large stock and flows of knowledge, virtuous circles that encourage widespread creativity and technological innovation emerge naturally, and allow sustained growth over long periods.

In societies with limited stocks of knowledge, bright and creative people feel stifled and emigrate as soon as they can, creating a vicious circle that traps those who remain in a more impoverished space. Such societies stay mired in poverty and dependency. The investment climate is crucial, as are the right incentive structures, to guide the allocation of resources, and to encourage research and development.

Successful countries have grown their ability to innovate and learn by doing, by investing public funding to help finance research and development in critical areas. Everyone is involved – big and small, public and private, rich and poor.

The benefits that are certain to flow from technological revolution in an increasingly connected world and knowledge-intensive world will be seized by those countries and companies that are alive to the rapidly changing environment, and nimble enough to take advantage of the opportunities. Those that succeed will make substantial advances in reducing poverty and inequality.
The last 30 – 50 years have revealed that the advances, contributions and roles of science and technology in all human endeavour are amazing and may sometimes appear beyond human’s imagination. Science and technology has transformed one’s world into a “global village” through the emergence of instant communication.

For instance, there is the fast followers (mostly East Asia countries like South Korea, Singapore, Hong Kong); the emerging economies whose economies have also grown at a fast rate in the last decade (BRICS), and then the lagging latecomers (largely, sub-Sahara Africa), and the least developed countries (Oyelaran-Oyeyinka, 2006). Therefore, to be an effective partner in the emerging global market, a country must master the necessary tools of industrial production and socio-political development which are based almost on the critical roles of its Science, Engineering, Technology and Innovation system (SETI) (Akpokodje, 2010). The examples of emerging industrialised economies such as China, Brazil, South Korea, Taiwan, Singapore, etc. demonstrate that high scientific and technical input and emphasis on a nation’s educational system are critical to the transformation of the nation’s economy and optimal utilisation of the natural resources.

Essential Capacities for the 21st Century

1. **Analytical and Creative Thinking and Problem-solving:** this requires the following skills of our learners:
   - identifying, managing and addressing complex problems
   - detecting bias and being able to identify reliable and unreliable information/sources
   - formulating meaningful questions
   - analyzing and creating ideas and knowledge
   - using knowledge and creativity to solve complex "real-world" problems

2. **Complex Communication - Oral and Written:** this requires learners to:
   - understand and express themselves in two or more languages
   - communicate clearly to diverse audiences

3. **Leadership and Teamwork:** learners need to be able to:
   - initiate new ideas
   - lead and influence
   - build trust, resolve conflicts and provide support for others
   - teach, coach and counsel others
   - collaborate with people of varied backgrounds

4. **Digital and Quantitative Literacy:** learners need the skills to:
   - create digital knowledge and media
   - use multimedia to communicate
   - understand traditional and emerging topics in maths, science and technology

5. **Global Perspective:** this requires learners developing:
   - open-mindedness in particular towards the values of others
   - an understanding of non-western history, politics, religion and culture
   - technology skills to connect with people and events globally
   - an understanding of global issues
   - an ability to work collaboratively with people from diverse cultures

6. **Adaptability, Initiative and Risk-Taking:** this involves learners:
   - being courageous in unfamiliar situations
   - exploring and experimenting
viewing failure as an opportunity to learn

7. **Integrity and Ethical Decision-Making:** it’s vital for our learners to display:
   - integrity, honesty, fairness and respect
   - moral-courage when confronted with unjust situations
   - ethical and reasoned decision making in response to complex problems

The three science and technology waves currently driving the world economy and industrial/social development are; **Information Technology, Materials Technology and Biotechnology.** To be an effective partner in the emerging global market, KwaZulu-Natal (KZN) must master the necessary tools of industrial production and socio-political development which are based almost exclusively on science and technology. Some of the most important and critical problems in which science and technology will certainly play major future role include; provision of more powerful but cheaper information technology, cure/immunization for major stubborn human killer disease (such as cancer, AIDS, sickle cell anaemia, malaria, etc), population explosion control, food security, poverty alleviation as well as quality and sustainability of the earth environment.

In order to enhance Science and Technology Education, it is necessary to understand the contribution of Science and Technology Education to national and regional development. Taking into context the global experience with a view of making it a tool for national development worthwhile. Since societies that discriminate technical (Vocational) education among its counterpart pays a high price in their ability to reduce poverty and develop. Enhancing national development depends on improving the situation, efficiency and efficacy of technical education. Reducing the gap in education reduces individual poverty and encourages economic growth and enhances national development. Problems and challenges to national education agenda as they relate to - difficulty in finding, training and retraining of well qualified-STEM teachers, difficulty in keeping up with emerging science and changing teaching practice, public perceptions related to science, difficulty in maintaining a relevant science curriculum at all levels, funding and lack of information – are well-documented. In order to overcome the challenges of science and technology education within the formal school system, **one proposes “out-of-school” recommendations with a view to enhancing the contribution of Science and Technology Education to strategic development of KwaZulu-Natal (KZN).**

The unemployment rate recently headlined at extreme high levels – approx. 27.7%; Hence job growth fails to outpace the demand for jobs whilst thousand of KZN’ers are optimistically entering the workforce to look for jobs. Sadly most of the jobs are not in KZN – so KZN ends-up with a” brain-drain” to Gauteng, Cape, UAE/GCC, UK and the EU, etc. Not only is the economy bucking national trends right and left, hopefully one is rounding a proverbial corner as the focus turns from the dwindling effects of the recession to the burgeoning potential of the future.

With each and every graduating student and expanding business, one is building tomorrow’s economy today. By strengthening education through a special focus on science, technology, engineering and mathematics — more commonly known as STEM — one will ensure tomorrow’s workforce is prepared for a slew of 21st century opportunities. STEM education builds a stronger and more nimble workforce. This effort is not just necessary for the economy, it is also beneficial for the people.

To help build this pipeline of innovation, the Department will enhance and expand their STEM education. The **MKI STEM Fund** should ideally provide new funding to help districts build curriculum that inspires students about the possibilities of STEM. One would want to unleash their curiosity in a relaxed and enabling atmosphere; so they will one day unlock their potential in the workforce. STEM education benefits all, but it can have a particularly powerful impact on KZN’ers stuck in the grip of
inter-generational poverty. One has a unique opportunity to empower the underserved populations with innovative tools through STEM education.

KZN’s future economy will have to be stronger and more nimble than ever before — and the workforce will need to keep pace. The same collaboration between education, business, and public-sector leaders that established KZN as the nation’s premier economy is needed now more than ever to maintain and enhance the trajectory toward a future of continued growth and innovation. KZN is poised at a moment of great opportunity to leap into the future through a concerted focus on STEM education for the youth. KZN’s greatest resource is its people. Investing in the workforce today will ensure economic success tomorrow — and for generations to come.

The development of a domestic Renewable Energy manufacturing industry (eg. Solar pv panels, wind turbines, biomass reactors, etc) in the still emerging market. Climate change is now widely recognized as the major environmental problem facing the globe, due in large part to emissions of so-called “greenhouse gases,” which mainly result from the production of energy using fossil fuels. In addition to environmental problems, some countries with limited fossil fuel reserves also suffer from energy-dependency. KZN should be exploring the possibility in which a strong domestic wind turbine manufacturing industry can be nurtured focuses particularly on some key measures such as investment subsidies, tax exemptions, corporate financing schemes, and information dissemination.

Latecomer sectors in late-industrializing economies follow different patterns in their development and growth processes, which largely determine the share acquired from the global value chain. The development and growth process of the sectors are generally argued to be the result of the interaction of macro level specific institutional context, and the role the meso-level sectoral systems also play a critical role in the development and growth process of latecomer sectors. A case in point is the automotive industries in South Korea and Turkey. The relative developmental failure of the Turkish automotive industry compared to other successful latecomer industries such as the South Korean automotive industry is a case in point; as one has seen in South Africa the pace of industrial transformation can be accelerated by multilevel proactive state intervention -

Over the past 50 years, low-income countries have increased their national incomes by shifting their production from the agricultural sector in which the efficiency of labour and capital is low to the manufacturing sector of which efficiency is higher. However, underemployment in the rural regions has decreased in parallel to the attainment of the middle-income level by these countries, wages have increased, and the level of international competitiveness has decreased. This highlights the significance of innovation policies as they relate to countries caught in the so-called middle-income trap – and by necessity demands policy alternatives required to be followed by developing regions if only to expose the inadequacy of the neoclassic approach on which the industrialization strategy is based in the light of the experiences of the countries that have discarded the middle-income trap.

The level of the KZN’s biomass energy potential (biomass energy and sustainable development and the way in which to make efficient use of this potential) raises two main questions:

- To what extent can the quality of environment be improved via biomass energy? and
- What changes occur in economic variables such as foreign trade, employment, and balance of payments when fossil fuel is substituted by biomass energy?

Given the recent issues with disastrous consequences for the KZN poultry and cement industries in particular, the role of dumping is a topical one for developing business, and KZN’s access to the African markets as well as the proximity to South America possibly makes these issues a strategic region for growth. How do one flip the challenge – i.e. Convert a negative into a positive!
South Africa is not fully aligning its economic and industrialisation plans to areas of future demand, including in the area of electric vehicles (EV’s). One laments the low levels of investment currently being directed toward generic research which would assist in ensuring the country’s economic policies were alive to “large questions” facing societies. It is of concern that South Africa does not miss out in calibrating its future automotive policy with the inevitable growth of EV’s, which are expected to take a large share of the future vehicle market. In fact, recent research published by Bloomberg New Energy Finance (July 2017) forecasts that EV’s will account for 54% of all new light-duty vehicle sales globally by 2040, displacing eight-million barrels of transport fuel daily and adding 5% to global electricity consumption.

Despite South Africa’s success in sustaining an automotive industry, initially through the DTI’s MIDP (Motor Industry Development Programme) and currently through the APDP (Automotive Production and Development Programme), the moot question is whether domestic policymakers were fully grasping the significance of the global EV trend. South Africa has motor industry programmes that the taxpayer funds to keep BMW, VW, Ford, Toyota, Mercedes-Benz and others in the country, but it does not seem like one is thinking about what will happen when the models that are becoming dominant in the world are no longer based on the internal combustion engine? All eight of the global original equipment manufacturers still present in South Africa had to compete with other jurisdictions to produce future models for the global market. To reach a point where there was certainty on South Africa’s positioning with regards to EV’s would require not only a coherent vision, but also consensus across government, cities, trade unions and the industry.

The fact that these technologies also offer new opportunities that, if one engages with them early enough, could yield major economic advantages; and some of the minerals used in batteries are mined in South Africa. It was essential that South Africa both understood these new opportunities by investing in research and by incentiving the development of new industries. The industrial base that one should be thinking about must be compatible with those areas that are growing. Where does KZN fit in this scenario??

There was still much uncertainty about what impact the fourth industrial revolution would have on KZN in particular and South Africa in general; manufacturing and employment, there is no question that South Africa would have to invest more heavily in research and innovation if it hoped to secure higher levels of growth and employment. This demands a high-road scenario that envisions a rapid transition which adopts a “modernist” policy agenda. However, even under such a scenario, average yearly growth of only 3.3% would be achieved to 2034, well below the National Development Plan goal of 5.4% a year. Under the other two scenarios growth forecasts of just 2, 3% and 1, 5% are predicted.

An examination of the unemployment statistics reveals a contradiction: Even with unemployment at historically high levels, large numbers of jobs are going unfilled. Many of these jobs have one thing in common—the need for an educational background in science, technology, engineering, and mathematics (STEM). Increasingly, one of the richest sources of employment and economic growth will be jobs that require skills in these areas, collectively known as STEM. The question is: “Will we be able to educate enough young South Africans to fill them?” Whilst the unemployment statistics makes poor reading; there has been good news too. While the overall unemployment rate has slowly risen to the current high; for those in STEM occupations the story is very different.

According to a recently released study from “Change the Equation”, an organization that supports STEM education, there are 3, 6 unemployed workers for every job in the United States. That compares with only one unemployed STEM worker for two unfilled STEM jobs throughout the country. Many jobs are going unfilled simply for lack of people with the right skill sets. Even with
more than 13 million Americans unemployed, the manufacturing sector cannot find people with the skills to take nearly 600,000 unfilled jobs, according to a study by the Manufacturing Institute and Deloitte. (March 2017)

The hardest jobs to fill were skilled positions, including well-compensated blue collar jobs like machinists, operators, and technicians, as well as engineering technologists and sciences. It is painfully obvious that too many learners (and adults) are training for jobs in which labour surpluses exist and demand is low, while high-demand jobs, particularly those in STEM fields, go unfilled. STEM-related skills are not just a source of jobs, they are a source of jobs that pay very well. A Georgetown University Centre on Education report (October 2016) found that 65% of those with Bachelors’ degrees in STEM fields earn more than Master’s degrees in non-STEM occupations. In fact, 47% of Bachelor’s degrees in STEM occupations earn more than PhDs in non-STEM occupations.

However despite the lucrative potential, many young people are reluctant to enter into fields that require a background in science, technology, engineering, or mathematics (STEM). In a recent study by the Lemelson-MIT Invention Index, which gauges innovation aptitude among young adults, 60 percent of young adults (ages 16 to 25) named at least one factor that prevented them from pursuing further education or work in the STEM fields. Thirty-four percent said they don’t know much about the fields, a third said they were too challenging, and 28 percent said they were not well-prepared at school to seek further education in these areas.

This is a universal problem—for young people and for KZN. One needs STEM-related talent to compete nationally and globally, and one will need even more in the future. It is not a matter of choice: For the KZN to remain the regional innovation leader, one must make the most of all of the potential STEM talent this province has to offer.

For KZN, improving achievement in science, technology, engineering, and mathematics will go a long way to ensuring that one can compete globally, create jobs, and achieve the levels of economic growth that will buttress the standard of living and social safety net. High-quality STEM education represents an opportunity that students, workers, educators, and business must seize if one is to keep the country strong.

When economists or labour market forecasters speculate about the future of work globally, it’s clear that science, technology, engineering and mathematics (STEM) skills will play a major role. An increasing number of jobs – many of which haven’t even been invented yet – will come to depend on STEM skills, and such careers are among the fastest growing worldwide. Technology-related professions in particular look set to skyrocket, with computer programming jobs growing twice the average rate for overall job growth. It’s fair to say that the dissemination of STEM skills will directly impact KZN’s future economic prosperity.

Unfortunately, there is a significant deficit in the availability of such skills in today’s job market. Employers struggle to find the right skills to fill vacant positions. Learners are turning their back on pursuing STEM studies or careers, often perceiving them to be too difficult, too dull or “not for them”.

The prevalent state of how STEM subjects are taught and learned is part of the problem. Traditional stand-and-deliver teaching methods are often too dry or abstract, lacking hands-on, problem-based or collaborative approaches. Such pedagogical models can severely hinder learners’ motivation to stay curious about a possible future in STEM. The challenge is particularly acute when it comes to reaching girls, who are often held back by stereotypes, a lack of female role-models, gender-biased
educational materials, or outdated career advice. All of these issues need to be tackled head-on if one is to foster the next generation of female STEM leaders.

In recent years one seen a concerted effort on the part of national policy and business leaders to shake things up. But there is still work to be done, particularly around support for educators and schools seeking to improve their skills offering. Technology can play a vital role in leading efforts with the Department of Basic Education, educators and learners to tackle challenges in STEM education and boost learner interest in STEM-related careers – with a greater emphasis on career guidance and exposure of the parent/community cohort to the range of possible career choices.

STEM educators are key to unlocking innovative and engaging STEM learning experiences for learners. Ensuring educators can upgrade their skills through professional learning opportunities should be a key focus. Using available technology, STEM educators can connect their classes to world-class experts and organize fascinating virtual field trips focusing on topics like marine biology, renewable energy and space science, while the learning value of games-based learning (Gamification, Artificial Intelligence, Virtual Reality, etc) to classrooms and helps unleash learners’ creativity around even the most academic of subjects.

