SDG 4: INCLUSIVE, EQUITABLE, QUALITY, LIFELONG LEARNING FOR ALL

4 QUALITY EDUCATION

ORIGINAL: ICTs are powering a revolution in digital learning, which has become one of the world's fastest-growing industries. Mobile devices now allow students to access learning assets anytime, anywhere. Teachers are now using mobile devices for everything from literacy and numerical training to interactive tutoring. Indeed, mobile learning has the ability to help break down economic barriers, divides between rural and urban, as well as the gender divide.

A SOUTH AFRICAN-SPECIFIC PERSPECTIVE[1]:

Contents:

[1] First draft compiled by Walter Brown, Johannesburg 22nd May 2019. Comments and suggestions welcome, email to: walter@sakan.org.za

A SOUTH AFIRCAN-SPECIFIC PERSPECTIVE:

Today's Internet is the new book of knowledge, facilitating the creation and recreation of new and old knowledge; the borderless distribution and dissemination of this knowledge across all geographic, cultural, demographic, linguistic, nationalistic, and even intellectual boundaries instantly and on-demand. The Internet and all its interrelated components have limitless and still growing knowledge capacities in which whole libraries and other repositories of knowledge can be squeezed into tiny hand-held knowledge access devices providing access to such knowledge to anyone, anywhere, at any time; and from anyone, anywhere, at any time. Is this Internet-connected world therefore an educator's and learner's utopia? Not exactly:

- Economic and social stratification defeats the ubiquitous nature of the Internet, its knowledge content, and therefore its utility as a potent tool for education and learning.
- Malicious use of all information and knowledge resources and repositories is a well-known human imperfection; vital books of knowledge have been burnt or otherwise destroyed throughout history, often with their creators and/or current owners and users. Today's Internet is not immune, as observed by one of its creators, Sir Timothy John Berners-Lee, who recently commented as follows: "*I've always believed the web is for everyone. That's why I and others fight fiercely to protect it. The changes we've managed to bring have created a better and more connected world. But for all the good we've achieved, the web has evolved into an engine of inequity and division; swayed by powerful forces who use it for their own agendas.*"[2]
- The Internet, accessed via increasingly powerful easy to use devices, is itself a major distraction. Unlimited quantities of useful and useless information, fake and credible news, highly informative research-based knowledge negated by insidious pseudoscientific documents or "news" published on social media platforms, are known to distract learners and their educators alike.
- The knowledge of how to position ICTs within South Africa's education systems for direct measurable and visible success in the delivery of all goals and targets enshrined in SDG4, and the nation's National Development Plan, remains an urgent requirement. An extensive OECD study on this matter concluded as follows:

Students, Computers and Learning: MAKING THE CONNECTION[3] OECD Report 2015.

"*Students who use computers very frequently at school do a lot worse in most learning outcomes, even after accounting for social background and student demographics*." The report measured the impact of technology use at school on international test results, such as the OECD's PISA tests taken in dozens of countries around the world. The study found that education systems which have invested heavily in information and communications technology have seen "no noticeable improvement" in results for reading, mathematics or science. The OECD urged schools to work with teachers to turn technology into a more powerful tool in the classroom and to develop more sophisticated software for experimentation and simulation, social media and games.

"The real contributions ICT can make to teaching and learning have yet to be fully realised and exploited."

South Africa's most recent publicised plans to provide tablet commuters to each of the ±8 million learners must be applauded in principle, but this must be balanced carefully with the development of appropriate pedagogies, intensive educator training at all levels, and social support systems for the known unintended consequences of such a strategy. The focus of all these interventions must be the +60% of the nation's children that live in poverty. The only children in South Africa who have adequate access to ICT at home and at school are those in the wealthy segment of the population – those that live in the ±10% of broadband connected homes as shown in the first chart of Annex 1. The reliance on technology alone, a form of technological determinism, must be strongly resisted. Excellent pedagogies far outweigh the utility of technology on its own, but the combination of technology and excellent pedagogy is vital in this 4IR world.

The Internet is a central component and interlink between and within all technologies known today, especially the growing population of artificial intelligence equipped machines (AI). It remains a central component of, and potent tool for the whole range of education and learning that has steered human evolution and development to what it is today. South Africa's role in the early evolution of the human species, and therefore its use of education, learning and early technological innovations as evolutionary and human development growth drivers, is now a victim of inadequate access to, and ineffective use of the descendants of those early technologies. Economic and social stratification lies at the core of South Africa's triple threats of inequality, poverty and unemployment, while the underutilization, misuse and abuse of

[2] July 2018 interview with Vanity Fair: "I was devasted", Tim Berners-Lee on the abuse of his invention: https://www.vanityfair.com/news/2018/07/the-man-who-created-the-world-wide-web-has-some-regrets.

[3] OECD Report 2015: Students, Computers and Learning: MAKING THE CONNECTION: https://www.oecd-ilibrary.org/docserver/9789264239555-en.pdf?expires=1546858628&id=id&accname=guest&checksum=F4ED9D2450BBDF6742B8C36182CCEDEC

the Internet as a vital tool for education deprives the country of the potential of ICT to help overcome these threats. The nation's poor performance in international educational assessments provides an early warning of this potentially destabilizing malaise.

The Internet, its peripheral connectivity and user devices, and educational content offers immense opportunities to reverse the potentially devastating poverty-driven damage to children's cognitive development, as discussed in section 1.6 of the related document ICT4SDG1. However, even in this regard, extreme caution is mandatory: The Internet today, with its proliferation of social media "apps", can be as additive, and as harmful, as alcohol and drugs. A growing body of neurological science suggests that teenage youth are especially vulnerable to substance and information abuse, until the brain functions mature in their early 20s (see e.g. Neurologist Dr Frances Jensen "the digital invasion of the teenage brain"). The internet today can be likened to Frederick Herzberg's 1950s Motivator-Hygiene theory – access to the Internet cannot guarantee high educational achievement, but lack of such access can/will guarantee poor educational achievement in this knowledge-competitive age.