As the need for ICT skills in the workplace grows, so does the need for formal, industry-recognized certification. Both educators and learners can access valuable up-skilling resources through programs to help learners attain globally recognized industry certification and training in key ICT skills.

It will take a concerted, coordinated and ongoing effort from policymakers, educators, learners and industry to bridge the STEM skills gap and various vendors (software companies) are prepared to help lead that collaboration via the right partnerships and with the right tools, e.g. The Province must be committed to help foster the STEM leaders of tomorrow, and ensure all KwaZulu-Natalians face a brighter economic future.

The KZN Government – in particular KZN EDTEA can play a critical part. The MKI STEM FUND campaign leverages mostly private-sector funding. It is envisaged that this initiative will involve the corporate sector and its leadership, with the cooperation of the KZN government and educational organizations and foundations to align corporate efforts in STEM education. This public-private cooperation will be a good example of business’s recognition of the importance of STEM to the economic future. Business needs a talent pipeline providing the skilled employees who can routinely use scientific and technological skills in their jobs. Fortunately, more and more companies and their senior executives recognize this and are putting their money where their long-term interests are.
The role of Corporate KZN in advancing the STEM agenda

Corporates and mid-sized companies in KwaZulu-Natal have the potential to greatly influence young minds in pursuing STEM careers. They provide real-life examples of what a job in STEM might look like, they can avail their in-house experts to talk to learners about their day-to-day activities and opportunities, and they present tangible goals for them to strive towards. With the help of the tools and programmes in the STEM continuum, businesses will be able to boost the impact of currently running projects, as well as raise awareness about STEM career prospects.

The next production revolution will occur because of a confluence of technologies. These range from a variety of digital technologies (e.g. 3D printing, the Internet of Things, advanced robotics) and new materials (e.g. bio- or nano-based) to new processes (e.g. data-driven production, artificial intelligence, synthetic biology). The economic and policy ramifications of a set of technologies likely to be important for production over the near term (to around 2030). As these technologies transform production, they will have far-reaching consequences for productivity, employment, skills, income distribution, trade, well-being and the environment.

There needs to be a concerted effort to bring the business sector on board by creating a forum that (a) makes the leadership aware of the implications of the Fourth Industrial Revolution (4IR), the Internet of Things (IoT), The Circular Economy (TCE), Artificial Intelligence (AI), etc. (b) the imperatives of utilising technology in their businesses and necessity of engaging a STEM-savvy workforce to remain competitive and relevant, (c) create a suite of benefits for industries and encourage partnerships and participation in the “MKI STEM-FUND” that offers them tangible assistance in preparing to meet the challenges facing them.

In return, companies can access tools like the envisaged “STEM- assessment tool”, which will help them assess the coverage and the quality of their activities using the feedback from peers and best-in-class players; businesses can also use the STEM Alliance’s network to promote their own programmes and projects related to industry-school cooperation - initiatives such as learner discovery placements, science-industry educator schemes, and science pedagogy coaching schemes are among the planned activities where companies can pass their experience on to young people and educators alike. In addition, participation in these STEM activities could lead to the flow of funds into the MKI STEM FUND by way of philanthropy, off-sets to rectify scorecard deficiencies, etc.

Productivity and labour market changes

New production technologies will play important roles in determining the availability and nature of work. Part of a strategy for coping with rising shares of high- and low-wage jobs must involve the growth of technology-intensive production work. Technological development will inevitably disrupt today’s industries, and incumbent firms will be challenged as new technologies redefine the terms of competitive success.

The precise pace and scale of future adjustments are unknown. But resilience and prosperity will be more likely in countries with forward-looking policies, better functioning institutions, better educated and informed citizens, and critical technological capabilities in a number of sectors.

Command over new production technologies also promises greener production, safer jobs (with some hazardous work performed by robots), new and more customized goods and services, and faster productivity growth. Indeed, the technologies considered in this report, from information and communication technologies and robots to new materials, have more to contribute to productivity than they currently do. Often, their use is predominantly in larger firms; however even in those firms, many potential applications are underused.
Compared to earlier industrial revolutions, induced by steam and electrification, the creation and international spread of inventions that can transform production will occur quickly; however it could take considerable time for new technologies, once invented, to diffuse throughout the economy and for their productivity effects to be fully realized. The past has seen unrealistic enthusiasm regarding timelines for the delivery of important production technologies.

While new technologies will create jobs through a number of channels, and productivity-raising technologies will benefit the economy overall, the associated adjustments could be significant. Hardship could affect many if labour displacement were to occur in a major sector, or in many sectors simultaneously. Policy makers need to monitor and actively manage the adjustments, e.g. through forward-looking policies on skills, labour mobility and regional development.

Knowledge, technology and skills diffusion
Diffusion of the technologies must include not only the hardware, but also the complementary intangible investments and know-how needed to fully exploit technologies, ranging from skills to new forms of business organization. Here, among other things, the efficient deployment and reallocation of human and financial resources is essential. Aligning framework policies that promote product market competition, reduce rigidities in labour markets, remove disincentives for firm exit and facilitate growth for successful firms is critical. New firms will introduce many of the new production technologies.

Effective institutions dedicated to technology diffusion can help. Especially among small and medium-sized enterprises (SMEs), a major challenge will be the digital transformation of firms which were not born digital. Institutions with specific remits to aid diffusion, such as technical extension services (which provide information and outreach, especially for SMEs), tend to receive low priority in innovation policy overall. But such institutions can be effective if properly designed, incentivized and resourced.

Rapid technological change will challenge the adequacy of skills and training systems. Some new production technologies raise the importance of interdisciplinary education and research. Greater interaction between industry and education and training institutions is often required, and this need may grow as the knowledge content of production rises. Effective systems for lifelong learning and workplace training are essential, so that skills upgrading matches the pace of technological change and retraining can be accessed when needed. Digital skills, and skills which complement machines, are vital. Also important is to ensure strong generic skills – such as literacy, numeracy and problem solving – throughout the population, in part because generic skills are a basis for learning fast-changing specific skills. Investments in data and science will need to be continually evolving to accommodate these shifting paradigms.

Data will be central to 21st-century production. Policy should encourage investments in data that have positive spill-overs within and across industries. Obstacles to the reuse and sharing of data, including public data, should be examined. And data governance frameworks are needed that address privacy and digital security considerations. The quality of digital infrastructure, including access to high-powered computing, will be critical for firms in many sectors.

Sound science and Research and Development (R&D) policies are important. The technologies addressed in this report have arisen because of advances in scientific knowledge and instrumentation emanating from both the public and private sectors. The complexity of many emerging production technologies exceeds the research capacities of even the largest individual firms, necessitating a spectrum of public-private research partnerships. Many of the research challenges critical to the next production revolution are also multidisciplinary. Evaluation metrics for
research programmes need to properly incentivize multidisciplinary research, research scale-up and linkages across stakeholders.

**Trust and long-term thinking**

Public understanding and acceptance of new production technologies also matter. A close connection exists between public resistance to new technologies and the disruption of trust in scientific and regulatory authorities. Policy makers and institutions should voice realistic expectations about technologies and duly acknowledge uncertainties. Science advice should be seen to be unbiased and trustworthy. Public deliberation can also help to build understanding between scientific communities and the public. Foresight processes, if applied appropriately, can support policy making during times of technological and socio-economic change. With participatory methods, stakeholders can be mobilized to develop shared views about the future, and negotiate and agree on joint actions. Foresight processes can bring benefits in themselves, such as strengthened stakeholder networks and improved co-ordination across policy domains.

Finally, long-term thinking is essential. In addition to addressing short-term challenges, leaders in business, education, unions and government must be ready to frame policies and prepare for developments beyond typical election cycles. Reflection is required on a variety of new risks and challenges that emerging technologies create, and how policy priorities might need to evolve, in fields as diverse as the intellectual property system, competition and trade policies, and the distributional implications of future production.

**Agenda for new skills and jobs**

**Professions**

This initiative is how MKI/EDTEA axis will help the KZN economy reach its optimal employment targets going forward of the working-age population (20-64 years) in work.

This agenda will also contribute to achieving KZN’s targets to get the early school-leaving rate lowered (ideally below 10%); transition more young people in higher education or equivalent vocational education (at least 40%), re-channel retrenched workers back into employment; as well as to have at least fewer people in or at risk of poverty and social exclusion by 2030. (KZN PGDP targets)

**New Skills for New Jobs**

**Purpose**

The New Skills for New Jobs initiative sets out to:

- Promote better anticipation of future skills needs
- Develop better matching between skills and labour market needs
- Bridge the gap between the worlds of education and work

**How?**

A set of concrete actions that will help:

- Stepping up reforms to improve flexibility and security in the labour market (‘flexicurity’)
- Equipping people with the right skills for the jobs of today and tomorrow
- Improving the quality of jobs and ensuring better working conditions
- Improving the conditions for job creation
MKI STEM FUND

The continued substantial shortage of STEM skilled workers seriously jeopardises the success of the KZN economy. This affects all industrial sectors and slows down the pace of innovation, which in turn has adverse effects on employment and productivity in the related industries. Consequently, the shortage of STEM professionals at all levels weakens KZN’s ability to compete nationally, regionally and globally. Industry and the various Ministries in KZN led by the EDTEA should agree to work together to improve the situation of STEM education in KZN. They will collaborate under the MKI STEM FUND initiative.

Within the envisaged “MKI STEM FUND” initiative, Industry and the provincial Ministries led by EDTEA join forces to:

- Support the competitiveness of companies by ensuring a STEM-skilled workforce;
- Promote the attractiveness and importance of STEM studies and STEM jobs;
- Contribute to innovation in STEM teaching in the education system;
- Improve and promote existing education STEM initiatives supported by industry;
- Enhance industry-education collaboration at provincial level across all Ministries/Departments/Municipalities/public entities

South Africa’s economy is currently in dire need for Science, Technology and Engineering skills. This could be partly attributed to inadequate outputs of such talent pipeline by the education system at various levels. If South Africa does not produce adequate science, technology and engineering skills, the country may be forced to rely on other countries, and furthermore, this may render South Africa unable to compete globally in the areas Science, Technology and Engineering. The South Africa’s education system output in Science, Technology and Engineering does not match the demand and thus the system is unable deal with high local demand Science, Technology and Engineering skills. On the other hand, government has planned and ambitious, trillion rand infrastructure for the next decade.

In the past 10 years the number of students enrolled in Science, Technology and Engineering higher learning increased dramatically and this could be attributable to increased government financial support through NFSAS. However, of over 511 564 students enrolled from 1998 to 2010, only 14% graduated. Consequently, SA still ranked 111th out of 142 countries for its availability of scientists and engineers, and is also ranked as one of the weaker nations for its ability to produce professionally skilled engineers. The 2012 survey conducted by Engineering Council of SA reported that SA has one engineer per 3000 of the population

BACKGROUND

Moses Kotane Institute (MKI) was established with a mandate to implement South Africa’s STEM Strategy, including the Maths, Science and Technology (MST) plan of the KZN Education Department. The goal of MKI is to contribute to economic development through leveraging an interventionist type strategy in the provision Science, Technology and Engineering. This area remains amongst the critical strategic challenges facing our government in realizing an acceptable level of radical economic transformation, and egalitarianism and sustainable development.
Subjects responsible for the low pass rate in KZN
Extract from KZN grade 12 examination analysis report on 2014-15

<table>
<thead>
<tr>
<th>Subject</th>
<th>Registered Entrants</th>
<th>Number passed</th>
<th>Number Failed</th>
<th>Pass Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics</td>
<td>71 634</td>
<td>29 188</td>
<td>42 446</td>
<td>40.8%</td>
</tr>
<tr>
<td>Physical Sciences</td>
<td>45 143</td>
<td>25 177</td>
<td>19 966</td>
<td>55.8%</td>
</tr>
<tr>
<td>Life Sciences</td>
<td>74 496</td>
<td>54 184</td>
<td>20 312</td>
<td>72.7%</td>
</tr>
<tr>
<td>Mathematics Literacy</td>
<td>70 070</td>
<td>53 154</td>
<td>16 916</td>
<td>75.9%</td>
</tr>
</tbody>
</table>

The above table indicates the performance sn Subjects taken viz. Mathematics. Physical Science, Life Sciences and Mathematics literacy. Tis renders an extremely small pool of learners entering the STEM fields of study in the post-school domain ie. Engineering and the Built-Environment, Medical and Health Sciences, Chemical and allied sciences, Accounting and Actuarial Sciences, etc

In pursuit of this mandate, the MKI focuses, among others on the following objectives:

- Provision of Science, Technology, Engineering and Mathematical skills for economic development and service delivery to the members of our society through a range of recognised school intervention programmes, further and higher education and training career paths to facilitate migration into areas of economic potential;
- Facilitate access to Science, Technology, Engineering and Mathematics careers at higher education institutions through comprehensive graduate development programmes, to enhance participation in the mainstream economy;
- Enhancing the knowledge and skills of educators, leadership and governance capacity and capabilities for government business, municipalities and traditional authorities to enhance service delivery and rapid economic transforming and development; and

Provision of continuous strategic political education underpinned UBUNTU, good governance, developmental state approach and embedding a historical perspective of poverty, lack of knowledge, lack of skills and associated underdevelopment

PURPOSE
The purpose of the Fund is to promote Science, Technology and Engineering education and skills development among the historically disadvantaged learners, youth and communities. It is hoped that the KZN Economic Development, Tourism and Environmental Affairs (EDTEA), in collaboration with corporate partners will work together to establish this fund with the sole strategic purpose to contribute towards funding strategic projects aimed at promoting access to Science and Engineering opportunities, addressing the inadequacies to provision of Science, Technology and Engineering education interventions to disadvantaged learners and youth to assist them to seize economic development opportunities

OBJECTIVES
Various research endeavours indicate that less and less learners choose mathematics as a preferred subject, and those who do so will rather do mathematics literacy. These decisions are having negative implications on the country’s future talent supply pipeline in Science, Technology, Engineering and Mathematics.

It is for this reason that the objectives of the STEM Innovation Fund have to articulate to the country’s strategy in Maths, Science and Technology Strategy of the KZN Education and the Institute five-year strategy. Therefore the objectives are:

- Promote Science, Technology and Engineering programmes and careers among historically disadvantaged learners and youth in order to improve uptake in these disciplines and careers
• Provide educational and academic and skills development interventions aimed at improving the quality of learning and performance of Maths, Science and Technology Educators so they can help learners and youth realise their potentials in these disciplines.
• Provide financial support to deserving learners, students and graduates from rural communities to enhance access to opportunity to study STEM disciplines both at FET and Higher Education levels.
• Resourcing of deserving Mathematics, Science and Technology rural community schools to enhance the quality of learning and learners’ performance in these subjects.

OPERATIONAL SCOPE OF THE FUND
The scope of the STEM Fund will first and foremost to respond strategic pillars five and six Programme of the NSLA Framework. Strategic Pillar five and six focuses on Mathematics, Science and Technology and Educator Development respectively. The limitations in funding impacts negatively on the implementation of MKI interventions where such interventions are most needed, i.e. rural schools especially within the Nine (9) identified underperforming education districts. The proposed Science, Technology, and Engineering interventions to be funded out of the Fund are:

1. Promotion of Science, Technology Engineering and Mathematics through innovative technology and engineering school competitions, science shows and festival, career guidance and research and innovation project at tertiary levels;
3. Promoting access (partnering with Universities to fund bridging programme) into tertiary studies in Sciences, Technology and Engineering related disciplines, undergraduate development, post graduate research and development and ACCESS apprenticeships, graduate internship opportunities

MANAGEMENT OF THE FUND
In July 2011, the government and business signed a National Skills Accord where firstly, (i) the government committed to ensuring a more active training mandate for State Owned Enterprises; secondly, (b) the business committed to increase training beyond the current 1% training levy; and thirdly, (c) companies committed to consider a stretch target of between 3% to 5%. The strategic collaboration on the establishment of the STEM Fund between EDTEA and private sector is critical, as it will ensure the fund is sustainable and therefore enables the Institute to expand its reach and footprint where its interventions are most required. It is against this context that the Institute has decided to establish STEM FUND.