An ancient historical South African context: Recent Paleoanthropological discoveries position South Africa at the forefront of human cognitive development in early human evolution (read: *Symbolic Material Culture and the Evolution of the Mind during the African Middle Stone Age 77–59 ka*)[4]. Can this very ancient and vital contribution to human development through innovative discovery and knowledge sharing be recreated in modern South Africa by using ICTs? Can ICTs help to reverse the potentially devastating impact of poverty on the development of South Africa's children? The alarming reality of South Africa's education systems in the 21st Century suggests this possibility**:** A profound description of South Africa's school systems is presented in the 2014 documentary video "Some Children Are More Equal Than Others"[5]. The video was produced by Stefan Gottfried on behalf of the Legal Resources Centre, an independent, client-based, non-profit public interest law clinic, litigating the South African Government for the eradication through replacement of mud schools, many without functioning or hygienic toilets (children use the bush!). Key extracts from the video are:

Some Children Are More Equal Than Others

1. An elderly Zulu father: "*The children's future is dead. When a child is growing up, and there is no improvement in school, then it means the child is being destroyed…..*".
2. An Eastern Cape mother with young daughter on her lap and tears in her eyes: "*I don't think she will have a bright future, I don't know. But what I do know is that there is no education. My daughter's rights were violated – she is the only one (amongst her friends) who cannot be placed in a good school – I have tried so hard without success*".
3. Professor Nomalanga Mkhize, Nelson Mandela Bay University: "*South Africa created this deeply unequal education system over time. It was most expressed when the Nationalist Government put in place Bantu Education that inequality was ideologically, systematically, administratively, financially and geographically entrenched*." (Quotation by Henrik Verwoerd: "*What is the use of teaching a black child mathematics when it cannot use it in practice!*"). Professor Mkhize: "*Deracializing South Africa's school system did not solve the problem - Black schools are schools of poverty and impoverishment, both intellectually and financially. What should have happened is that we should have gone to the black schools first and turned them into beacons of hope*" (author's emphasis).
4. Dr Nicholas Spaull, Stellenbosch University: "*We basically have two South Africas within one, and this basically follows the apartheid type dimension. If (the) parents are in the top part of the labour market - they send their children to the well-functioning school system. If the parents are in the bottom part of the labour market, which makes up 80% of the population, they send their children to the "free" schools. These two cycles perpetuate each other. As a result, we have higher inequality (in 2014) than we had in 1984. Social mobility for most South Africans is a myth – your life-chances are determined by where you were born, the race of your parents and their income and educational status. Your life opportunities have nothing to do with your ability, your motivation, or your aptitude.*"
5. STATISTICS: Schools in the same town: 98.5% Matric passes, 80% throughput from grade 1 to bachelor passes in the better public schools; 50% pass rate and 11% throughput in the "Township" schools.

One critical feature of current knowledge about the relationship between ICT and education/learning is that we need far more research to counter the "unknowns" that outnumber the "knowns". But, the urgency for corrective action in South Africa cannot wait for these answers – action is needed immediately. This action will be discussed further as we address the underlying question in the following paragraphs:

[4] The Still Bay and Howieson's Poort, 77–59 ka: Christopher Stuart Henshilwood and Benoît Dubreuil: https://cognitivearchaeologyblog.files.wordpress.com/2015/11/still-bay-howiesons-poort.pdf

[5] "Some Children are More Equal Than Others": a documentary film by Stefan Gottfried produced for South Africa's Legal Resources Centre in 2014: https://www.youtube.com/watch?v=hiEUu-Is0Ao

Background:

The process of education and learning is nearly as complex, and as old, as humanity itself. The sharing of knowledge through formal and informal education, especially the transfer of knowledge to future generations of humans, has served humanity well throughout the evolution of the species. This knowledge sharing led to the invention of technological tools which evolved progressively to the most powerful information creation, processing and dissemination tools known to mankind – the ICTs. And yet, these powerful human tools have failed to service the needs of humanity as a whole. South Africa ranks amongst the most unequal nations on earth today, in nearly all aspects and measures of inequality. A discussion of how ICTs can be positioned to speed up the reduction of the nation's inequalities, adding to the current national programmes of action, follows.

1. Pedagogical Philosophies: The role of ICT:

It is vital that the full range of pedagogical philosophies are examined in the context of South Africa's deeply divided social environment and structures. A "one pedagogical philosophy fits all" scenario does not exist, and yet there seems to exist a national tendency towards such an assumption, with far too few exceptions. The annual media frenzy surrounding the publication of each year's Matric results, with accusations and counter accusations of impropriety, misleading interpretations of the results, and clear evidence of growing knowledge inequalities in the nation, leads to the perception of the existence of a "one pedagogical philosophy fits all" neo-Confucian national pedagogy. The nation seems to follow a neo-Confucian education tradition, in which the target of education and learning seems to be to pass standardized tests that define the success or failure of individual learners. And yet, a closer examination of the Confucian tradition shows that even this model has continuously evolved from a near-constructivist philosophy[6] during the time of Confucius, towards the current perceptions of the philosophy as one that favours "*rote-learning by students, the teacher as an authoritarian figure for transmitting knowledge to passive students to commit to memory without question or reflection, and a primary focus on standardized examinations requiring recall of accepted answers*."[7]

Most nations, particularly those of East Asia (e.g., China, Japan, Singapore and South Korea), which have followed the Confucian pedagogical tradition, and still excelled in most international assessments, are changing and modernizing their national pedagogical models. The new technologically-driven 4IR age demands such changes. Examples of how some of South Africa's developed and developing country peers are changing and modernizing their national educational systems are presented in following sections of this ICT4SDG4 discussion document.

The critical question for South Africa is: Which educational/learning philosophies, or combinations of philosophies, are best suited for South Africa's deep socioeconomic and therefore educational inequalities? The answer to this seemingly simple question is extremely complex, following the multidimensional complex relationships presented in the first document in this series, ICT4SDG. Attempting to address such vital philosophical complexities in a document such as this is clearly impractical and even inadvisable:

- The process of change is extremely complex, influenced strongly by the level of knowledge and experiences at the highest decision-making levels, and at all levels of the national educational hierarchies: (a) the policy makers who must shape long-term development trajectories in an environment where all change meets strong resistance; (b) the bureaucrats who must implement policy decisions in extremely volatile, often hostile environments; (c) the educators, whose levels of knowledge, experiences, capabilities and motivations are extremely variable; (d) most importantly, the learners who are defined by the nation's deep inequalities in capabilities, opportunities, localities, and socio-economic-cultural-linguistic backgrounds; and (e) the massive inequalities in educational infrastructures: schools; ablution facilities; access to basic infrastructure such as electricity, ICT connectivity, and even water; general support services.
- Inequalities in capability and opportunity are especially challenging. South Africa boasts numerous world class educational facilities, producing world class graduates, but, such welcome achievements also contribute towards much deeper national challenges: small pockets of excellence within an environment of massive mediocrity or worse, effectively fuel inequality further, imposing exceptional added difficulties to the process of change (see e.g. the Hechinger Report[8]). South Africa is not alone in facing this mammoth growth challenge. The country can draw

[6] Constructivist pedagogy in the context of South Africa: University of Pretoria 2008: https://repository.up.ac.za/bitstream/handle/2263/24836/04chapter5.pdf?sequence=5

[7] Reforms in pedagogy and the Confucian tradition: looking below the surface: Felix M. Ho 2017: https://link.springer.com/article/10.1007/s11422-016-9795-8

[8] The Hechinger Report of 2015: Schools exacerbate inequality: https://hechingerreport.org/schools-exacerbate-the-growing-achievement-gap-between-rich-and-poor-a-33-country-study-finds/

valuable lessons, which include the importance of continuous incremental progress in the face of adversity, from the experiences of the Nordic countries, most of which invested decades of systematic socioeconomic reforms to reach their current global dominance in socioeconomic equity[9]. Finland's globally acclaimed educational qualities, which took more than 40 years to achieve, are discussed in the paragraphs that follow.