It is proposed that a special committee be established to take responsibility for the management of the fund. The proposed committee will be report to the Institute’s Board sub-committee on finance, and shall have clear terms of reference, which among others will include but not limited to

1. Fundraising and raising the profile of the institute and its strategic projects to potential funders and donors
2. Defining the scope and funding plan and the distribution of funds
3. Establishing strategic partnership with various institutions of learning to among other enhance STEM access and allocation of STEM graduate funding
4. Collaborate with the Institute sub-committee on STEM education, academic and skills development to identify funding priorities, monitor the utilisation of the FUND and report to Finance committee

FINANCING, IMPLEMENTING AND MONITORING AND EVALUATION
It is proposed that the following process should be followed in implementing, financing and monitoring and evaluating the impact of the STEM Fund
FINANCING PROCESS
It is envisaged that the Economic Development, Tourism and Environmental Affairs will initiate the first seed fund into the STEM fund as part of the launch. Further potential contributions are expected from state departments and such as Basic Education both national and KZN provincial department, Departments Science and Technology, Higher Education and Training through National Skills Fund, the Sector Education and Training Authorities (SETAs) in Science, Technology, and Engineering economic sectors private business and donors locally and internationally as well as state Entities like SANRAL, SITA, TRANSNET and others.

Potential funders and donor will be approach individually through the Institute Business Development unit to fund various interventions, which will among others include
1. School Mobile Science Laboratory,
2. Science and Engineering promotion,
3. STEM educator development,
4. Undergraduate and post graduate scholarship
5. Provision of internship and apprenticeships opportunities

IMPLEMENTING PROCESS
The Science and Engineering promotion competition herein referred to as “I am an Engineer” School Competition” targeting 20 schools per district which will be the first intervention to be implemented during the second quarter of this financial year. This event should also be used to launch the Institute’s STEM Fund. This project will be facilitated in partnership with non-governmental organisations operating in the space of Science and Engineering. During this phase various donors and funders will be consulted and invited to make contribution to the fund in the areas of their interests as covered in the scope of the STEM Fund. It is preferred that funding be ring-fenced around the three (3) year Memorandum of Agreement with KZN Department of Education. The MoA broadly covers the following strategic interventions, which the Institute is unable to fund due to budget constraints:
1. Educator Development- resourcing of the STEM Laboratory to conduct practical training for grade 8 to 12 educators
2. Purchase and supply of the Mobile Science Laboratory for identified STEM schools in the Nine underperforming education districts
3. Science Curriculum Delivery Innovation- Purchase and supply of Cyber-class resources and equipment for identified STEM schools as part of science curricula delivery innovation intervention and related training of the educators on the use of equipment

MONITORING AND EVALUATION PROCESS
In order to ensure effective utilisation of the fund, an annual performance plan will be put in place, with clearly defined interventions, performance outcomes and indicators, including the budget plan. Each funded project or intervention will be evaluated following the formative and summative evaluation process to determine its impact against set process outcomes. In addition to monitoring and evaluation report, proper financial reporting in accordance with the Institute’s expenditure reporting budget and expenditure reporting policy framework will be produced and communicated to various donors and funding partners

CONCLUSION AND RECOMMENDATION
The establishment of the STEM Fund is critical if the Institute service delivery footprint is to reach the majority of the disadvantaged learners, youth and rural communities. The Institute also needs to build strategic service delivery collaborations with specialist organisation in order to increase its STEM Fund impact. Effective fund distribution and governance of needs to be the foundation of the management of the fund.
KZN TECHNOLOGY HUBS

The KwaZulu-Natal provincial government has identified this need for technological innovation and collaboration and has begun developing Technology Hubs (science and technology parks) in four key regions across the province to promote the so-called knowledge economy, drive socio-economic development and increase competitiveness. Today’s business leaders understand that technology and innovation are the cornerstone of their company’s future success. And they also understand that seeking partnerships and collaborating with other companies can lead to faster and more meaningful innovation - stimulating growth and creating greater economic opportunities.

Technology Hubs around the world have been recognized as key developments, to cater to technology innovation and boost today’s economy. Although the internet is rapidly improving in South Africa, setting up a business is not always achievable due to unavoidable costs. The KZN Techno Hubs promises to offer an alternative. The technology hubs do not only offer access to physical infrastructure, world class facilities, great rates and rebates but they also provide information and networks with like-minded entrepreneurs. It is predicated upon a vision that promises to stimulate growth and create greater economic opportunities in KZN. It is envisaged that the four Technology Hubs will be used and supported by technology and innovation “clusters” comprising interconnected companies, specialised suppliers, service providers, and associated institutions in a specific sector or industry. This co-operation will enable the industry in which they operate to grow and compete on a national and even international level. The presence of incubators and active mentoring will only serve to enhance these physical enablers.

Public anxiety about how people interact with science has spawned cycles of discourse across a wide range of media, public and private initiatives, and substantial research endeavours. National and Global STEM (science, technology, engineering, and mathematics) education initiatives and research have addressed how learners interact with science and pursue careers in STEM fields. Researchers concerned with adult interaction with science have focused on factors that influence how citizens gather and interpret scientific knowledge and form positions on scientific issues, applications, and/or policy in a politicized democratic milieu. Building on how the public interacts with science in and outside of formal education; as well as paired the STEM experiences of adults with their children.

However, evidence exists that the extent to which parents are positively oriented toward science significantly shapes their children’s attitudes toward science. Furthermore, learners with parents holding positive orientations toward science are more likely to sustain positive attitudes toward science. Since the foundation for most adults’ interactions with science develops in the formal education (ie. School) environment, it is as expected that the foundation, as expressed in adulthood, may directly affect the ways the next generation of learners interacts with science. One has to carefully consider critical insights into the importance of developing learner learning into the social scientific research on public understanding of science and how important scientific issues of today interplay with society.
Important lessons for KZN policy-makers and leadership to consider!

Is the meaning of work about to change?

The world is facing a crisis-cubed: jobs are disappearing faster than they are being created; companies are struggling to attract people with the right skills; and people rightly worry how new technology will threaten their livelihood. These global challenges affect developing countries as much as highly industrialized economies. One has heard plenty of suggestions from all corners that this crisis can be solved by “creating more jobs”. Unfortunately, in KZN (as well as South Africa), it is well known that we struggle to create sustainable jobs. It’s increasingly clear that creating more jobs is not enough, nor is it the real solution. This solution is based on a big misunderstanding. To tackle this crisis cubed, we need to focus on not just jobs but on people earning incomes. This requires the development of a new model of work.

What is clear is that the transformations that are now taking place worldwide, resulting in the loss of jobs, are caused by forces we cannot alter. The disruption of our world of work is the result of a tectonic shift just as dramatic as industrialization and urbanization - and it occurs along three fault lines:

1. **Technology**: The speed and breadth of today’s innovation affect every single job and skillset. Automation, artificial intelligence, Big Data analytics, the Internet of Things and mobile technologies are levelling the playing field – not only geographically but also across the spectrum of businesses from small to large. Not all of this disruption is positive. New technologies could result in a net loss of more than 5 million jobs by 2020 (*WEF – The Future of Jobs*)

   **TOP 10 SKILLS**

<table>
<thead>
<tr>
<th>IN 2015</th>
<th>IN 2030</th>
</tr>
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<tbody>
<tr>
<td>COMPLEX PROBLEM SOLVING</td>
<td>COMPLEX PROBLEM SOLVING</td>
</tr>
<tr>
<td>COORDINATING WITH OTHERS</td>
<td>CRITICAL THINKING</td>
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<td>PEOPLE MANAGEMENT</td>
<td>CREATIVITY</td>
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<tr>
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<tr>
<td>NEGOTIATION</td>
<td>COORDINATING WITH OTHERS</td>
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<tr>
<td>QUALITY CONTROL</td>
<td>EMOTIONAL INTELLIGENCE</td>
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<tr>
<td>SERVICE ORIENTATION</td>
<td>JUDGEMENT AND DECISION MAKING</td>
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<tr>
<td>JUDGEMENT AND DECISION MAKING</td>
<td>SERVICE ORIENTATION</td>
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<tr>
<td>ACTIVE LISTENING</td>
<td>NEGOTIATION</td>
</tr>
<tr>
<td>CREATIVITY</td>
<td>COGNITIVE FLEXIBILITY</td>
</tr>
</tbody>
</table>

2. **Talent**: We are facing a massive skills gap. Today’s education systems simply can’t keep up with the rapid pace of change. Too many of today’s graduates are merely not business-ready for the jobs that now exist. For the rest who may not have the academic credentials and special skills, they face barriers as well, as the non-cognitive skills they might possess are often discounted.

3. **Millennials**: In another 10 years, the millennial generation will make up 75% of the global workforce. ([www.wired.com/insights](http://www.wired.com/insights)). They are different, very different. Not only are they digital natives, they also have a different set of values; they want purpose in their lives, flexibility with their time and a healthy work-life balance. More than half don’t even want a job but want instead to do something on their own. This shift is tearing down many familiar features of the economic landscape to which we have become accustomed. Corporations as we have known them may soon run out of skilled workers and will also fail to produce enough jobs to provide to those who want to work within the traditional definition of jobs.
Additionally, Millennials, who are fast becoming the core of the global workforce, have little appetite for jobs and careers, since they offer too much structure and too little personal fulfilment.

**What did people do before there were jobs?**

It’s a fallacy to think that governments nor companies can become sustainable engines of job creation. But then this crisis is not actually about “jobs”. In the early 19th century: what did people do before there were jobs? Well, certainly they worked - usually for themselves - in agriculture, as craftspersons, as trades-people or in other ways as part of their local economy.

This “cottage industry” work lacked scale; it was local by necessity. When corporations came along in the 19th century, they simply took these workers, organized them and with the aid of steam-powered factories and early industrializing technology, created focus, efficiency and scale. They brought us the big corporations we now have today and that worked for a long time. Yet this model is fast becoming obsolete.

Today’s most valuable companies, like Apple, employ a proportionally small number of people. At the same time the job market is shrinking almost everywhere because of the forces mentioned above. We simply must change our model of work and look beyond traditional jobs, beyond governments, beyond corporations. We must develop concepts that provide the flexibility and resilience needed for people to thrive amidst this massive disruption.

Rolling out the alternative to a job with the government or with a corporation requires focusing on start-ups, self-employment, self-made work, entrepreneurship. Yet, for most people many of these notions conjure up images of larger-than-life figures, of a Zuckerberg or, perhaps, some youth who burn the midnight oil coding new apps. When we hear terms like these, we think of a path that’s risky, requiring top education and out-sized intelligence and ambition to succeed.

In the absence of today’s hierarchies of corporations; what are we left with? At their core, companies are a collection of people engaged in collaborative efforts. It is this collaboration that is at the heart of our new model of work. Let’s look at it from the perspective of individuals. What they need for success are business templates that leverage their skills, match their interests and most importantly - nurture the right mind-set that will allow them to be collaborators in this emerging new economy. They should not just be trained with **cognitive skills or STEM-smarts**, but also non-cognitive skills such as creativity, self-discipline, resourcefulness, endurance – none of which are measured by tests and few of which are taught in school.

People with those non-cognitive skills may not feel comfortable calling themselves entrepreneurs ... but from a mind-set perspective they are! And with the right tested templates, models and tools, they will be able to generate an income that allows them to be independent and stand on their own two feet.

**Shared Office** is another **disruptive business model**, is a chain of shared office spaces that rents workspaces on a “pay-per-use” basis for budding entrepreneurs. The spaces are actually working social incubators where, for example, a computer whiz meets up with a graphic designer ... Think Steve Jobs and Steve Wozniak.

Critically, one needs to discard any mismatched ambitions; the **KZN ecosystem** has to help people realize that striking out by oneself is not a necessity but an opportunity, and that the risk can be managed. Individuals should feel confident to operate at whichever scale they feel comfortable –
small and local or dynamic, scalable and global; fully independent or collaborating with a larger corporation.

**Lessons from the world's most valuable companies**

Take Apple and Google - the world’s two most valuable companies; their strength does not come from making things but from the collaboration within the huge ecosystems they have created. Think Nike, too. They are designers and marketers supported by collaborative companies and individuals.

So to survive, corporations have to **reinvent** themselves as conveners of collaborators. That is their new template. They have to morph into collaborative ecosystems - with their own rules and community ethos - in which individuals can plug in their skills. The collaboration economy can be our new model of work. This may require companies to change their business model; or it could be as simple as introducing dynamic and flexible procurement systems. The transition to this collaboration economy won’t be easy. The three fault lines – technology, talent and demographics – have ruptured, and the disruption brought on by this tectonic shift is simply too big.

**It is now incumbent upon the KZN leadership to spot the opportunities in the disruption and equip people not just to cope but to thrive beyond jobs and beyond corporations.**
Innovation for socio-economic development of KZN

Science, technology and innovation are the basic pillars of progress and driver of economy for any country. A strong STEM (Science, Technology, Engineering and Mathematics) education programme lays the foundation for these pillars. STEM, however is focused on education and on moulding a mindset of innovation towards nation building. STEM as one of the pillars needs to contribute towards an umbrella policy being proposed here as STI (Science, Technology and Innovation) policy. Moreover, the awareness, understanding and appreciation of STI is crucial to appreciate the nuances of the policy.

This proposal is to develop an umbrella STI policy and an executable plan for STEM and Innovation as a main pillar of the STI policy towards the socio-economic development of KZN. The proposed policy involves stakeholders that will form the basis of socio-economic development and science and technology literate society with skills and awareness to face the challenges of a dynamically changing world.

The policy recommendations addresses the following:
1. Status of STI in KZN
2. Identification of potential areas for STI intervention
3. Evolving guidelines/strategy for STI policy implementation
4. Development of action plan for STI
5. Development of pilot project for STEM and Innovation and its implementation

Action Points for Pilot STEM and Innovation project:
1. Identification of gap areas in STEM and innovation curriculum in schools/colleges and in public awareness creation programme including deficient skills.
2. Developing pilot programs to connect new intervention programs in line with the umbrella policy.
3. Identification of key stakeholders involved in the STI policy together with the level of engagement between each stakeholder.
4. Development of infrastructure in key institutions and/or creation of standalone non-formal institutions like science centres, planetariums, botanical and geological parks to implement the new plan
5. Professional development of teachers and support mentoring staff
6. Support, monitoring and evaluation
7. Identify sources of funding including corporate bodies

The modified scheme will focus on
1. Hands-on STEM modules of delivery incorporating design thinking, problem solving, innovation nurturing and entrepreneurial/business concepts and skills etc.- Modified Creya Concept
2. Creation of public awareness, understanding and appreciation delivery modules to develop scientific attitude/temper in society and develop a scientifically literate and innovative society.
3. Professional development of teachers, mentors and start-up enthusiasts through entrepreneurship and start-up vocational courses. This programme will be linked to industry required skill training with support from corporate bodies.
4. Co-creating programs with corporates that are unique for the province to provide research capacity for companies and in return increase employability from the training and engagement

Expected Outcomes:
1. Science and technology literate society with tech-savvy mindset.
2. Innovative youth and society
3. Job creation through new start-up businesses
4. S&T Trained and skilled manpower -employable
5. Economic growth of the province

The specific activities and items that could be incorporated into a typical S&T facility:

- **Interactive Exhibits** – Exciting, attractive exhibits that actively engage participants *(tell me I’ll forget, show me I’ll remember, involve me I’ll understand)*. Exhibits that address scientific concepts in a fun, exciting and memorable way.
- **Computers** – People are given the opportunity to learn computer skills after hours at the centres.
- **Mobile Labs** – Mobile labs are used to reach remote rural villages with science outreach activities. Mobile labs make it possible for learners in the rural schools to perform scientific experiments hands-on. Mobile labs help to eliminate the problem encountered by many first year university learners who only get the opportunity to see and touch laboratory equipment at university for the first time and then have a distinct disadvantage when compared to learners from urban areas.
- **Learner Activities** – Learner activities range from transporting learners to the centre to participate in programmes, conducting learner workshops, camps for learners, and assisting science clubs in the vicinity of the centre. It is a challenge for most learners to pay travel costs to science centres, therefore the centres often use grant funds for transport. Popular educational activities are rocket building and telescope building workshops.
- **General** – Centres also use the funding for libraries, where learners are encouraged to read and do research since some centres do not have Internet facilities for research purposes. Career guidance centres are also being introduced in order to address problems related to a lack of information on career choices. Centres have acquired funding to build laboratories to enable learners to perform prescribed experiments.