- South Africa, even with the best intentions, cannot reverse its socioeconomically divided and fragmented nation and its educational systems in the short or medium terms. A long-term incremental change process may be the only way forward, given the exceptionally deep experience and knowledge inequalities that beset the nation as a whole, and the education sector in particular. The ICTs present a vital tool that can reduce the nation's educational reform timeframes, but even this vital sector is defined by deep inequalities, as clearly illustrated in the Access to Information and Knowledge chart of Annex 1. The dangers of such a long-term incremental approach in this world of instant access to information through ICTs, is that public impatience may build up, leading to short-term socio-political instability. A two-pronged approach is therefore strongly recommended:
  - A direct focus on the urgent provision of the most modern ICTs possible to all educational establishments, educators and learners. This must be tempered where necessary, by the equally urgent need to develop the user skills base and the supporting pedagogical tools and capacities. This will of necessity be a long-term process – the human factor will dominate the challenges far beyond the direct benefits of the technology.
  - An equally direct, and perhaps heightened focus and urgency, on the provision of ICT access and user skills to the +30 million South Africans who live below the national poverty lines, and their children who account for ±60% of the national child population. The public broadband access model introduced in section 6 of ICT4SDG1 – Alleviation of Poverty, provides an elegant, affordable and simple to implement platform for this purpose. The model also delivers a source of income for community-based SMMEs, and an affordable broadband access platform for use by the communities, and especially their children. Even very young children can benefit from Early Childhood Development (ECD) and technological appropriation in preparation for livelihoods in the 4IR era. There is a wealth of software tools available in the public domain to support an ECD initiative for South Africa's poor, the only challenge remaining is to create an environment for their application.
- Detailed discussions of the full range of ICT4SDG4 in the above context is clearly beyond the scope of this briefing document; the focus of the strategy must be on practical implementation, creating large-scale "living laboratories" that enable experts in education and learning to develop the specific ICT-supported pedagogical strategies that are necessary. The "good news" is that the philosophical discourse is taking place in South Africa today, as shown in the text box below. The question that remains is: "how can South Africa broaden the scope and scale of such inquiry to benefit all of South Africa's children, especially those in economically marginalized communities?"

1.1. One Example of the pedagogical philosophies under consideration and in progress:

Inquiry-based learning: A Constructivist form of learning vital for this technological information-driven 4IR age[10]:

University of Pretoria - Faculty of Natural & Agricultural Sciences:

"*Inquiry-based learning from undergraduate level links to UP's status as a research-intensive university. Students should expect to be exposed to research by others from their first year but also to be inducted into research techniques within their fields of study. The University strives to graduate independent learners who know what questions to ask and the methods needed to explore those questions. UP graduates possess intellectual curiosity and an inquiry-led approach to knowledge. They rigorously apply knowledge and research methodologies, from a variety of paradigms, appropriate to their fields of study and professions, to create innovative solutions to challenges and communicate their knowledge effectively.*"

- How can this pedagogical method be extended to Early Childhood Education (ECD) in the economically marginalised "informal" urban and rural settlements of South Africa where 55% of the poorest population survive?
- How can such ECD begin to erode the potentially devastating national challenges enshrined in all the SDGs, especially those related to inequality, poverty and unemployment?
- How can the method begin to prepare children exposed to poverty-induced cognitive capacity deterioration for the emerging technologically-dependent 4IR world?
- How can the conversation be broadened in scale, scope and reach so that the outcomes hasten the achievement of all SDG4 objectives and targets?

[9] 2011 Swedish Example: The rise, fall and revival of a capitalist welfare state: what are the policy lessons from Sweden? http://www.ifn.se/wfiles/wp/wp873.pdf. AND: Finland's 40-year history of educational development: https://www.oecd.org/pisa/pisaproducts/46581035.pdf

[10] Inquiry-based learning: An approach to educating and inspiring kids: http://youthlearn.org/wp-content/uploads/Inquiry_Based_Learning.pdf AND: University of Pretoria, Faculty of Natural & Agricultural Sciences: https://www.up.ac.za/faculty-of-natural-agricultural-sciences/article/2701501/inquiry-based-learning

2. **Examples of educational policy and systems changes:** Lessons from South Africa's peers:

2.1. **China**[11]: In the 2015 PISA international assessments, China ranked 10th out of 70 participating countries (PISA is a global educational assessment favoured by the OECD, which is similar to PIRLS in which South Africa participates). In the 2016 PIRLS assessment, China, represented by Hong Kong (rank 3rd after Russia and Singapore) and Chinese Taipei (ranked 9th), South Africa's rank of 50th out of 50 participating countries suggests that South Africa can learn much from its BRICS partner China. But China's education system itself is changing rapidly:

2.1.1. In 2014, the Government of China announced major education policy changes, from the Neo-Confucianist model based on memorization of facts, standardized testing and a rigid exam regimen, towards a more flexible pedagogy that emphasizes cognitive flexibility, critical thinking and creativity;

2.1.2. The stated intent for the policy shift is to alleviate poverty and the growing inequality between rural and urban areas, and to equip learners with the skill sets needed by the modern technologically-driven 4IR world;

2.1.3. To do this, China has embarked on large-scale development of universities of applied science and vocational training institutions and colleges (TVETS), all for a better fit with the evolving 4IR industry and environment;

2.1.4. Recognising the complexity of these changes, China is reinforcing and drawing valuable lessons from its well-established pedagogically advance international partners such as Finland and the Netherlands;

2.1.5. Can South Africa begin a similar process of change by drawing on its close partnerships with China through the BRICS community, and other well-established partners like Finland through cooperative agreements like COFISA? The cooperative process has already started, e.g. through Finnpartnership but needs to be intensified through a focus on the base of the nation's development pyramid. The ICT4SDG4 proposals, which focus strictly on creating a fertile environment for learning for the +60% economically marginalized South African children beyond the national school systems, can benefit greatly from the experiences of the nation's more progressive partners, while at the same time contributing to the refinement and reinforcement of the national educational development agenda.

2.2. The case of Finland: How can South Africa's ICT4SDG4 strategy learn from Finland's experience?

2.2.1. Finland's mastery of the educational process is well-known and very well documented. The critical question is: Can South Africa's ICT4SDG4 strategy and its focus on economically marginalized children emulate some, if not all, of the Finnish experience and success? A short review of some features of Finland's educational systems follows:

2.2.2. Finland's transition from a relatively resource-poor agrarian economy prior to the first and second world wars, to global leadership in most human wellbeing measures, owes its success to an excellent national education system. This educational transition was far from easy, taking nearly half a century to achieve the high standards so admired today by the world at large. The key attributes of Finland's education system are:

2.2.3. An emphasis on absolute equality: All schools are of equal quality, all children learn together irrespective of their economic, social or ethnic background. Finland takes pride in full integration of immigrant children.

2.2.4. An emphasis on play with learning. A stress-free learning and teaching environment for learners and educators alike is a priority; No homework, very short comparative classroom attendance; Informal seating arrangements, no insistence on desks; cushions, beanbags, mats as preferred by the children.

2.2.5. No standardized tests or examinations until upper secondary school (Matric equivalent); Excellent educator training, rewards and social status.

2.2.6. Minimal use of technology in junior schools: Finland has a very high ICT penetration and usage level, but one of the lowest use of computers in classrooms in the EU. Electronic devices are encouraged, both in the classroom and at home, but educational outcomes depend much more on exceptional quality pedagogy in stress-free learning environments.

2.2.7. Finnish children excel in all international tests, without preparation.

2.2.8. Can South Africa emulate some of these values for children from economically deprived communities? Is it possible for community members themselves to provide such pro-poor education as a way of generating income while providing vital social services? Can these interventions be introduced as informal extracurricular activities outside the formal school system, thus avoiding conflict/competition with the formal structures? Can such a strategy be made a critical part of the ICT4SDG4 strategic focus on the +60% of the nation's children living in poverty?

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[11] OECD 2016: Education in China: https://www.oecd.org/china/Education-in-China-a-snapshot.pdf AND: University partnerships are vital to China's ambitions, Yojana Sharma 04 March 2016: https://www.universityworldnews.com/post.php?story=20160303231850597

2.2.9. The above summary of Finland's experience suggests that all the above is possible, but it needs political will, national commitment and support, and for the formal national school system, the lengthy timeframes demonstrated by Finland's 40-year experience.

2.3. Australia, Finland and Singapore: What can we learn from this comparison?

2.3.1. **PIRLS 2016 rankings**: Singapore, 2 of 50; Finland, 5 of 50; Australia, 21 of 50; South Africa, 50 of 50.

2.3.2. **Computer usage in class (2012):** Australia, 1 learner per PC; Singapore, 2 learners per PC; Finland, 3 learners per PC. Classroom Internet usage per learner: Australia, 58 minutes per day; Singapore, 20 minutes per day; Finland, 18 minutes per day.

The PIRLS rankings and the data on ICT usage in schools indicates that the link between ICT usage and educational outcomes is tenuous at best, as suggested in the OECD study from which the data was drawn. There is clearly much more value in the use of ICTs in education than the mere passing of tests and examinations. Such value must be identified and leveraged fully through innovative design of ICT4SDG4. Numerous documented researches have shown that ICT usage for play and learning from a very early age helps the development of critical thinking in early childhood. This must be the primary focus of South Africa's ICT4SDG4 strategy, in addition to using ICTs as the most effective means of information and knowledge dissemination. In the classroom, the critical balance between ICT usage and pedagogy must be established by educators and their institutional oversight agencies, and applied progressively in the interests of South Africa's development and survival in this challenging 4IR world.

2.3.3. **Education models:** (1) Australia**:** A common perception is that the national emphasis is on passing exams; a major objective is to be high achievers in international tests like PISA and PIRLS. Intensive competition between learners and between schools, with rewards for high achievers, is one symptom of this objective. Results: severely stressed children and comparatively low international competitiveness.

Australia has embarked on a major review of the national educational policies and systems, with special attention on the STEM subjects, Science, Technology, Engineering and Mathematics. The major concerns of current Australian policy makers include growing inequality levels amongst the nation's learners, international competitiveness, and the growing skills gap between the needs of industry and the skills provided by the current educational systems. Australia is examining the Finnish system, and consulting with experts from Finland. The strategy is available in the Final Report of April 2018.

(2) Singapore**:** A Neo-Confucianist model with high emphasis on exams and tests; intense competition between learners and between schools; significant rewards for high achievers, little or none for average and low achievers. Results: excellent international tests achievements, high levels of learner stress, minimised to some degree by good social safety nets for failures. Singapore has already embarked on fundamental changes of the national educational policies and systems, to take effect in 2019. Many of the changes align closely with the Finnish model. An excellent summary of Singapore's educational reforms is available in "6 Changes To Singapore's Education System".

(3) Finland: An emphasis on stress-free learning with play; exceptional educator skills; very little reliance on tests or exams; continuous progress assessments and monitoring of all learners; high levels of educator autonomy, expectations, and accountability; absolute equality in education – a "no child left behind" philosophy. Results: excellent internationally competitive knowledge acquisition, global recognition of excellence.

2.4. **Section conclusions:** The above brief summary helps to illustrate the complexity of the educational process in this modern very demanding technologically-driven era. There are no easy fixes; the failure of one model in a given country can be the success of another. The single common factor is that all countries discussed are changing/modernising their national educational processes for a better fit with the emerging 4IR skills demands.

Given the extreme national educational and social challenges faced by modern South Africa as reflected in Annex 1, and in the related documents ICT4SDG1, ICT4SDG2, and ICT4SDG3, reform of the national educational process is urgent, but it will be extremely difficult and time consuming. Decades may be required before the deep educational and socioeconomic inequalities can be ameliorated through education for visible, measurable results. The use of technology in education is vital, but this must be applied with great wisdom before results become visible and equitable. The process is underway, but must be intensified. ICT4SDG4 must be prioritized as an important tool of the process, focusing on two aspects of the nation's educational systems development; reform of the national educational systems themselves in the long term, and short-term extracurricular interventions of ICT4SDG4 that focus primarily on children and youth in the economically marginalized segments of the population.

3. Critical issues for an ICT4SDG4 strategy: Skill sets for the 4IR:

3.1. The most recent high-level Government statements on the purpose of national education relate to preparing the nation for the Fourth Industrial Revolution: "*President Cyril Ramaphosa is set to announce a major overhaul of the country's education system as government tries to prepare the future workforce for the fourth industrial revolution (4IR): City Press report 6th January 2019*" (details in the text box that follows).