Afterschool programs are a great way to get children (learners) and youth excited about STEM and should be integral partners in STEM education. It is a fallacy to think of afterschool programs as child care, unaware of all the incredible learning opportunities programmes are creating for our students. They have a great opportunity to be involved in innovative and engaging STEM learning is occurring in afterschool programs across the province; this can be a means of inspiring our next generation of scientists, engineers and mathematicians. This is why educating our leaders and the public through advocacy is so important! It is vital that all of us make the case to a variety of stakeholders about the importance of including afterschool programs in STEM education reform efforts. Working through the following questions will help prepare you to make the case for afterschool STEM learning.

Some exciting future STEM careers that doesn’t exist yet

Many school learners’ future jobs aren’t a reality just yet, and many of them are STEM-orientated careers. How does a learner prepare for the unknown? Why are these future STEM careers important? Herewith a few examples of possible future jobs and what learners need to do to prepare for them

1. **Robotics Engineer**
   Why send a robot to Mars when it could go get more snacks instead?
   Self-checkouts at the grocery store become more popular? Before long, robots will be taking over simple jobs. The demand for brilliant scientists to design, build, and fix them. This will be a huge field in future STEM careers.
   **How to Prepare:** Possibly enrol for the most advanced mathematics and science courses available. Choose majors in something along the lines of electronics engineering or mechanical engineering at post-school level. Join coding clubs and take-up hobbies like coding that advance one’s learning (and boost one’s resume), too.
2. **Drone Development & Exploration**

Drones already offer some incredible leisure (visuals – photography and videos, etc.) and commercially-orientated (smart ports, etc.) but they can be used for so much more. Future STEM careers involving drones will span from logistics (delivery of drugs to remote communities, retrieving of pathology samples, postal services, etc.), law enforcement (via surveillance) to designing (aerial architecture) to agriculture (crop spraying, irrigation, etc.)

**How to Prepare:** Given the exorbitant cost of a drone, consider getting together with a group of like-minded people and splitting the price of one. Share experiences of piloting same and enjoy the natural and built environments in a novel manner. Note the legality of drone usage is a grey area – especially in built-up/urban environments.

3. **Space Pilot**

There was a time when it was thought to be impossible to fly airplanes, but now thousands travel using commercial airlines every day. The next frontier? Space. Before one know it, one could be in the cockpit flying customers on a non-stop trip to the moon.

**How to Prepare:** Although one can’t just casually leave the atmosphere yet, attending aviation school or joining the Air Force is the way to transition into flying a space shuttle.

4. **Organ Designer**

People are living longer and longer, and pretty soon, instead of waiting for organ transplants when something vital begins to fail, doctors will find a way to create organs using that person’s own cells. Scientists are already on their way – some medical companies predict simple organs, such as bladders, will arrive soon – but organs like lungs, kidneys, and hearts are trickier because they are more complex. Couple this with 3-D printing capability, many possibilities exist.

**How to Prepare:** Ensure that the appropriate subject choices (STEM-orientated) at school that allow a career in bio-engineering at University.

5. **Water Harvester**

Given the drought experiences, and the current challenges in the Western Cape and KZN not too long ago – a potential future STEM career is “water harvester”. Humans will always need water, but one will have to find more creative ways to gather it to get it to people all over the world. Even now, more and more regions are experiencing record drought. From atmospheric water harvesters to those who desalinate seawater, innovators will find new sources of drinking water with low environmental impact.

**How to Prepare:** A degree in environmental science or engineering in college will prepare one; and make one knowledgeable about safe environmental practices.

**Some Additional Thoughts :**

- **What is STEAM?**
- In this climate of economic uncertainty, KZN is once again turning to innovation as the way to ensure a prosperous future. Yet innovation remains tightly coupled with Science, Technology, Engineering and Mathematics - the STEM subjects. Art + Design are poised to transform our economy in the 21st century just as science and technology did in the last century.
- We need to add Art + Design to the equation — to transform STEM into STEAM.
- STEM + Art = STEAM

The objectives of the STEAM movement are to:

- transform research policy to place Art + Design at the center of STEM
- encourage integration of Art + Design in pre-school to post-school education
- influence employers to hire artists and designers to drive innovation
Discover
Art + science research go hand-in-hand
- Adding Art + Design to STEM research will enhance economic competitiveness.
- In a rapidly changing world, the tools and methods of design offer new models for creative problem solving and interdisciplinary partnerships.
- Artists and designers can effectively communicate complex data and scientific information to multiple stakeholders and broad audiences.
- Artists and scientists both ask big questions; designers and engineers both provide inspired solutions. Together they are more powerful than apart.

Educate
Integrate the arts into STEM curricula
- Integrating Art + Design into STEM education promotes critical thinking, a key 21st century skill.
- The tools and methods of design offer new models for creative problem solving, introducing innovative practices of design thinking into STEM education.
- Art education teaches the flexible thinking and risk taking that are needed in today’s complex and dynamic world.
- STEAM education promises to increase student engagement and unlock creative thinking and innovation.

Hire
Tomorrow’s innovators are artists and designers
- STEAM is a pathway to increase KZN’s economic competitiveness
- Art + Design provide real solutions to our everyday lives, will enhance and distinguish KZN products in the global market place, and create opportunity for economic growth
- Design is increasingly becoming a key differentiator for technology start-ups and products
Big push to Agriculture, Tourism and Manufacturing

At the broader level, the KZN government’s (in particular EDTEA’s) strategy has been two-pronged. To stimulate growth, development, wages and jobs, it has given high priority to infusing new life into Agriculture Tourism and Manufacturing; all of this to inject direct relief to the poor and needy, it has maintained all social programmes and schemes while introducing some new ones. In the medium-to-longer term, the government has committed itself to providing shelter, electricity, clean drinking water, toilet, health, education and skills for all KZN citizens by 2030.

The recently launched (22 June 2017) Operation Vula seeks to localise the economy by, initially, exploiting the government buying power to buy from SMMEs and cooperatives. It will target specific societal groupings, such as blacks, women, youth and people with disabilities, in the province; align and coordinate enterprises regionally and sectorial; and assist targeted enterprises with skilling, funding and markets. Through the RASET programme, KwaZulu-Natal seeks to improve the participation by small scale farmers from historically underprivileged communities in the lucrative food production value chain. The initiative endeavors to promote co-operation amongst various government departments with respect to the prioritization of black participants in the agribusiness with respect to access to land and markets.

To elaborate just a single yet catalytic activity on an aspect of the strategy regarding agriculture, one has to re-orient public investment in ways that would raise productivity while economizing on KZN’s scarce water resources. Emphasis on micro-irrigation, soil cards, better seeds and improved extension programmes are all steps in this direction. Coupled with intent to bring the Green Economy to the rural areas.

Policies and initiatives to accelerate manufacturing and job creation in KZN. Even a partial list of these policies and initiatives is impressive. Many economists have written for years that onerous labour environment pose insurmountable barriers to the creation of good jobs in the manufacturing sector.

An increased public investment in infrastructure, commitment to build smart cities and industrial corridors and facilitation of private infrastructure investment would contribute to ‘Make in KZN’. Adopting the “Make in India” concept; one humbly suggests that consideration be given to a campaign styled “Make in KZN” - not for the sake of just manufacturing products in KZN - it is ultimately for job creation and poverty alleviation.

As a source of livelihood, agriculture (including forestry) remains a significant sector of KwaZulu-Natal economy. A significant percentage of rural KZN’s rural population still remains dependent on agriculture. This is without a significant contribution by the 3rd leg of the Agriculture, Forestry and Fishing continuum. With the opportunities in Operation Phakisa as well as aquaculture – one is fairly optimistic that this primary area of endeavor lends itself to great potential. Given the low share of this workforce in the GDP, on average, it earns much lower income poorer than its counterpart in manufacturing industry and services. Hence it goes without saying that any meaningful progress in agriculture has a bearing on the fate of the largest proportion of the low income population in KZN.

Agriculture:
This attempt to identify (with all humility), five important aspects of agriculture that need immediate attention to bring economic advantages to thousands of farm families.

- **First**, output per hectare, which is a common measure of agricultural productivity, remains low for many crops when compared to many other regions. There are also large regional
variations within the province. Reasons include low and faulty input uses, poor access to modern technology and no real technological breakthrough in recent times.

- **Second**, on average, farmers do not realize remunerative prices due to limited reach of the agricultural marketing system that delivers only a small fraction of the final price to the actual farmer.
- **Third**, the farm size of the majority of the household has declined to unviable levels inducing farmers to leave land and look for better job opportunities elsewhere. Given the uncertainty and prolonged delays with respect to land restitution; land-ownership and leasing laws make it risky to lease land - increasingly, productive land is being left uncultivated. Changes in the land tenure (maybe usufruct rather than the burden of ownership) may bring consolidation of land holding at operational level and attract better investment along with access to credit and relief to tenants.
- **Fourth**, relief measures in the event of natural disasters are inadequate and suffer from procedural inefficiencies and delays. The risk adaptation measures are poorly executed and have not worked effectively. This situation needs to be rectified with at least minimum quick relief to farmers for crop-loss in case of natural calamities.
- **Finally** the potential of the region needs to be harnessed with suitable interventions. This region is unique for its suitability to the production of most commodities. However, taking advantage of this potential would require institutional support and investment in technological innovations. The question for policy makers and administrators is how these problems can be addressed so as to accelerate agricultural growth and bring remunerative prices to farmers.

**New Technologies**

In recent decades, growth in agriculture has been driven by price incentives and input subsidies. In this process, there has been injudicious exploitation of soil, water and other natural resources. Excessive use of fertilizers has led to heavy salinization of soil. Further overexploitation of groundwater is a major concern given the recent drought scenarios. To maintain productivity growth in a sustainable manner, there is a need to move from input intensive to technology intensive and skill intensive agriculture.

Benefits of technology and skill intensive farming are beginning to be experienced albeit on a limited scale in recent years. Genetically modified (GM) seeds for cotton production, hybrids in maize and vegetables, system of crop intensification, precision farming and farm mechanization, hi-tech cultivation of fruits and vegetables and flowers, resource conservation technologies and many off-farm activities related to mechanization, primary and secondary processing introduced in earlier part of this century offer some areas of success. While measures that have been outlined are essential for rejuvenation of agriculture as well as ensuring a decent life for farmers, one must not lose sight of the fact that relief to farmers will remain incomplete without the creation of job opportunities for them in non-agricultural sectors. With industry and services able to grow much faster than agriculture. In order that today's farmer families can share in the faster growth occurring in industry and services, it is essential that some of them be able to find good jobs in these sectors. As some of the farm families move out of agriculture, the opportunities for consolidating and enlarging land holdings will open up as well. In turn, this will allow greater use of modern machinery and farm techniques allowing productivity and wages to rise rapidly in agriculture as well.

**Perhaps some thoughts to remedy this:**

- Despite rising scarcity and stress on water resources, the use of irrigation is very inefficient. Area under irrigation can be doubled in the country without requiring extra water if KZN is to attain water use efficiency level of countries like China, USA, and Brazil. One needs to learn
from and adopt irrigation technologies used in the other countries and adopt new agronomic practices for realizing the goal of “per drop - more crop”.

- Revitalize the seed chain with focus on replacing varieties older than ten years by new ones. Accelerate seed replacement rate with the objective of raising it to high yielding varieties and hybrids. Incentivize public sector and facilitate private sector to raise quality seed production to generate adequate supply.

- To ensure that the farmer can buy subsidized fertilizer when he/she requires it, break the cartels and allow transactions to take place at the import price and pay fertilizer-subsidy directly to farmers and domestic urea producers. Sadly whilst KZN have a major phosphoric acid (the precursor of fertilizer) plant in KZN, all of its production is exported.

- In the post-1994 era, South Africa has relied more heavily on prices to expand agricultural production with technology and other non-price factors taking backseat. This has had the unhappy side effect of relatively high food inflation and cyclical growth pattern. In the process, the technological factors have been neglected.

- The concern for sustainability and efficiency necessitate harnessing of natural-resource management technologies and improved practices. Modern machinery such as laser land-levelers, self-propelled sprayers, precision seeders and planters, trans-planters for vegetable seedlings, multi-crop threshers, harvesters available today allow technically highly efficient farming and resource conservation. The Agriculture Department and extension agencies and development departments need to change their orientation from varieties and inputs to other areas like resource-conserving technologies, farm-mechanization, post-harvest and marketing.

- KZN must also keep an eye on the use of Nano technology applications in agricultural inputs to enhance input use efficiency.

- Due to several weaknesses that have crept into agriculture training, low participation of post-school cohort in this sector as well as private sector in R&D and technology generation, KZN is perhaps falling behind in agricultural technology. If public sector does not deliver and private sector is not welcome, both farmers and consumers will suffer. Urgent steps are needed to overhaul, reform, restructure and revitalize the system to make it effective. Public sector alone cannot meet future challenges and requirements of agriculture. There is a need to create favourable environment for private sector participation in agricultural research and technology development.

- Demand side factors are highly favourable for diversification towards high value horticultural and livestock products and attribute-based products. However, infrastructure, institutions and public policy need to be favourable. There is a need for measures to improve health and hygiene of the livestock for improved quality of meat and meat products, expand cold storage facilities and provide market finance to farmers. Special attention to veterinary services and vaccination to avoid the disease outbreaks and sustain the growth of the livestock. KZN EDTEA - together with DAFF - must also exploit more fully the potential for inland fisheries in the many dams and water bodies reinforced by post-harvest management and export-oriented fish farming in brackish water (mariculture). The facilitation of the development of food processing industry will go a long way towards creating demand at lucrative prices for high value commodities. Turning food-processing industry into a major export industry can also create vast employment opportunities for workers since it is a labour-intensive industry.

- Another instrument for creating vibrant land-lease market is a provincial land bank held by a public agency. Interested landowners may deposit their land parcels in the bank and potential cultivators may lease in land from it; the public agency acts as an intermediary and transfers rent from actual cultivator to owner while charging a small fee to cover its costs. This could be the panacea to the unemployment situation.
Institutional arrangements such as contract farming, producers’ organizations, and cooperatives that provide farmers easy access to markets, distribute price risks, and reduce marketing and transaction costs can go a long way in pushing high value agriculture. The removal of restrictions to buy and sell agriculture produce can revolutionise fruits and vegetable production particularly at small farms. KZN EDTEA/Agriculture and Rural Development need to encourage integrator and vegetable and fruit buyers to collect and purchase produce at source and supply these directly to retailers in towns and cities. This backend to front-end linkage will connect farm to consumers and is a win-win step for both the producer and the consumer.

Organic farming could be rewarding. The appropriate support for quality input supply, quality testing and certification and processing would be pre-requisites. Value addition in the produce can be achieved with appropriate branding for export promotion. The western countries as well as the Gulf states are obvious markets.

Finally, thanks to the highly successful visits of the political leadership to numerous important countries around the globe, KZN has now returned to the world stage as the most promising emerging market. Wider opening to direct foreign investment in agriculture, manufacturing, maritime, etc. has reinforced this image. The attraction of WEF having its meeting in Durban in May 2017 is adequate proof that the global leaders are noticing the KZN effort. The Annual African Renaissance Conference also has placed KZN high on the international agenda.