3.2. Given the national focus on the 4IR, the following top 10 skill sets have been identified as the most critical across all industries (sources: WEF16 *The Future of Jobs*; Forbes 2018; Others). These skill sets are summarized below:

3.2.1. **Complex Problem Solving**: The ability to identify and acknowledge complex poorly defined problems that result directly from the 4IR socioeconomic and technological changes, and the ability to seek and implement solutions to ameliorate the negative impacts of these problems on society.

3.2.2. **Critical Thinking**: The ability to deconstruct complex problems, and to use logical, rational and objective analyses to develop effective responses to them. This will entail questioning of all underlying assumptions, hypotheses, theories and accepted knowledge about them where necessary, as a way of finding real-life solutions that are consistent with the 4IR.

3.2.3. **Creativity:** The ability to develop new and/or disruptive and innovative ways of solving complex problems.

3.2.4. **People Management:** The ability to manage people in the complex 4IR world, going far beyond the confines of current practices and understanding of Human Resources Management (HRM). As the 4IR drives irreversible changes in the world of work, traditional HRM principles and practices must change: use of labour and its interaction with the 4IR; new digitally savvy people management skills, **ALL** leaders must be able to understand the intricate relationship between humans and machines, and able to guide a large segment of workers into a new undefined and uncertain work environment.

3.2.5. **Coordinating with Others:** The ability to coordinate the activities and/or responses to real-life situations. Coordinating the activities (and thinking) of a vast range of "others" with vastly different belief systems, experiences and knowledge. This vital capability is extremely difficult in the complexity of massive life-style changes resulting from the 4IR. The era of "big data", with its vast potential for both constructive and destructive impact on human behaviour and development, imposes severe difficulties for coordination between, within and external to traditional institutions, communities, cultural and demographic groups. All key priority skills listed in this summary of the 4IR skills requirements must be applied to develop this coordinating capability and capacity.

3.2.6. **Emotional Intelligence:** This difficult to define quality with its conflicting definitions by psychologists and related human behavioural scientists, is defined in the "WEF *The Future of Jobs*," document as: "Being aware of others' reactions and understanding why they react as they do". Irrespective of whether or not it is a form of intelligence or a skill, it remains a vital quality in these times of great change. Understanding one's own emotions, and those of "others" in the complex 4IR interpersonal relationships, could define the fine line between individual success and failure.

3.2.7. **Judgement and Decision Making:** This traditional management skill continues and evolves into the complexity of the 4IR; the "*Future of Jobs*" document defines it as: "Considering the relative costs and benefits of potential actions to choose the most appropriate one." The complexity in this age-old management skill lies in the massive changes of the nature of work and labour force needs of the 4IR; creative application of this skill is needed if chaos is to be avoided as the world of work changes.

3.2.8. **Service Orientation:** This traditional management skill will also need to be revised and updated to accommodate the complexity of the evolving 4IR and beyond. With mass automation of traditional forms of work, new accountabilities for, and definitions of service delivery will be needed. With robots and other AI machines replacing some human labour, and an explosion of big data dependency which too few people fully understand, how must the principles of responsibility and accountability for service delivery change? Preparing future generations of managers, leaders and employees for the new work (or lack of work) requires a completely new set of "people-focused services" skill sets. Failure to plan for an effective transition of work into the new 4IR era with much reduced traditional forms of work can have devastating results on societal stability.

3.2.9. **Negotiation:** The vital art of negotiation will need to change to accommodate a vast variety of interpersonal, inter-institutional, and human/machine interfaces and relationships. Mediation between people and the new environments created by mass automation will become an essential skill or capability, vital for the transition from the current world of work to the new dispensation in which work traditionally undertaken by humans becomes automated and mechanized.

3.2.10. **Cognitive Flexibility:** This vital quality (or skill) is an application of all the preceding 4IR skills, the capacity to think through the whole range of interrelated multidimensional human challenges enshrined in all 17 SDGs, and the complicating intervention of 4IR machines into the mix. Cognitive flexibility begins in early childhood, nurtured during the development of critical thinking capabilities, a personal quality that will have direct lifelong influences on individual capabilities, and their relationships with the changing environments. This feature of this "skill set" therefore positions it at the highest level of the ICT4SDG4 change process. How can this critical skill be developed (or taught) in early childhood, especially for those children living in poverty, who are already victims of cognitive impairment due to their poverty status[12]? How can this vital skill be maintained and expanded throughout the learning processes? These questions are perhaps the most important in national preparations for 4IR readiness.

3.3. South Africa's Response:

3.3.1. **Media statement of a major overhaul of South Africa's education system, 6th January 2019**.

> Preparing the country's future workforce for the fourth industrial revolution[13], 6 January 2019:
>
> *"The South African President's state of the nation address in the National Assembly next month is expected to announce:*
> - *A universal roll-out of tablets for all pupils in the country's 23 700 primary and secondary schools;*
> - *Computer coding and robotics classes for foundation-phase pupils from grades 1 to 3;*
> - *The digitisation of the entire curriculum, including textbooks, workbooks and all teacher support material.*
>
> *Other plans on the cards include the conversion of a significant number of schools to technical high schools and the introduction of a compulsory two years of pre-primary school for all South African children."*
>
> Comments and criticisms:
>
> - High costs: There were approximately 8 million children in South Africa's schools in 2016. At approximately ZAR1000 bulk order prices per tablet, a budget of ZAR8 billion would be needed. The pronounced intention to manufacture tablets locally will be costly with a range of unexpected results: a small local market competing with the massive economies of scale enjoyed by manufacturers in China and other East Asian giants; the intended import substitution may be defeated by an unstoppable black market for very cheap products. Software protection of all mobile devices has been shown to be easily "hackable".
> - With many local schools still without electricity and toilets, and even ICT connectivity, can such expenditure, necessary as it may be, be deemed a priority over such basic needs?
> - Crime is one of the biggest problems hampering the use of technology in poorer communities, with criminals targeting learners and schools to steal any valuable equipment: "*In 2017, news emerged that tablets allocated to high schools in Gauteng have been smuggled out of the country and sent to Pakistan and India.*"
> - In explaining the alarming theft and illegal export of tablets allocated to learners, the Gauteng Education MEC Panyaza Lesufi said that "social issues" were to blame for the lost and stolen tablets, forcing government to suspend the initiative.
> - The MEC proceeded to explain his observation of "*tablets being used improperly*": (a) learners carried their devices to football games on the weekend; (b) used state-sponsored mobile data to download movies and TV shows, and even pornography; (c) the MEC attributed Gauteng's improved matric results to the tablet project.

Comment on the last bullet point: Is education and learning limited to passing Matric or other examinations? Or is it a broader process of knowledge acquisition that includes knowledge of "social issues", how to deal with them without breaching decency and prevailing safety and security laws, and ultimately, how to develop the knowledge and skills needed to build a high growth stable society for all?

General comments on online education/learning: The provision of tablet computers to all learners, especially those from impoverished families and communities, must be welcomed in principle, but their use in the classroom as teaching/learning tools must be balanced by educator and pedagogical development. Evidence from virtually all countries, ranging from China, Europe and the United States of America, suggests that high utilization of connected computers in the classroom does/can lead to poorer results than direct tuition by highly trained competent educators, with or without the assistance of online tools. In addition, broadband access at home is a vital component of ICT4SDG4.

3.4. A summary of selected research results on the effectiveness of online tuition:

3.4.1. The OECD 2015 study referenced on page 2 of this document concludes as follows:

"Building deep, conceptual understanding and higher-order thinking requires intensive teacher-student interactions, and technology sometimes distracts from this valuable human engagement. Another interpretation

[12] Effects of poverty and health on children's cognitive development: Margot Jackson, Associate Professor of Sociology at Brown University, 2017: https://www.irp.wisc.edu/publications/focus/pdfs/foc332f2.pdf

[13] Major hi-tech overhaul planned for South Africa's education system: https://mybroadband.co.za/news/government/290820-major-hi-tech-overhaul-planned-for-south-africas-education-system.html?source=newsletter

is that we have not yet become good enough at the kind of pedagogies that make the most of technology; that adding 21st-century technologies to 20th-century teaching practices will just dilute the effectiveness of teaching. If students use smartphones to copy and paste prefabricated answers to questions, it is unlikely to help them to become smarter. If we want students to become smarter than a smartphone, we need to think harder about the pedagogies we are using to teach them. Technology can amplify great teaching but great technology cannot replace poor teaching."

This study was based on the 2012 PISA international assessments. Irrespective of the many criticisms of both the PISA and the PIRLS standardized testing process, they remain the most popular tools for national and international benchmarking of the quality of education. Accepting this, it is useful to summarise the results of the OECD study, comparing average daily time spent online in the classroom against the PISA rankings. The table below provides the PISA rankings against the lowest and highest users of connected computers in the classroom.

Low ICT classroom users: Daily usage (2012)			**High ICT classroom users: Daily usage (2012)**		
Country	**Minutes/day**	**Pisa Rank**	**Country**	**Minutes/day**	**Pisa Rank**
S. Korea	9	5	Australia	58	19
Shanghai China	10	1	Denmark	46	22
Hong Kong China	11	3	Greece	42	42
Poland	13	14	Sweden	39	38
Macao-China	14	6	Spain	34	33

Irrespective of the efficacy of this comparison on the effectiveness of online education in the classroom, it provides an excellent starting point for further evaluation and development of appropriate 4IR-ready pedagogies, and educator training for greater effectiveness of ICT in education.

3.4.2. The McKinsey 2017 report: Drivers of Student Performance: Insights from Europe:

The key findings of this study were:

- Giving school students access to iPads, laptops or e-books in the classroom appears to hurt their learning, however, putting this technology in the hands of a teacher is associated with more positive results.
- *"While technology can support student learning outside of school, the report found its record inside school is mixed. In some countries, adding one teacher computer per classroom had more than 10 times the impact of providing computers to each learner for use in the classroom."*

This research supports most other complimentary researches, which conclude that technology can/must be beneficial for the educational/learning process, but the associated and enabling pedagogical processes have yet to be developed. Until the pedagogical software (and perhaps hardware) tools to improve the outcomes of in-class online learning are developed, high performance educational processes will continue to depend on competent educator interventions, with technology providing valuable but external or peripheral support.

3.4.3. London School of Economics and Political Science, 2015: Technology, Distraction & Student Performance:

The key findings of this study of selected English schools concludes as follows:

- The study measured a student performance improvement of 6.41% of a standard deviation in schools that had banned smartphone use in the classroom;
- Low achieving learners, generally from poorer communities, achieved a performance improvement of 14.23% of a standard deviation after the mobile phone ban;
- Low-achieving students were more likely to be distracted by the presence and use of smartphones in the classroom.

3.4.4. UNESCO 2012: ICT in Primary Education: an analytical survey:

The stated goals of this study of ICT usage in nine schools in Africa, Western and Eastern Europe, Central America, the Middle East, and South East Asia, was to "*analyse different approaches, priorities, obstacles and strategies, and articulating recommendations for integrating ICT into the everyday work and play of primary children and their teachers*." The value of the study was its global coverage, virtually all regions were represented. One perceived weakness was its clear attempt to highlight the positive aspects of ICT usage in primary schools, and its selection of relatively well-resourced schools. For example, the school selected for the study in South Africa was St Andrew's Anglican School for Boys located in Bloemfontein. This private school is not a typical "township" school catering for poor children; annual tuition fees for 2018 were R22 880.00 per annum for pre-primary, rising to R34

760.00 per annum for grades 8 to 12. Irrespective of these criticisms, the report provides valuable insights into the possibilities of ICT usage in primary schools. The ICT4SDG4 initiative can/will use these insights for the development of strategies suitable for the poorest schools in South Africa.

3.4.5. UNICEF 2017[14]: Children in a Digital World.

This excellent report, focussing as it does on children, provides a balanced view of the opportunities, and risks, of the unfolding digital world. A summary of the contents of this 215-page report is best presented by the following extracts from the table of contents:

- Chapter 1: DIGITAL OPPORTUNITY – The promise of connectivity. "*Technology needs to be supported by strong teachers, motivated learners and sound pedagogy.*" This chapter provides valuable anecdotal evidence and stories told by children about their experiences and encounters with ICTs. The chapter introduces the immense learning opportunities provided by ICTs, balanced with vital cautionary advice of some of the risks of online lives, and the reality of digital exclusion*: "These opportunities (for learning) must be considered alongside the reality that they are not available to millions of children.*"
- Chapter 2: DIGITAL DIVIDES – Missed opportunities: This chapter aligns well with the strategic focus of this ICT4SDG4 initiative as it applies to South Africa; a focus on the ±60% of the nation's children living below the national poverty lines. Key observations like "*Disparities in access are particularly striking in low-income countries: Fewer than 5 per cent of children under 15 use the internet in Bangladesh and Zimbabwe*", and "*The risk that connectivity can become a driver of inequity, not an equalizer of opportunity, is both real and immediate*", are both pertinent to South Africa. The country may not be a "low income country", but if more than 50% of the population survive below the national poverty lines, which equate to the international poverty lines as explained in section 1 of the related document ICT4SDG1, then the observation applies equally to South Africa.
- Chapter 3: DIGITAL DANGERS – The harms of life online: This chapter correctly focusses on the criminal abuse of children made possible by today's digital world: *"It has never been easier for bullies, sex offenders, traffickers and those who harm children to contact potential victims around the world, share images of their abuse and encourage each other to commit further crimes. Digital connectivity has made children more accessible through unprotected social media profiles and online game forums. It also allows offenders to be anonymous – reducing their risk of identification and prosecution – expand their networks, increase profits and pursue many victims at once."* There are of course more dangers lurking in cyberspace, ready to harm the lives of children and adults alike: the dangers of fake news and malevolent botnets that drive antisocial behaviour; the impact on children's cognitive development as discussed briefly on page 3 of the introduction of this document; the dangers of online abundance – Internet Addiction; and in South Africa, the dangers of smartphone ownership, children become targets of violent robberies targeting their online access devices.