Additionally, faster growth accompanying it would speed up growth in revenues allowing further rapid expansion of social programmes. In the medium-to-long run, these revenues could help the government deliver the basic minimum needs such as housing, electricity, clean drinking water, sanitation, road connectivity, health, education and skills to all KZN Citizens by the 2030 as per the KZN PGDP’s commitment to achieving the goals of the NDP2030 goals. Hence it goes without saying that any meaningful progress in agriculture has a bearing on the fate of the largest proportion of the low income population in KZN.

Drawing on network, once again – in all humility - herewith attempt to identify five important aspects of agriculture that need immediate attention to bring economic advantages to thousands of farm families.

- **First**, output per hectare, which is a common measure of agricultural productivity, remains low for many crops when compared to many other regions. There are also large regional variations within the province. Reasons include low and faulty input uses, poor access to modern technology and no real technological breakthrough in recent times.
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Finally the potential of the region needs to be harnessed with suitable interventions. This region is unique for its suitability to the production of most commodities. However, taking advantage of this potential would require institutional support and investment in technological innovations. The question for policy makers and administrators is how these problems can be addressed so as to accelerate agricultural growth and bring remunerative prices to farmers.
RECOMMENDATIONS

However notwithstanding the existing interventions via the formal education system, one strongly advocate an extra-curricular (out-of-school) approach with a view to enhancing the contribution of Science and Technology Education to strategic development of KwaZulu-Natal (KZN). This approach will inter alia encouraging the optimal use of existing (public and private) infrastructure (museums, libraries, service-delivery centre’s, etc.). These will be predicated on informal/non-formal learning activities such as fun activities, learning, experimenting, inquisitive inquiry, tinkering, etc.

Preamble:
The use of public, private, corporate and other facilities – in a seamless, non-competitive, cohesive manner can only enhance the overall desire to create optimal exposure to the STEM project. Hence it is envisaged that in each of the 11 districts of KZN, there will be a replication of an ideal situation as summarized below. This approach by the KZN EDTEA – takes note of existing efforts, similar, projects, and those currently in planning – and sees such activities as complementary rather than in an antagonistic and competitive light. The rationale is simple – when we are attempting to secure scarce resources, empower every single human in the province, and trying to find multiple channels to achieve this – no effort should be seen as unwelcome. A critical component that will be the participation of the local municipalities, museums, ngo’s, education sector, universities and TVET colleges, etc. The issues of access, health and safety, etc must be addressed and understood by the participants.

Of course there must be some honest attempt to harmonise the delivery models so as to present a unified, diverse experience that meets all of the necessary quality and intended outcomes.

As the custodian of the KZN initiative, the MKI on behalf of the EDTEA will secure facilities sourced from public, municipalities, NGO’s, private and corporate entities, etc to set-up a range of facilities that will inter alia incorporate the basis of a local presence in each of the 11 districts. The actual kitting out of the facility will be a function of its location, space available, target population, accessibility, security, etc.

A template should be developed that provides a standard dimension for exhibitions. Commissioning of exhibits, artefacts, etc will ideally entail an enterprise that will look to optimally engage the education, manufacturing sector, unemployed, innovators, tinkerers, etc in the design, manufacture, set-up, demonstration, evolution and upgrades, replication, and maintenance of the displays.

Whilst there will be a level of standardization, allowance must be made for localization and innovation. It is not envisaged that each centre will be a replica of another (certainly not in close proximity); hence the suggestion that MKI develops a template of a suite of facility genotypes and kit-outs that must by necessity be contained in say each district.

There will be a combination of:

- permanent exhibits – static and dynamic;
- space allocated for travelling exhibits (exhibits that lend themselves to be moved from a semi-permanent setting to another – so as to circulate their accessibility.
- external facilities for mobile exhibits – eg. Those on the back of a truck or trailer.

This initiative is aimed at creating a cohort of ignited minds - Neoterics – which means a person/s who advocates new ideas. Innovation is a key strategy for growth and sustainability in the current global economic environment. If so much value is placed on innovation around the world, innovation must be important! But why? Innovation is important to the advancement of society. New and innovative products have increased the standard of living and provided people with opportunities to
improve their lives. Breakthroughs in medicine and technology have had dramatic impact to individuals and communities alike. There's no denying the importance and inspiration of these large-scale innovations. But, it's understandable if you're wondering why innovation is important for organisations that aren't saving the world every day. The importance of innovation can be condensed into two key areas: Efficiency & Increased Value and Competitive Advantage.

- **Efficiency & Increased Value**: Organisations need more than good products to survive; they require innovative processes and management that can drive down costs and improve productivity. Innovation not only improves productivity by allowing greater efficiencies in production but also through increasing the value of products and services that an organisation produces. Increasing global competition and the steadily rising rate of global technological change means that competing through efficiencies delivered by structural reform and competition is no longer enough.

- **Competitive advantage**: Innovation is one of the primary ways to differentiate your product from the competition. If one can't compete on price, one will need innovative products and ideas to make one's business stand out from the crowd.

Innovation has the potential to create competitive advantage by providing new technologies, products and services. Competitors that offer alternative customer solutions to your products range can erode your business. Your company must be on the lookout for new opportunities and be able to get there first. Innovation is important, in any context, on any scale, for any organisation. The efficiency & increased value for your organisation, as well as the competitive advantage you will gain through innovation is not something you can afford to overlook.

The concept of **Tinkering Labs** (UKUPHUZA in Zulu ????) – exploratory spaces where “tinkerers can be nurtured” - a path breaking initiative for kick starting and fostering innovation right from the early-childhood level itself. As a nation, for far too long we have focused on a system of learning that did not keep pace with the 21st Century where focus has moved from knowledge acquisition to the application of knowledge to solve real world problems. The objective to foster creativity and curiosity along with skills like design mind-set and critical thinking is best served by providing an environment equipped with latest tools and equipment of STEM like 3D Printers, Development Platforms for Internet of Things, Robotics and Mechanical tools. The staff along with mentor network can initiate the program to spur and excite young minds on a journey of discovery. While it is true that excessive structure can hinder freedom of thinking and curiosity, it is equally important that certain basic thinking processes are imbibed in young impressionable minds so that they can embark on the journey of innovation. For example, an introduction to the generic design thinking cycle is de-rigueur for anyone wanting to work on the design and prototyping a service or product. Similarly for the teachers, a deeper understanding of inquiry based teaching process is essential to guide the students to go beyond the superficial activities.

Challenges and learning’s from experiences in similar implementations are as an example:

- Vendors ‘just selling STEM Kits’ with no specific project approaches and training programs had to fold up as implementations failed even in the best of private schools
- Ample Longitudinal research studies suggests Makers Mindset alone is not enough to drive sustainable results without adequate direction, guidance and engaging challenges
- Schools in China with world class investment in tinkering equipment are now looking to get support of a structured approach to driving STEM projects and training for staff
- MKI should avoid the outsourced management of the envisaged Science Centres as there needs to be direct support for the experienced STEM and Design Thinking staff
- Mentor network effectiveness only when students go with some clarity on problem and possible approaches as mentors are not trained in the process of inquiry based learning
• Learners/students require formal support in approach and training

**Possible Solutions:**
It is helpful to increase effectiveness and the initiative sustainable on longer term:
• A kick-starter curriculum covering the basics of design thinking process as well as a loosely guided structure to documenting the process and learning as students tinker
• A professional development training to mentors/teachers on the process of inquiry-based learning and STEM related project based learning to guide and encourage students aptly
• A boot-camp training to students to initiate them into the world of tinkering by acquiring skills for creative and critical thinking, communication and collaboration as well as the use of digital tools: all essential for an enjoyable journey of innovation.

![KZN Economic Hubs / Municipalities](image)

In line with the national Department of Science and Technology (DST) mandate, the delivery of science, technology, engineering and mathematics (STEM) awareness campaigns in collaboration with various institutions, including science centres. Using interactive and/or hands-on exhibits and related programmes, science centres provide a platform for society to engage with SET (Science, Engineering and Technology) - as defined by DST; MST (Mathematics, Science and Technology) being the preferred nomenclature within the DBE).

There are currently five Science Centres in KZN (out of 34 in South Africa):
• ArcelorMittal Science Centre in Newcastle
• Isibusiso Esihle Science Discovery Centre based in Manguzi, Isimangaliso
• Olwazini Science Centre at the Golden Horse Casino, Scottsville, Pietermaritzburg
• STEC-UKZN Science Centre based at Howard College, UKZN
• The KZN Science Centre – formerly at Gateway Shopping Centre; now at Transnet MSoe
• Unizulu Science Centre at the University of Zululand

Plainly this is a basis to expand but hardly adequate; one envisages at least 4-5 facilities per district; constructed as complementary rather than competitive centres.
PROPOSED MKI Science and Technology and Career Guidance Centres

Preamble
- To contribute to the improvement of life of KZN by improving scientific knowledge and skills through the utilization of interactive living science and technology discovery centres (S&T centres).
- To disseminate knowledge in science and technology to the public in general and the youth in particular through imaginative and enjoyable hands-on exhibits, displays and programmes, so that they can appreciate the relevance of science and technology in their daily lives. Use of smart toys and gadgets eg. LEGO, ATARI, Findlay and Baker, etc as well as partnerships with software entities such as Microsoft, Google, CISCO, IBM,
- To serve as a catalyst for the youth to develop their creativity and to nurture their interest in related fields.
- To establish a centre of excellence and innovation in non-formal science education.
- To provide satisfying careers for the S&T centre workforce.
- KZN will advance through a world-class complementary out-of-school education system that supports learners to develop the knowledge, skills and qualities they need for the future.
- KZN must continue to innovate to meet the demands of a globalised world and that they are ready to be our partners in preparing learners for the opportunities of changing technologies and new industries.
- This requires continued effort so that learners and young people become lifelong learners, connected global citizens and successful people engaged in their community.
- Building a knowledge-based economy is important to create jobs for all KZN’ers.
- More opportunities for learners to study science, technology, engineering and mathematics – including coding and robotics – will prepare them for the challenges of the jobs of the future.
- Working together we will make a difference for every child and young person.

Aims and Objectives
- To stimulate interest in S&T centres.
- To establish more S&T centres in rural areas.
- To investigate and support mobile centres and transportable units.
- To stimulate ideas in the design of new exhibits
- To hold regular workshops and meetings in different centres.
- To evaluate the impact of S&T centres.
- To establish contact with industry.
- To establish links with international bodies.
- To address the issue of funding.
- To provide training in the management of S&T centres.
- To encourage the sharing of resources.
- To develop a national marketing strategy.
- To provide a national network of information interchange between S&T centres.
- To have a joint voice that is nationally recognized, to lobby government and industry.

Education
- To promote S&T in schools.
- To link S&T centres to the formal educations structure.
- To stimulate interest in careers in S&T.
- To encourage workshops and courses aimed at upgrading science teachers’ practical teaching skills.
- To encourage the formation of science clubs.
The Community
- To promote technology and the natural and physical science in general.
- To ensure that S&T centres are linked to the broader community.
- To promote S&T awareness and literacy amongst the broader community including parents, out-of-school-youth, graduates, employers, civic and community groups, etc.
- To establish ‘S&T routes’ for school groups or tourists to visit.
- To encourage visits from non-traditional visitors.
- fast-track the implementation of the Digital Technologies curriculum and coding and robotic programs
- establish STEM virtual academies, including a specialist coding academy
- incubate the next generation of IT entrepreneurs

Children and young people are preparing for a very different future to that of their parents. The evolving ecosystem are inspiring students to rise to the challenge of this future and become:
- Lifelong learners who are knowledge creators, technology savvy, problem solvers, innovators and effective communicators who share ideas with others and respond positively to change
- Global citizens who have relationships based on fairness and respect, are developing cultural capacity and able to connect locally and globally
- Successful people who have goals, who are resilient, able to create opportunities and are confident in pursuing their passions.

Opportunities for every child
KZN will make it easier for all children to have quality early childhood experiences by:
- offering families a 12 month membership of Playgroup KZN on the birth of their child
- supporting more children with disability to engage in early learning through extra funding
- providing innovative options for quality early learning programmes for rural communities
- upgrading physical early learning environments for rural and remote communities.
- Integrated services for families

NDP Proposal: Improve the skills base
A. Work and Skills Project:
   a. Develop a pilot-project aimed at providing unemployed youth, aged 18 to 35 years with a Matric or equivalent qualification, the opportunity to engage in a 12-month work experience programme.
   b. Under the programme, the youth with a subsidy/stipend for the duration for the 12 months.
   c. The municipalities could serve as an ideal platform to meet the demand for skills in key sectors of the economy, with special courses to develop these skills in partnership with the region’s four leading tertiary institutions.

B. Maths and Science Schools:
   a. Consideration should be given to work in tandem with the KZN Education Department to develop a number of specialised secondary schools that focus on science, technology, engineering and mathematics education (STEM Centres).
   b. These schools should ideally feature highly trained teachers and specialist facilities such as computer laboratories, mathematics study rooms, physics and chemistry laboratories and technology centres.
   c. These schools give learners the competitive skills they need to compete in the job market, or lay the foundation for subsequent higher education and training.
C. **NDP Proposal: Improve teacher accountability and performance**

   a. **KZN DoE Initiatives:** The KZN DoE has a number of programmes in place that track, evaluate, incentivise and improve the performance of school teachers and principals.

   b. First, the DoE has introduced performance contracts for principals and deputy principals. These agreements ultimately link performance assessment to the quality of learner outcomes at a given school.

   c. Further, consideration should be given to implement a comprehensive programme of training workshops during school holidays to improve teachers' literacy and numeracy teaching skills.

**DST Initiatives:**

The Department of Science and Technology (DST) has approved a national plan for a Network of Science Centres in South Africa which has the following goals:

- To promote Science & Technology literacy among young people and the general public.
- To contribute to the enhancement of learner participation and performance in science, technology, engineering and mathematics (STEM).
- To identify and nurture youth talent and potential in STEM.
- To provide career education in STEM-based discipline.

Coordination around science engagement across a wide scope of stakeholders and institutional types requires an appropriate institutional base. A 2013 international comparison of science, technology, engineering and mathematics (STEM) education (ACOLA) established that in almost all instances, structures such as centres, agencies and institutes have been established as part of the STEM infrastructure. The objectives of such coordination structures vary and may include provision of advice to government, communication of science to the community, and stimulation of young people’s interest in STEM education and professions.

The effectiveness of the coordination function, to a significant extent, depends on its operational location. In structuring an institutional landscape to promote science engagement and coordinate individual institutional initiatives across cognate organisations, a delicate balance has to be struck: the central function needs to be vested with an organisation enjoying credibility in both the national science system and the broader public base, while not located too close to the central political “landlord” of the science system. Locating the function in an institution with weak or no standing in the science community dooms its efforts to failure, while placing it too close to the political centre creates at least the impression of conflict of interest – that science engagement will become a pretext for propaganda and non-critical, purely positivist dissemination of science information.

Currently and for several years, the National Research Foundation (NRF) has played a major role in implementing a variety of science engagement activities, both of its own volition and on behalf of the Department; it has effected those activities through the South African Agency for Science and Technology Advancement (SAASTA). In conjunction with SAASTA and the NRF, the Department will formalise and systematise further SAASTA’s role as its agency for science engagement, and over the medium term investigate the feasibility of establishing a separate national agency for science engagement.

The current statutory mandate of the NRF does not explicitly incorporate the role that SAASTA plays in promoting and coordinating science promotion and engagement. The Department will therefore need to amend the NRF Act to incorporate an explicit mandate for science promotion and engagement, thereby formalising the NRF’s and SAASTA’s function in this regard. Moreover, in
conjunction with the NRF, the Department will seek to grow SAASTA’s core or baseline budget by incorporating into its core business relevant projects SAASTA currently manages on behalf of the DST on an ongoing basis.

**Capacity Building**

A. The Science Centre Capacity Building (SCCB) Programme was initiated by the DST with the aim to capacitate the South African science centre community to operate their centres effectively through a number of initiatives and means, including training. In addition to training, the programme also offers opportunities for networking and information sharing among various science centre practitioners.