An extreme example of criminal abuse of children by children in the online world:

Why smartphones are skewing young Indians' ideas of sex: BBC Report by Divya Arya, 28 December 2018

"*A troubling trend of rape videos going viral in India has led many to believe that smartphones and easy access to violent porn, coupled with a lack of sex education, could fuel sexual violence.*"

The ease of content creation, distribution and dissemination has led to the disturbing trend discussed in this article – filming the rape of women and girls by misguided adults and youth, and posting them on various online social media platforms as "entertainment".

While making, distributing and disseminating pornographic material is illegal in India, enforcing the laws is difficult. Furthermore, freedom of speech and access to information considerations, entrenched in India's constitution, impose limits on what the Indian Government can do about explicit sexual content in publicly accessible media.

The prevailing opinion is that education is both the answer and solution: children and youth must be educated in sexuality and sexual relationships to become part of the solution, not perpetrators and victims of the problem.

Parallels with South Africa: Violence against women and children is a major concern in South Africa as it is in India (see Government Agenda here). Policy and legislation have been revised or updated to combat the scourge, but enforcement remains a major challenge.

Can the ICTs be used as an educational tool to combat the very same scourge that they may have helped to create? The possibilities are endless, and must be built into the ICT4SDG1, ICT4SDG4, ICT4SDG5, ICT4SDG10, and ICT4SDG16 strategies, all of which are interrelated in many ways. Numerous human behavioural scientists have demonstrated that poverty and ignorance are part of the root causes of this malaise.

[14] UNICEF 2017: Children in a Digital World: https://www.unicef.org/publications/files/SOWC_2017_ENG_WEB.pdf

- Chapter 4: DIGITAL CHILDHOODS – Living online: "*Unlimited – and especially unsupervised – connectivity has the potential to cause harm, just as access to the wealth of information, entertainment and social opportunity has the potential to benefit children around the world. So, the task is to find ways to provide children with the support and guidance they need to make the most of their online experiences.*" This chapter discusses the non-criminal dangers of Internet connectivity – how much screen time is too much screen time? These factors are particularly pertinent for children living in poverty. After experiencing the power and enjoyment of the online world, either at school, through more economically endowed friends, or through the very limited access that they can afford, what impact can this overabundance and/or exclusion have on children's mental wellbeing?
- Chapter 5: DIGITAL PRIORITIES – Harness the good, limit the harm: "*The most disadvantaged and marginalized (children) are least likely to reap the benefits of the Internet and connectivity, and most likely to experience harm from the negative aspects of technology*." This is the central theme of the proposed ICT4SDG4 South African strategy. How can South Africa balance the lack of connectivity for vast populations of children and their parents/guardians living in poverty, with the abundance of user devices issued to all school-going children in the country as per the latest government pronouncements? South Africa needs to bridge the massive affordability, user skills and connectivity divides that plague the nation's participation in the Information Society.

3.5. Other critical factors in ICT4SDG4:

3.5.1. **Laptops/desktops versus smartphones and tablets:** Laptops and desktops continue to trump smartphones and tablets as learning and productivity tools:

- Smartphone and tablet technologies have improved exponentially – they are as powerful as mini-computers and most laptops, but their screen size, lack of keypads and mouse, renders them less effective for creative writing, reading graphics-rich documents longer than emails or short messages, graphics and presentation design and development, working with spreadsheets, and creating rich entertainment and learning content such as movies and sports programmes demanding the higher resolutions of larger screen sizes.
- Children and youth will prefer the smaller, lighter and more portable handheld devices, but eye strain and the potential for addictive use due to their convenience and portability, is a growing concern. Desktops in particular are becoming devices of choice for very young children – the big screens provide greater pleasure and less eye strain, and the lack of portability discourages extended use thus allowing more time for physical activities and socializing that is vital for children's development.
- For advanced power usage, including high level gaming, laptops and desktop PCs remain the devices of choice.
- As the massive demand/supply for smartphones approaches the current growth plateau, research into extending the lifespan of the smartphone market by using them as desktop and/or laptop progresses. The race is on for the historical concept of docking stations that enable extensions on smartphones to enable connections to larger screen sizes, keyboards, mouse ports, and flash memory ports. Examples from current market leaders in both smartphones and PC vendors include Samsung's Dex, the Huawei Mate 10 with monitor cable port and wireless connectivity for keyboard, mouse and memory extensions. And Microsoft enters the fray with its Continuum – "*it looks like a phone, does like a PC.*"
- How can South Africa's ICT4SDG4 strategies accommodate these important device attributes without investing heavily in less than optimum or obsolescent user devices for children?

3.5.2. ICT Connectivity Challenges:

Information access devices of any cost, quality or sophistication are of limited value if they are not connected to the Internet, and through the Internet, to global sources of data, information and knowledge. South Africa has the most extensive, and perhaps the most advanced, ICT infrastructure on the African continent, but access to this infrastructure is not shared equitably amongst the citizens of the country. Affordability of ICT for personal and community development imposes a major barrier to connectivity for more than 55% of the nation's population. This barrier remains insurmountable under the current free market and individual connectivity national ICT development and investment models, irrespective of any policy or regulatory intervention based on this model. New highly creative, sustainable and highly scalable solutions are needed to bridge this "affordability divide".

The first two charts introducing Annex 1 illustrate the depth of this national challenge. Affordable broadband access at home is as vital for individual learner competitiveness and success as is broadband access at school. But such affordability cannot occur under the standard national economic growth model given the scenario presented by the second chart. Income inequalities and the prevailing free market ICT price structures combine to sustain or even expand this affordability and access gap. The 55% population living below the national poverty lines must spend up to 100% of their disposable incomes for unlimited fixed (wired) broadband access, and up to 20% for 1GB per month mobile broadband.