B. The Science Awareness Platforms (SAP) Unit at SAASTA has the responsibility to identify training interventions meant to capacitate science centre staff. The participants range from floor presenters to Managers. The training interventions are identified in collaboration with the DST and the local chapter of the South African Association of Science and Technology Centres (SAASTEC).

C. Science Centre personnel through centre managers are provided with a list of identified training interventions for the year and invited for participation. The list includes dates for implementation thus allowing participants to plan on time and in line with their centre programmes. Relevant staff members, depending on their roles are nominated at the centres for participation and the SAP Unit at SAASTA is responsible for covering all the costs.

**SAASTA role is to:**

- Establish and implement an effective and efficient grant-management system to support participation of the network of collaborative institutions in science engagement programmes.
- Design and implement programmes that enhance the strategic aims of the framework, including establishing necessary partnerships with relevant institutions.
- Design an appropriate performance monitoring and evaluation system for science engagement, specifically for SAASTA and DST programmes.
- Collect, collate, analyse and disseminate data on the performance of the system, going beyond the work of the DST and its entities to include any institutions that receive support for their science engagement activities or benefit from the grant system operated by the coordinating body.
- Extend its coordination of science engagement activities across all DST entities, and developing a systemic way of reporting on their involvement in or support of science engagement activities.

**Science Centre Support**

A. SAASTA has been mandated by the DST to administer funds for the enhancement of science centre programmes in South Africa. The overall aim of the Programmatic Support Grant Intervention (PSGI) is to contribute to an environment that enables science centres to respond to the following objectives of the Youth into Science Strategy (YiSS):

B. promotion of science and technology literacy among the youth and the general public;

C. enhancement of learner participation and performance in science, technology, engineering and mathematics (STEM);

D. identification and nurturing of youth talent and potential in STEM; and

E. Promotion of STEM career education.

The original STEM concept has spawned a series of innovative adaptations. As an example, the concept of C-STEM. C-STEM is an acronym for Computers, Science, Technology, Engineering and Mathematics. The term C-STEM is used to express the immensely important educational goal of integrating specific academic curriculums behind the skills most vital to the success of students in the 21st Century. The University of California’s C-STEM Mathematics Centre trains teachers to
implement their technology-based curriculum to extend student learning and provide alternative experiences to learners who are not reaching proficiency in the regular mathematics classroom. The objectives of the C-STEM program are to “close the achievement gap by broadening the participation of learners traditionally underrepresented in computing and STEM related careers and post-secondary study” and to “develop learners 21st century problem-solving skills to tackle real world concerns through integrated computing and STEM education.” The goal of C-STEM is to “provide formal computing education for all learners (grade 1 – 12) through existing math courses” (C-STEM, 2017, UC Davis).

C-STEM is a computer (coding and robotics program that focuses on incorporating the common-core mathematics curriculum into all lessons for hands-on experiential learning programming is to close the achievement gap in STEM for underrepresented minorities and women, while at the same time developing 21st century problem-solving skills for all learners. C-STEM curriculum taught in Mathematics as an intervention learning via C-STEM based lessons (linkbots, coding, roboblockly, MobyMax or Prodigy Math Game). C-STEM learners will learn to create computer programs to model real world situations. Additional technologies will be featured including other coding activities, Google Apps For Ed (GAFE), the creation of websites, and more. The philosophy is premised on the concept that digital natives must be content creators and not simply users of technology.

With science and technology driving the future, many teachers are motivating their learners to succeed in the STEM fields due to all of the technological advances that are occurring daily. However there is a school of thought that advocate that all learners regardless of desired field should acquire knowledge in the liberal arts and sciences. Skills like thinking critically, emotional intelligence and other soft skills are invaluable in the corporate world to many employers.

MKI should consider creating a province-wide initiative to advance public awareness, appreciation and engagement of science, technology, engineering and technology (STEM) in KZN. It is believed as one has stated elsewhere in this document that Arts and Design as well as Innovation should be inculcated into the broad thrust to enable KZN to be at the leading edge of the Innovation and Competiveness agenda – hence STEAMI.

However for the purposes of international nomenclature and public resonance- we will limit this to Science and Technology.
STEM Strategy Implementation – an Immersive option

Phase 1:
• Introduce STEM learning to stakeholders without disrupting existing school systems. **External points of stakeholder engagement** beyond the ‘formal’ school system such as - community facilities, government department facilities, public facilities Libraries, Museums, KZN Techno-hubs; digital innovation hubs and industry-academia collaboration sites, Public and Private Science Centres, the workplace, Strategic alliances with entrepreneurs, etc. - can be utilized as STEM Learning Centres to ensure STEM activities that are easily accessible and available as optional but incentivized to be consumed.
• The strategic use of Digital, Mobile and E-learning platforms should be investigated and implemented

Phase 2:
• Providing STEM learning engagements within the school system as a **complementary and supplementary program**.
• Focuses on exciting, shorter duration, easy to immerse-in STEM engagements to pre-primary (ECD), primary, and high-school learners leading to development of skills with career-guidance initiatives; develop college readiness strategies.
• Start capacity building through educator (teacher/principal) on STEM relevance, skills and processes for implementation
• Build collaborations with Industry; alignment of programme goals & industry needs: essential for employment, entrepreneurship

Phase 3:
• This is a ground-breaking phase requiring the entire ecosystem (not just the education system) to be re-aligned at a conceptual level to deliver all learning through a project-based learning methodology (trans-disciplinary and multi-disciplinary immersion) and every classroom/workplace/facility is an integrative STEM Learning Centre in itself.
• This Full immersion model is more like a 21st Century workplace and is the aspirational and desirable future to be in.
STEM Strategy Implementation – some suggestions

Public Awareness Campaigns

- STEM education plays a big role as the catalyst to meet the challenges and demands of the present and future economy
- Encourage more youth and learners to select STEM subjects; Educate the public about the diversity of career opportunities in STEM
- Informal approach to strengthening interest in STEM education and careers; Provide hands-on learning opportunities for learners and parents

Enthusing young people is vital, but teachers remain key

- **After-school programs** – encourage learners participate in extra-curricular (out-of-school) programs; by providing with engaging materials with preparation and guidance on how to use those materials to enrich experiences in STEM.
- **STEM contests** – that can reward creativity and problem solving. Science fairs to show-case projects in this fair so as to introduce them to a community of like-minded peers. Designing and building – which is another form of out-of-class is another program that is suitable for stimulating student’s interest in STEM program; extended projects based on inquiry, construction, and discovery for learners.
- **Vacation programs** - learning with the objective of building the interest of science-orientation; as well as professional development for the teachers, unemployed youth etc.

Source other public sector-implementation partners – an example

The KZN Provincial Developmental Finance agency - Ithala is well positioned to serve emerging markets in outlying/rural areas — where a dire need for a better quality of life exists — with its empowerment programmes.

- **The Siyasebenza initiative ("we are working")** is a series of development-based outreach programmes created to uplift & empower aspiring youth, women and SMMEs in townships and rural areas to become entrepreneurs.
- **Imbokodo iyazenzela ("women doing it for themselves")** is an enterprise development for women.
- **The Inkunzi’isematholeni ("Youth in Business") programme** to tackle unemployment.

Likewise, other government agencies traversing the entire spectrum can also be useful partners eg.

- Dept. of Transport regional depots can be hubs where learners are exposed to the hydraulics, pneumatics, PLC’s of the “yellow-goods” equipment and the workings of such heavy plant
- Dept. of Health Facilities: lend themselves to potential exposure not just to potential health and medical careers but also the maintenance of physical plant and infrastructure, rotating equipment, HVAC plant, laundries, electronic and mechanical equipment, infection control, etc
- All municipalities are the repository of multiple activities – from exposure to administration, finance, governance, operations, maintenance, etc
- Dept. of Public Works as the custodians of property portfolio will have enormous needs for understanding the optimization of utilities, use of renewal sources energy – especially on a retro-fitted basis, etc
- etc
Career Guidance

There are numerous challenges that stakeholders experience in their endeavour to provide career development or guidance services. These challenges include:

- the lack of clear negotiated roles and responsibilities;
- no systematic collection of career development related information;
- sharing of experiences; and
- standardisation of services.

The National Skills Development Strategy III (NSDSIII) aims “to encourage the linking of skills development to career paths, career development and promoting sustainable employment and in-work progression”.

It specifically refers to SETAs to include a goal to build career and vocational guides. The strategy furthermore refers to:

- “The key driving force of this strategy is improving the effectiveness and efficiency of the skills development system. This strategy represents an explicit commitment to encouraging the linking of skills development to career paths, career development and promoting sustainable employment and in-work progression.”

- “There is a need for much more substantial programmes that improve qualifications, support career-pathing, enable greater flexibility and mobility and increase productivity.” and “. . . all our skills development initiatives must contain within them specific programmes and strategies to promote gender equality in skills development, in employment and career development and in our economy as a whole.”

- “Our entire skills development system must dedicate the necessary resources to support career and vocational guidance, as this has proved to be a critical component in successful skills development initiatives world-wide. Both the SETAs and the NSF respectively must seek to build career guidance initiatives in their sectors and generally as a key component of the NSDS III.”

The strategy also specifies a career development outcome:

“NSDS Outcome 4.8.1: Career paths are mapped to qualifications in all sectors and sub-sectors, and communicated effectively, contributing to improved relevance of training and greater mobility and progression.

- Output 4.8.1.1: Career guides are developed with labour market information from SETAs, addressing sub-sectors within their sector.
- Output 4.8.1.2: Sector stakeholders are engaged and programmes are adjusted to meet the skills and qualification needs to promote comprehensive career development.”

The National Skills Development Strategy III Progress report 2011 – 2013 provides an update on progress, highlighting:

- The establishment of Career Development Services by the DHET in cooperation with the South African Qualifications Authority (SAQA), which includes a telephone helpline;
- The strengthening of career development in SETAs;
- The development of career guides by SETAs and government departments;
- The creation of a National Career Advice Portal (NCAP); and
- The approval and publication of the ‘Framework for Cooperation in the provision of Career Development (Information, Advice and Guidance) Services in South Africa, as the basis for policy development’ and the establishment of an implementation task team.

The Youth Employment Accord’s “commitment 2” refers to work exposure, stating: “Connect young people with employment opportunities, through amongst others support for job placement schemes
and work-readiness promotion programmes for young school leavers and provide young people with work experience. (Page 19)

The parties agree to build on the labour centres of the Department of Labour and the career fairs that government has introduced. This forms part of the development of public employment services in South Africa.” (Page 19)

Numerous activities occur but with very little co-ordination and scheduling to ensure optimal attendance by the learners.

As an example

- **DHET** hosts Mandela Day Career Festival and events related to the Apply Now! Campaign;
- **DBE** hosts career exhibitions as part of the Girl Education Movement (GEM) and Boy Education Movement (BEM);
- **DST** host the Science and Technology Awareness Project which includes a National Science Week;
- **DoT** hosts a National Tourism Career Expo;
- **DPW** hosts a library week, which includes a Career Expo targeting their employees;
- **DEA** has a variety of careers awareness programmes ranging from workshops, conferences, community based programmes and radio campaigns;
- **DoL** hosts Job Summits in different provinces;
- **DED** hosted a National Youth Indaba;
- **dti** used to host Career Indaba. The service was discontinued in 2014. The current focus is on attending exhibitions by invitation;
- **NYDA** hosts a Start Here Campaign but no career event for the Youth Month;
- **GSETA Forum** co-ordinates career exhibitions for provincial governments targeting rural areas;
- **FASSET** hosts career expos in each province in the form of Mandela Day Career Festival hosted by the DHET.
- **The MQA** hosts several events promoting careers in mining and some of these events are done in collaboration with the DME.

The OECD lists the following necessary attributes to provide effective career guidance

- Recognise that rapidly evolving jobs and careers have expanded career opportunities, but choices are becoming harder, and career guidance is therefore becoming both more important and more demanding. If young people choose the wrong career, the costs of later changes can be high.
- Provide reliable and impartial sources of guidance so that young people do not have to rely on informal sources of guidance, such as family and friends, which have their strengths, but may only offer choices that are familiar.
- Develop effective guidance services that can yield large returns by developing the career-related skills, self-awareness and self-esteem which lead to rewarding choices.
- Tackle weaknesses in existing provision, including:
  - staff providing career guidance often deal inadequately with labour market issues
  - services may be fragmented and under-resourced
  - advice often lacks objectivity
  - relevant labour market information is not always available
  - career guidance initiatives are often not effectively evaluated

Establish a coherent, independent and comprehensive guidance profession
- Develop a separate profession of career advisors. Too often the career guidance profession is assimilated into psychological counselling, distorting and marginalising its role.
- Ensure that career advisors have:
  - a good knowledge of labour markets, careers and learning opportunities
  - the capacity to identify further relevant sources of information to provide more specific advice
  - the ability to draw out from young people their interests, aptitudes and objectives so as to help them make choices which are both realistic and fulfilling
  - the competencies to help individuals to manage their own careers
- Design training for career advisors to provide these competences
- Develop a qualification system for career advisors that covers not only those in schools but also other guidance professionals working in tertiary education and in employment offices and other services for adults. This would facilitate recognition and transferability of career advisor skills across institutions.
- Preserve their independence of guidance professionals from the institutions (such as schools) in which they are based. This could be achieved in several ways including:
  - externally managing a professional career guidance service that functions in schools
  - training teachers as guidance professionals, held accountable to standards agreed with the external guidance service, and with a fixed time allocated to guidance work
- Embed individual career guidance within a comprehensive career guidance framework, including a systematic career education programme to inform students about the world of work and career opportunities.
- Encourage an understanding of the world of work in schools from the earliest years, backed by visits to workplaces and workplace experience.

**Support Guidance with resources, information and evaluation**
- Provide adequate resources for guidance services and protect them against the risk of being squeezed because they are resourced at the margins of an activity such as regular teaching.
- Deliver key elements of guidance pro-actively to all students, so that students can be supported by one-to-one guidance by professionals when they make key career decisions.
- Regularly update information sources to identify emerging occupations and areas of skills shortage, as well as current and potential areas of skills oversupply and redundancy. An important function of guidance personnel will be to guide individuals in their use of all these information sources.
- Properly evaluate career guidance initiatives to establish the case for effective resourcing and identify how best to employ those resources.
Anecdotal Evidence ex the Central Admissions Office (CAO)

The situation is so dire that The Central Admissions Office (CAO) – a non-profit organization set up by the KZN Tertiary public institutions to co-ordinate and consolidate applications for places in the first year of study at the institutions. In fact there are a number of TVET Colleges and private colleges who are part of this initiative.

At the Annual General meeting held last week (Wed 23 August 2017) in Durban, the CEO George van der Ross lamented that “the CAO had to take matters into its own hands by giving career advice to school pupils. The organization felt pupils were not getting proper guidance in their formative years which would affect them when they applied to tertiary institutions.”

Van der Ross stated that “the organization was providing guidance counselling to Grade 9 pupils because their Grade 10 subject choices would influence their choices of career and further study. Correct guidance was important as many high school pupils went to tertiary institutions unprepared.”

Citing research from 2013, he said “30% of students dropped out within their first year”; “55% of students did not graduate and less than 5% of African and Coloured students prevailed in higher education.”

This is a poor reflection not only on the education system, but society at large, as these pupils make the entry requirement, but are not properly counselled on career choices and the appropriate choice of subjects.

In addition to the drop-out rate, and casualization of these potentially bright learners, they end up in debt and also their potential role-model status is lost; for most of this cohort – it could well be that they are the first in their families reaching tertiary education and the key elements in carrying an entire family’s dream of escaping poverty.
**Recommendation 1**

Recognizing the critical role that STEM plays in driving innovation and KZN’s competiveness; it is recommended that:

a. KZN’s STEM capacity building should be aligned to clearly articulated goals and areas where KZN has a comparative advantage or critical need – viz. maritime and coastal issues, disaster management (e.g. predictive lightning intelligence, etc.), tourism, agriculture, agro-processing and aquaculture, etc

b. The rollout of a provincial STEM strategy is supported by a comprehensive statistical database on STEM that includes data on initiatives and performance relating to education, training, workforce, research, international engagement and competitiveness of the workforce.

c. Clear objectives, target, milestones and a STEM measurement framework is developed to monitor progress in building KZN’s STEM capability. This includes:
   i. Human Resource planning, Labour market studies and Mapping outcomes against workforce needs; and
   ii. Tracking the maturity of KZN’s innovation capability relative to increased STEM capability.

d. Initiatives such as the Science Centres, Entrepreneur Incubators and Infrastructure programmes incorporate a strong STEM focus. Including attraction of STEM expertise and focus on STEM-driven innovation.

e. Incorporation and hosting of Career Guidance and development initiatives

f. Development of a strong core of able and willing mentors

g. Access to infrastructure and finance

h. The Innovation thrust include relevant expertise from all STEM disciplines and has the ability to make policy recommendations related to developing KZN’s STEM capacity.

**STEM, R&D and commercialization**

The absolute focus on STEM-driven R&D is imperative. However concerns over the current R&D legislative settings are a disincentive to technology R&D – effectively requiring that technology R&D have a higher proof-of-concept threshold. Whilst the legislative domain sits at a national level (DST/DTI), company-level R&D in specific circumstances. The ‘Internal Administration’ exclusion in the R&D tax legislation can be debilitative in negating R&D undertaken by a company for its internal use – including where it is undertaking related R&D to improve delivery of its services to customers – is ineligible for tax incentives. This contradicts strong arguments for investing in innovative and specific R&D for both economic and social gains.

Technology is “non-rival”: one’s use of a technology does not limit its use by others and the cost for an additional agent to use an existing technology is negligible compared to the cost of inventing it. Hence, not all the benefits of technological knowledge are appropriated by the inventor. Technological investments typically generate social returns that far outweigh private returns. Technology, once invented, can be used and diffused internationally with small added cost but substantial added benefit.

Importantly, technological R&D generates two types of spillovers. First, new technological knowledge can be used in any country to produce more efficient or higher quality goods/services. This spillover increases the labour productivity of the country that adopts it. Second, technological knowledge can be used to produce new ideas or new applications in research and development (R&D). This increases R&D effectiveness that is the benefits from evolving and refining technological knowledge. The first type of technology spillovers are usually mediated by market mechanisms (trade, investments and intellectual property rights) and are sometimes called technology diffusion. The second type of technology spillovers involve diffusion of knowledge to other firms via mobility of workers, learning, imitation, sub-contracting and are considered technology externalities.
Recommendation 2

To ensure STEM based R&D, in particular the importance of technological R&D is prioritized it is recommended that:

a. In executing the KZN STEM Strategy the priority of encouraging STEM based R&D is emphasized to the potential incentive processes.

b. The success of STEM based R&D is showcased and used as an example of the type of R&D KZN wishes to incentivize.

c. R&D Tax Incentive requirements are reviewed to ensure technology based R&D is incentivized.

d. Certainty and stability around the operation of the R&D scheme is prioritized - continual changes to the R&D tax incentive undermine business investment in R&D and innovation capability development.

e. Any changes to the R&D tax incentive should be undertaken through a systematic approach in the context of a whole of government tax and innovation system reform.

STEM and Collaboration

While the idea of integrating STEM experts across industry, business and public sectors is highly desirable; reasonable, there is a work to be done to identify what motivates people with STEM skills to work with business and vice versa. But this must be supported with a clear commitment to work with businesses and research to develop and recommend successful models for collaboration. The view incentives for researchers and business are misaligned and this is a barrier to commercial returns being realized. The current system incentivizes universities to focus on research publications rather than commercial applications. The inherent rationale especially for the Universities of Technologies (UoT’s) should be applied research. Given KZN has two UoT’s (DUT and MUT, a comprehensive university (Zululand) and a traditional research university (UKZN) – theoretically there should be a huge focus on finding appropriate uses of technology and seeking solutions to local challenges. Further current practices typically ‘lock’ intellectual property in universities.

Similarly, the business environment can hamper research collaboration – short business planning cycles and risk aversion can limit the extent to which business seek research collaboration opportunities. Business, understandably, are primarily focused on their own commercial strategy, therefore research opportunities need to be appropriately targeted to engage business properly. This misalignment – with researchers focusing on research excellence and business focusing on commercial outcomes, can lead to many missed opportunities.

The DST/DTI are a good start for collaboration. However the lack of well-structured or permanent information sources available to participants in the innovation system combined with the absence of innovation hubs that provide a focal point to bring together the relationships and resources they need to innovate – are symptomatic of the bigger issue in an innovation system that lacks formal and effective collaboration frameworks.
**Recommendation 3**

Recognizing the critical role of collaboration (at all levels) to drive high performance innovation and STEM outcomes, it is recommend that:

a. Government to work in tandem with industry to recommend and help develop successful models of collaboration for people with STEM skills to work with business.

b. Universities are incentivized to collaborate with industry to develop the commercial potential of their research. This requires reassessment of performance based block funding arrangements under the existing programmes to rebalance the current focus on producing published research papers as opposed to applied outcomes.

c. A register of intellectual property (IP) for KZN-funded research institutions is established to speed up the commercialization process. IP could be charged (or not) at different charge rates. Where IP from university based research is not used within a specified timeframe that IP is made commercially available.

d. A mechanism is implemented to support small and medium sized businesses contract with universities to provide stronger research capacity to their projects.

e. Smart digital technology is used to drive the creation, diffusion and application of knowledge.

**Integrating STEM in business**

It is painfully obvious that if one is not developing the foundational skills to ensure one’s ecosystems (social, economic, public, private, education, business, etc.) will be competitive in a global, knowledge based, digital market. A recent McKinsey report (March 2016) quotes that while some 98% of businesses have an internet presence (95% of those with access to broadband) less than half of all business have a web presence. There are key sectors of the economy that have very low or no IT support and while many businesses use the internet to undertake financial activity, few use it for information sharing or data exchange with other businesses or organizations; the number of businesses using the internet to identify future market trends, to assist their development of new or improved products or monitor competitors is even lower.

The afore-mentioned seem to suggest that KZN businesses do not have the “T” skills necessary to operate and grow an effective business in the new digital environment. This is not simply about having a presence online, but leveraging technologies such as data analytics, cloud services and mobility to support new business models, operate efficiently and competitively with local and international peers and innovate their products, services and process.

STEM skills should not be focused only on those with interest and inclination but an integrated component of education, professional and business capability development processes. Businesses of all sizes and maturity require STEM skills to compete effectively in the modern market; more especially in the Fourth Industrial Revolution.
Recommendation 4
Recognizing the importance of basic STEM skills, in particular technology skills, to the operation of all modern businesses it is recommended that:

a. STEM capability is an integrated component of all education, professional and business capability development processes.

b. An Entrepreneur Infrastructure programme be initiated to raise the profile of STEM-based skills in business.

STEM and entrepreneurialism
According to the OECD Science, Technology and Industry Outlook (2012), many countries have broadened their policy focus to strengthen education for innovation beyond traditional STEM fields. Schools and universities often offer specific programmes for entrepreneurship education which use active, learner-centred and context-rich pedagogies (imitating real-world situations). Even where specific programmes do not exist, “entrepreneurial skills” are seen as a competency to develop across subjects and school levels. For example:

- Denmark formalized in 2009 a strategy for education and training in entrepreneurship (targeting all levels of education) and in 2010 ran a competition to establish a University of Entrepreneurship.
- Finland has issued Guidelines for Entrepreneurship Education (2009);
- Ireland’s National Strategy for Higher Education (2011) promotes entrepreneurship training as part of their curricula;
- Norway has developed an action plan for entrepreneurship in education (2009-14) and included entrepreneurial skills as a core competency in the National Qualification Framework for Higher Education; in Norway and New Zealand, moreover, how to set up and develop a business is part of the business or economic studies curriculum in secondary schools.
- Belgium, Estonia, Germany, Luxembourg, Portugal and Slovenia also have state-funded initiatives to include entrepreneurship training in the school or university curriculum.
- India announced in early May 2017 its plan to develop 20 world-class universities that will favour institutions strong in science, technology, engineering and mathematics (STEM) subjects,
- With the right support it is estimated that “the Australian tech startup sector has the potential to contribute $109 billion or 4% of GDP to the economy and 540,000 jobs by 2033 with a concerted effort from entrepreneurs, educators, the government and corporate Australian”.
- Recent analysis shows that entrepreneurs supplied 57% of all jobs in the EU in 2012 and 75% in China while in the US start-ups and companies less than five years old account for nearly all net job creation in the last three decades.

Notwithstanding that repeat entrepreneurs who have failed once before have been shown to have a higher chance of success than those trying for the first time, one has to assess KZN’s tolerance for business risk and failure? The low acceptance of business failures means potential innovators are often reluctant to launch new ventures for fear of harming their reputation. It is also reflected in the reluctance of talented people to transfer from the tertiary education sector to private sector organisations – the perception that it is a failure to go from research in university to business.

It is also proposed that the KZN government consider providing incentives for more venture capital investment. Entrepreneurs need an environment that is conducive to investment in activities that drive new ventures, new products and services and new jobs. South Africa has one of the lowest rates of venture capital investment in the developed world.
Lack of access to ‘affordable’ capital - at reasonable rates and on reasonable terms - is one of the most significant market failures in a start-up ecosystem. To support an effective innovation ecosystem, Hence KZN needs to develop more innovative funding platforms. These include crowd funding, microfinance, targeted venture capital funds and incentives.

In order to attract venture capital KZN needs to ensure it provides an ecosystem in which innovative start-ups are relevant and attractive in a competitive commercial market. This requires innovative products and services which, in our increasingly knowledge and digitally based economy, must be underpinned by STEM capabilities. Addressing concerns about the failure of venture capital arrangements will only reap results if competitive offerings are available. KZN needs to ensure in the first instance that it has the skill base to drive a pipeline of innovative ideas that are attractive and viable for venture capital interests.

Part of the answer lies in ensuring students have access to cross discipline and innovative new study opportunities such as those offered by the University of Technology in Sydney (UTS). Courses incorporating entrepreneurialism, creativity, innovation and commercialization with other more mainstream disciplines will play a key role in equipping our young people with the expertise and skills essential to the discovery of commercially attractive new business enterprises.

**Recommendation 5**
To drive a culture of entrepreneurship, it is recommend that:

a. Innovation and entrepreneurship are incorporated into the broad range of university degrees, including STEM professions.
b. The Government’s Prime Minister’s Prize for Science is expanded to recognize and reward achievements in all STEM disciplines including technology, engineering and mathematics.

**Recommendation 6**
To enable KZN to build an effective and sustainable STEM capability it is recommended that:

a. A Provincial (in tandem with national) education strategy is developed incorporating all aspects of Science, Technology, Engineering and Mathematics.
   i. Inquiry-based learning and project-based learning, with a focus on real-world contexts and situations must be incorporated.
   ii. The framework should be centrally driven and funded and include curriculum reform and new teaching standards. It should include decentralized program initiatives and partnerships and link STEM activities in schools, technical/vocational schools, TVET’s and vocational interventions, and higher education with industry, business and the professions.

b. Address the existing silo-ed approach to STEM by expanding existing awareness campaigns and programs such as ‘Science meets Parliament’ to include all STEM disciplines. One assumes that MKI will be particularly supportive of a program involving students, industry and Government leaders to engage in coding exercises that highlight the relevance of computational thinking and basic coding skills (e.g. such as ‘hour of code’ forums hosted by the Digital Careers program.

b. Language describing STEM is consistent.
c. The importance of STEM for all young people not just high achievers is clear.

**Curriculum**
Changes to the curriculum that incorporate digital technologies. However, broader curriculum and pedagogy reform focused on making STEM more engaging and practical, through problem-based
and inquiry-based learning, and which emphasize creativity and critical thinking, including entrepreneurship remains a priority.

While the local government structures greater commitment to providing greater exposure to computer coding and establishing an innovation focused are welcomed, they are limited. Given the strong links between mathematics, problem solving skills, application skills and coding, the introduction of computer coding at an early age makes sense and importantly, is foundational to developing the capabilities to enable it to be a creator not just a user of technology innovation.

An innovative model of education-industry collaboration (currently operational in the US and Australia) that provides students studying for their NSC/matric level with an industry supported pathway to a science, technology, engineering and mathematics (STEM) related diploma, advanced diploma or associate degree. Partnerships between schools and industry provide opportunities for students to engage with the world of work and better understand the relevance of their learning to jobs and post-school pathways. The STEM focused pilot has tested and adapted key elements of this innovative US approach to education-industry collaboration in this context.

Collaboration between the education and industry sectors strengthens the connection between student learning and the skills that employers need. In addition, the relationships students develop with their mentors and the school’s industry partners improve their prospects when employment opportunities are available with a partner organization, or within the partners’ broader business networks.

The benefits of becoming a STEM industry partner:

The STEM model allows industry to play an active role in the learning and development of young people to ensure that they are entering the labour market with the skills they need to succeed at work.

There are many forms of support industry can provide, including, but not limited to:
- working with teachers to align classroom learning to the skills employers need
- providing opportunities for hands-on workplace learning
- supporting authentic project-based learning (either in the workplace or at school)
- offering mentor support for students
- enabling access to the latest technologies used by industry
- providing traineeships, apprenticeships or internships as part of the program.

With the assistance of industry, the program ensures students will enter the labour market with the technical and personal skills they need to succeed.

Fundamental to the effective execution of curriculum is the quality of teachers. This includes both content knowledge and expertise as well as the skills to teach STEM subjects effectively – and arguably inspirationally. While the paper recognizes this, more practical initiatives are required.

Building a culture where school teachers enjoy high esteem for their STEM expertise is a critical starting point; for example through review of aspects such as remuneration, promotion structures and qualifications. In China, STEM teachers receive salary increases not on the basis of seniority but through continuing professional development programs, specific to the discipline. To be promoted China’s teachers must demonstrate an improving standard of work. In Finland, where all teachers have a Masters’ degree, teaching is harder to enter than most other professions, and the strongest teachers are paid to work in school districts serving poor families and students with the most learning difficulties.
Teaching should not equate to class management and credentialing alone. There must be a focus on knowledge of subject matter. In countries where STEM is most successful, STEM teachers are expected to be fully qualified in their discipline and to teach in that field and not others. This is a contrast to the Irish, Australian, Finnish, etc systems where it’s common for teachers to instruct across multiple disciplines.

Opportunities and incentives for industry and tertiary institutions to better engage with teachers for knowledge transfer and skills developed should also be developed.

**What is Authentic Learning?**

In education, the term **authentic learning** refers to a wide variety of educational and instructional techniques focused on connecting what students are taught in school to real-world issues, problems, and applications. The basic idea is that students are more likely to be interested in what they are learning, more motivated to learn new concepts and skills, and better prepared to succeed in college, careers, and adulthood if what they are learning mirrors real-life contexts, equips them with practical and useful skills, and addresses topics that are relevant and applicable to their lives outside of school.

An “authentic” way to teach the scientific method, for example, would be to ask students to develop a hypothesis about how ecosystems work that is based on first-hand observations of a local natural habitat, then have them design and conduct an experiment to prove or disprove the hypothesis. After the experiment is completed, students might then write up, present, and defend their findings to a panel of actual scientists. In contrast, a “less authentic” way to teach the scientific method would be to have students read about the concept in a textbook, memorize the prescribed process, and then take a multiple-choice test to determine how well they remember it.

In the “authentic” learning example above, students “learn by doing,” and they acquire the foundational skills, knowledge, and understanding that working scientists actually need and use in their profession. In this case, students would also learn related skills such as critical thinking, problem solving, formal scientific observation, note taking, research methods, writing, presentation techniques, and public speaking, for example. In the “less authentic” learning situation, students acquire knowledge largely for purposes of getting a good grade on a test. As a result, students may be less likely to remember what they learned because the concept remains abstract, theoretical, or disconnected from first-hand experience. And since students were never required to use what they learned in a real-life situation, teachers won’t be able to determine if students can translate what they have learned into the practical skills, applications, and habits of mind that would be useful in life outside of school—such as in a future job, for example.

Another principle of authentic learning is that it mirrors the complexities and ambiguities of real life. On a multiple-choice science test there are “right” answers and “wrong” answers determined by teachers and test developers. But when it comes to actual scientific theories and findings, for example, there are often many potentially correct answers that may be extremely difficult, or even impossible, to unequivocally prove or disprove. For this reason, authentic learning tends to be designed around open-ended questions without clear right or wrong answers, or around complex problems with many possible solutions that could be investigated using a wide variety of methods. Authentic learning is also more likely to be “interdisciplinary,” given that life, understanding, and knowledge are rarely compartmentalized into subject areas, and as adults students will have to apply multiple skills or domains of knowledge in any given educational, career, civic, or life situation. Generally speaking, authentic learning is intended to encourage students to think more deeply, raise
hard questions, consider multiple forms of evidence, recognize nuances, weigh competing ideas, investigate contradictions, or navigate difficult problems and situations.

In perhaps its purest expression, authentic learning culminates in students making some form of genuinely useful contribution to their community or to a field of study. While few students will develop better ways to diagnose cancer, schools create authentic learning experiences in a variety of ways. For example, a science class might study water conservation, conduct an analysis of their school’s water usage, investigate potential ways the school might reduce its usage, and then present a water-conservation proposal to the school board that includes a variety of recommendations—e.g., posting signs in bathrooms encouraging students not to leave water running, installing low-flow faucets with automatic on-off sensors, using rain barrels below drain spouts, planting drought-resistant plants in the schoolyard that are watered using the collected rainwater, etc. Once these solutions are put into practice, students might conduct observations to calculate how much water the school conserves on a daily, weekly, or annual basis, and then develop a website, infographics, or videos to share the information with school leaders and the broader community.

Authentic learning is closely related to the concept and theory of “constructivist teaching,” and in some contexts it may be used synonymously.

Reform
As a school-reform concept, authentic learning is related philosophically and pedagogically to strategies such as personalized learning, community-based learning, and project-based learning, among others. In addition, instructional strategies such as demonstrations of learning, capstone project, personal learning plans, and portfolios may be associated with authentic learning.

Authentic learning is also a central concept in educational reforms that call for schools to place a greater emphasis on skills that are used in all subject areas and that students can apply in all educational, career, and civic settings throughout their lives. It’s also a central concept in reforms that question how teachers have traditionally taught and what students should be learning—such as the 21st century skills movement, which broadly calls on schools to create academic programs and learning experiences that equip students with the most essential knowledge, skills, and dispositions they will need to be successful in the collegiate programs and modern workplaces of the 21st century. As higher education and job requirements become more competitive, complex, and technical, proponents argue, students will need the kinds of skills that authentic-learning experiences can provide to successfully navigate the modern world, excel in challenging careers, and process increasingly complex information.

Debate
Calls for “more authentic learning” in education are, generally speaking, a response to the perception that many public schools pay insufficient attention to developing the intellectual abilities, practical skills, work habits, and character traits required for success in adult life. In other words, the concept of “authentic learning” intersects with larger social debates about what public schools should be teaching and what the purpose of public education should be. For example: Is the purpose of public education to get students to pass a test or to earn a high school diploma? Or is the purpose to prepare students for success in life after graduation, including postsecondary education and modern jobs or career paths? Advocates of authentic learning may contend that the purpose of public education is to look beyond test scores or graduation rates—success in school—to the knowledge, skills, and character traits students actually need to succeed in adult life—success outside of school.

In addition, authentic learning may also intersect with a variety of ongoing debates about how and what schools should teach. Critics may question whether authentic-learning experiences can cover
enough academic content in the core subject areas to ensure that students acquire a broad, well-rounded knowledge base. Critics may also argue that authentic learning, and related instructional strategies, may displace more traditional yet effective forms of teaching, fail to equip students with “the basics,” or lead to disorderly classrooms, among other possible arguments. Advocates would contend, however, that these criticisms are unfounded, and that a well-planned curriculum built around authentic-learning experiences can cover all the academic subjects and concepts that students need (unless the learning experiences are poorly designed and executed, of course). In some cases, criticism arises in response to a negative experience with authentic learning or from an insufficient understanding of the concept.

Authentic learning may also place more burdens—both logistical and instructional—on teachers. For example, authentic learning may require significantly more planning and preparation, and teachers may need to acquire new and more sophisticated instructional techniques or substantially revise lesson plans they have used for years. Authentic learning may also introduce more logistical complexities, particularly when learning experiences take place outside of the school or classroom (in schools, even seemingly minor logistical tasks, such as making travel arrangements or securing parental permissions, can take up a lot of time).
Recommendation 7

To ensure KZN is equipped to support an effective STEM education program it is recommended that:

a. Incentives to encourage and support well qualified STEM tertiary graduates and high performing STEM students leaving school into teaching professions are introduced.

b. An actionable program to support teacher professional development training in STEM education is developed and this is embraced by all States and Territories.

c. Educators are incentivized to specialize in teaching STEM and ensure their knowledge is up to date with relevant contemporary developments.

Career pathways

Support the proposal to require local publically funded research agencies to engage in school programmes and as part of this, develop a database of businesses willing to engage with schools and students in support of STEM development. However engagement is not enough. Concrete pathways to careers in STEM must be developed. The notion that internships must be tied to degree programs offer significant incentives to drive students towards STEM subjects and help generate demand for STEM. This will also foster increased organic engagement between universities and industry.

To this end, MKI should develop STEM internship support incentives and training materials that help businesses (particularly SMEs) host, engage and work with students to provide real world business training opportunities.

The European trend of student research centres are another example of fostering career pathways. These commonly operate in a private-public partnership model. Contrary to science centres, where students follow pre-defined experiments, a student research centre is an environment where students pursue their own research projects. This can be done under a government supported framework and partnered with Industry to foster a culture of creation rather than consumption; with tools such as microscopes, 3D printers, augmented reality etc.
Recommendation 8

To ensure STEM career pathways are clear it is recommended that:

a. There is a commitment to long term acceleration of STEM career pathways through industry matched support that goes beyond pilot programs.

b. Career STEM pathways are clear:
   i. Leverage existing programs such as Digital Careers to facilitate public private-partnership maker-spaces or STEM-labs across the country;
   ii. Increase the use of internships tied to degree programs;

c. Develop STEM internship support incentives and training materials that help businesses (particularly SMEs) host, engage and work with students.

d. Form a ‘future skills’ taskforce project group, comprised of government, private and tertiary sector representatives to develop a career guide for both, future STEM roles jobs and broader STEM in X careers. A key aim would be to help parents, teachers and students better understand where Industry is heading and what role they might explore once they are ready to enter the workforce

STEM Role Models

To raise the profile of STEM education and careers one need political champions and industry leaders to both support change and build a profile of STEM careers young people can aspire to achieve. A celebrative culture that is inclusive of all disciplines of STEM is necessary to catalyze such a shift.

While there are numerous advocates for STEM related careers, the voice is diluted by the focus on individual STEM disciplines. A unified STEM framework, promoting the opportunities of diversity in STEM careers, supported by a STEM ‘ambassadors’/role model program would positively influence community awareness of the value of STEM based careers and their broader importance to the economy.

Best practice Industry equality programs need to be better shared across industries; successful minority support initiatives should be celebrated and implementation steps available to maximize progression towards equal rights, gender-balance and pay consistency.
Recommendation 9

To raise the profile of STEM education and careers it is recommended that:

a. A STEM careers awareness Public Relations campaign is developed in collaboration with Industry and various STEM initiatives and that this identify and celebrate STEM role models/champions promoting the opportunities of STEM and the jobs of the not too distant future. This targets all levels of training and education including TVET/vocational and University education and training options.

b. A gender and equity diversity audit of current STEM take-up is undertaken with a view to driving STEM take up by women and identified disadvantaged groups...

Research

STEM and Research

Unequivocal support for the objective of building a strong STEM research enterprise and one needs to applaud government support for public funding to maintain a vibrant national science and research capability. The key concern however, is that the current focus is not inclusive of all STEM disciplines – an issue raised throughout this response and a potential major flaw of a strategy moving forward.

The STEM research effort must be broad, span universities, industries and publicly-funded research agencies. Investments in research must include a strategic base, with commitment to areas of interest, areas of comparative advantage, and areas of priority. Publicly-funded research outcomes must be recognized as a public good, and also be widely diffused or used commercially in ways that benefit the public.

Recommendation 10

To ensure a holistic STEM research agenda it is recommended that:

a. The proposed STEM research enterprise agenda of the future is inclusive of all STEM disciplines.

b. Existing research expertise, should be integrated into such a program.

c. The requirement that all publicly funded research agencies participate in school engagement programmes is expanded to include government contracts, i.e. reward a culture of STEM through government procurement weighting.

Recommendation 11

To secure KZN’s STEM position internationally it is recommended that:

A strategic fund is established to support a dedicated cluster/zone for STEM engagement. AKZN EDTEA/MKI could take a lead role in driving a cooperative focus on valuing and developing STEM capability in the region.

STEM and International Engagement

One is rightly proud of the STEM researchers and business leaders that have placed on the global stage but one cannot afford to assume that one’s place on that stage is secure. Businesses and higher education providers are crucial STEM ambassadors. But, effective and informed engagement requires the leadership of the MKI, KZN EDTEA and KZN Government. As the custodian of one’s reputation and the architect of one’s global agenda, it can position KZN to excel.

One must recognize that the competition for skills is fierce—and will only continue to grow. One has to come to the table with something to offer - a strategic fund for STEM engagement. A forward
looking plan for a South Africa/SADC/Africa/global agenda would keep KZN at the centre of its rapid economic progress.

The report outlines the extent of the economic and job opportunities that are dependent on high quality STEM education, and also outlines that a step-change is needed in the provision of that education if one is to compete on an international level. It also sets out how, for social policy and community reasons, it is important to have scientifically literate citizens in a modern democracy.

One has identified some of these actions for initial priority implementation. These include:

- All STEM teaching should be delivered by qualified STEM teachers. Currently there are challenges in the sciences, including an imbalance between the number of teachers with biology, chemistry and physics qualifications, where one is are committing to address
- Introduce computer science, including coding, as a Leaving Certificate subject
- Deliver improvements in continuing professional developments for teaching in STEM, including a coherent Policy framework in the area, development of a comprehensive suite of STEM Continuing Professional development (CPD) programmes, up-skilling programmes in the sciences, and Technology-Enhanced Learning CPD Programmes for Primary and Post-primary teachers
- More inquiry-based learning as part of the curriculum in STEM subjects
- Develop a means of recognising participation in extra-curricular STEM events and activities (e.g. Coder Dojo, BTYSE etc.) as part of STEM curriculum and assessment
- Improvements in teaching methodologies in STEM subjects, including better curricular materials, including a central cloud-based repository for digital learning and STEM teaching resources
- Support online communities of learning and practice
- Better marketing of STEM qualifications, including highlighting career possibilities for students and parents. The report finds that there is a gap in awareness of the importance of these subjects
- Address gender imbalances in specific STEM disciplines
- Produce an integrated National STEM Education Strategy (STEM Education Policy Statement)
- Review minimum entry requirements into the B.ED. programme for Primary Teachers

Take the teaching of coding in primary schools; should coding as part of a review of the primary school. The incorporation of coding the STEM initiatives will ensure that every child/learner has an opportunity to develop the computational, and flexible and creative thinking skills that are the basis of computer science and coding.
CONCLUSION:
The priority actions are summarised below:

- **Public Understanding of STEM and the Fourth Industrial Revolution**

- **Out-of-school/After School Initiative**
  - Establishment of a provincial compact that encompasses a wide continuum of role-players, incorporating multi-pronged interventions in close proximity to the community
  - Development of Science Centres (or variations thereof) in every one of the 11 districts in the province with a variety of themes
  - Properly equip such facilities and ensure sustainability of same
  - Co-opt Corporate KZN, organized business, social-partners and the NGO sector

- **Education sector**:
  - Preparation of teachers (at primary and post-primary level) for STEM education:
    - Support all primary teachers (in Initial Teacher Education) in building their subject matter knowledge (SMK) and pedagogical content knowledge (PCK) in science, mathematics and technology as part of a broader professional portfolio of expertise and related activities.
    - All STEM teaching in post-primary schools should be delivered by qualified STEM teachers, and the imbalance in the proportions of teachers qualified in biology, physics and chemistry should be addressed as a matter of urgency.
    - The minimum entry requirements into the B.Ed. programme for primary teachers should be reviewed.
  - The best methods of supporting the current cohort of STEM Teachers within the system (with a particular focus on Continuing Professional Development):
    - Develop a coherent policy framework for CPD in STEM education, recognising that this may be part of a broader CPD framework for teachers.
    - Working with the SA Council of Educators (SACE), all stakeholders should ensure that a comprehensive suite of STEM CPD programmes is available to post-primary teachers as part of their professional learning requirements under the SACE Framework for Continuous Professional Learning.
    - Develop STEM up-skilling programmes in physics, chemistry and biology for science teachers (post-primary) so that they can upgrade their registration status to a level of being qualified to teach in these subjects. Such programmes could build on the successful DES blended education model developed for the out-of-field teachers of mathematics via local tertiary institutions
    - Maintain a strong CPD programme in mathematics, because mathematics is fundamental for all STEM education.
  - The introduction of new teaching and learning modalities that would enhance STEM education in the schools and for which there is a strong evidence base:
    - Put essential measures in place to support the implementation of inquiry-based learning within the Primary School Curriculum and at post-primary level as part of the revised curricula for STEM subjects. Innovative assessment that aligns with inquiry-based teaching and learning should be developed.
    - Develop a means of recognising participation in informal (extra-curricular) STEM events and activities (e.g. Science Fairs, BTYSTE, SciFest, CoderDojo, Intel MiniScientist) into the STEM curriculum and assessment at Primary and Post-primary levels.
    - Develop extensive curricular materials for teachers that operationalize learning outcomes in STEM subjects at primary and post-primary levels.
  - **The use of technology to enhance learning (especially digital and / or on-line approaches):**
• Support the creation of online communities of Learning and Practice together with rich multimedia educational content.
• Provide a central (cloud-based) repository for digital learning and teaching resources in STEM subjects, approved by the Department of Basic Education; SETA’s, etc. This should also include a collaborative space for teachers and learners.
• Promote and facilitate hardware-enabled approaches to technology learning, e.g. Tablets, Maker boards and kits; 3D Printers etc.

• **Career Guidance Interventions**
  • The promotion of STEM careers and the identification of methods to enhance the engagement of students in STEM subjects:
    • The career possibilities for students who follow a STEM career path should be highlighted not only to students but also to parents. Parents have a strong influence on students’ subject choices. Market STEM qualifications with an emphasis on future economic needs and as a pathway to important, challenging and well-paid careers.
    • Ambitious targets and a sustained, multi-faceted action plan for addressing the gender imbalance in specific STEM disciplines should be established and implemented as a matter of urgency. Particular emphasis should be placed on the marketing strategies and language used in this regard.
    • Avail of partnerships with STEM enterprises (e.g. within the national initiative) to promote STEM careers at all levels in education.

• **MKI STEM Fund Development**

• **Conclusions and general recommendations**
  • Produce an integrated STEM education Strategy (STEM Education Policy Statement) with input from, and relevance to, all stakeholders across the continuum of education (primary, secondary and tertiary level). This strategy should include a detailed implementation plan with responsibilities and timelines clearly outlined.
  • Introduce computer science (including coding) as a subject. This is critical to address the ICT skills deficit in SA
  • MKI to establish the STEM 2030 Partnership in consultation with the provincial Ministries of EDTEA, Finance, Agriculture & Rural Development as well as the national Ministries of Labour, Agriculture, Forestry & Fisheries (DAFF), Rural Development, Economic Planning, SMME’s, DTi and DST, etc., with the initial focus of the Partnership being the establishment of a common vision and approach for supporting STEM education among enterprise and the education sector.
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