The latter limit of 1GB per month begs the question: how much broadband is enough for all learners in this changing 4IR world? Discussion of this limit usually ends up with survey derived data of current usage patterns, a conclusion that can be likened to the "chicken and egg" dilemma. Bandwidth demand and usage is shaped by the quality and cost of broadband service, and by the availability of desirable/useful content, not by its inherent qualities or capabilities. The former is a function of a function of Neilson's Law (broadband grows at 50% per year), fuelled by the Internet of Things and 4IR bandwidth needs, while the latter (content) is in effect a moving target driven by human creativity that extends beyond technology in this 4IR era, and by the capability of disseminating and sharing it. If children in wealthy communities have access to rich content high resolution video-based learning materials through their home broadband access, does this give them an (unfair) advantage over their poorer peers? Will such access inequalities add to the already high levels of socioeconomic and opportunity inequalities? The social costs of inequality within and between nations have been known and demonstrated throughout recorded history – they can be devastating to a nation's or region's socio-political stability.

South Africa has made numerous attempts over recent years to bridge the nation's vast information and knowledge access divide, with minimal success. Some of these attempts are summarized in section 3 on page 6 of ICT4SDG1. Bridging the national information and knowledge divides via ICTs remains an urgent priority for South Africa. The various policy, regulatory, and institutional efforts undertaken by the South African Government have tended to focus on the macro economic development layer, based on the assumption that success at this layer will "trickle down" to the excluded masses. The history of South Africa suggests that this will not happen, and has/will fuel further the growth of socioeconomic inequality.

Other key reference documents include:

3.5.2.1. **Will a new push for free wireless internet help rural students get online?**[15] Pending FCC rule change could help close the 'homework gap': 12th November 2018. This article discusses current consultations by the FCC (USA's ICT Regulator) for the licensing of portions of the 2.5 GHz spectrum band for Educational Broadband Service (EBS). South Africa's inequality and educational challenges are far greater than those in the USA. Can South Africa begin the same consultations and reserve valuable spectrum capacity for national educational use? This is possible, and can be accommodated and funded in current ICT policy formulation processes. Spectrum capacities exist in several spectrum bands of interest, e.g. the 700 MHz "Digital Dividend" band with its potential single-hop line-of-sight range of 200Km, and in the 2.5 GHz band with reduced but still useful potential range of 100Km. The USA article includes the statement: "*According to an April 2018 Department of Education report, 18 percent of 5- to 17-year old students in "remote rural" districts have no broadband access at home*". **The chart in Annex 1 suggests that the equivalent statistic for South Africa is about 90%**.

3.5.2.2. **Finland Rural Connectivity for Education:** In 2010, Finland became the first country in the world to declare broadband a "Legal Right". To deliver on this promise, especially to sustain the nation's already high educational outcomes, Finland used all available technologies to deliver broadband services to even the most remote rural communities: (a) 99.9% national LTE coverage using the 450 MHz spectrum (this spectrum band is available for use in South Africa if the policy and regulatory decisions can be made); (b) Finland set 100 MB/s universal connectivity by 2015 as a national target. This was achieved, with the help of an extension of the 700 MHz "Digital Dividend" band to cover 90% of the country, ensuring that all children have access to at least 100 MB/s broadband access at home.

South Africa has been discussing spectrum utilization for more than a decade now, but has yet to free and allocate the vital Digital Dividend spectrum bands that include 450 MHz, 700 MHz, and 800 MHz for national and child development. Can this refocus of ICT4SDG4 on the poorest children and youth assist South Africa in making the simple decisions that have helped Finland to become a dominant force in global socioeconomic equality and educational achievement? The warm political and economic relationships that exist between South Africa and Finland suggest that this can be done.

3.5.3. ICT tackling South Africa's reading crisis and cognitive catastrophe:

South Africa has recognized the immense value of ICTs as tools for education and learning, but to date, the results of massive investments in the supply of tablets and other technologies to educators, learners, and even schools

[15] FCC considers licensing the 2.5 GHz band for EBS: https://hechingerreport.org/will-a-new-batch-of-licenses-help-rural-students-get-online/

and classrooms (cyber-labs) have been disappointing (see section 3.2.11 on page 9 above). Massive thefts of tablets and smartphones led to a wholesale recall of these items in recent years; lack of connectivity inside and outside schools has been a major inhibiting factor; lack of reliable electricity supplies to recharge portable computing devices has rendered these costly items less effective; educator's lack of computer user skills and related pedagogies have imposed severe limits on the effectiveness of ICT in education and learning: "*With close to 400 000 teachers in South Africa, it should be clear that the training (perhaps we should call it up-skilling) of teachers is a massive task. It will be an expensive and a labour-intensive exercise. But unless it is done in tandem with the roll-out of technology devices in schools, there will be minimal return on the technology investment,*" Kobus van Wyk recently told Fin24.

The exceptions to all the above shortcomings are the well-resourced former model "C" and private schools – they can afford well-trained educators who can balance the best mix of pedagogies with technology, and provide the security systems needed to protect educators, learners and equipment. Furthermore, the learners in general have access to family support in the learning process, and high-quality connected computers at home.

There is a wealth of evidence in every country that children are particularly adept at learning how to use electronic devices, including computers, even without formal tuition. Their natural curiosity, inquisitiveness and instincts, childhood confidence, and willingness to share their experiences equips them well for these attributes, but they do need guidance. The short anecdotal case study from Ethiopia in the following text box demonstrates this well, as do numerous experiences stemming from the One Laptop per Child (OLPC) experiences in all countries where they have been introduced. This inherent quality of children must be leveraged aggressively, but also balanced with the reality that a technologically deterministic approach, i.e. a reliance on technology alone, will not work, and may even be harmful.

Case Study 1: Given Tablets but No Teachers, Ethiopian Children Teach Themselves (MIT 2012)[16]:

In an experiment to observe how illiterate children with no previous exposure to written words can learn how to read all by themselves, the One Laptop Per Child foundation dropped tablet computers with preloaded alphabet-training games, e-books, movies, cartoons, paintings, and other programs, in a remote Ethiopian village for children to play with:

Motorola Xoom tablets with solar charging systems were used. Once a week, a technician visits the villages and swaps out memory cards so that researchers can study how the machines were actually used;

20 first-grade-aged children in rural Ethiopia who had never previously seen printed materials, road signs, or even packaging that had words on them, participated in the experiment;

After several months of using and recharging the machines, children were reciting the "alphabet song," and even spelling words. One boy, exposed to literacy games with animal pictures, opened up a paint program and wrote the word "Lion.";

In an earlier experiment, closed boxes containing the tablets, taped shut, with no instruction, were dropped off in the village: "I thought the kids would play with the boxes. Within four minutes, one kid not only opened the box, found the on-off switch and powered it up. Within five days, they were using 47 apps per child, per day. Within two weeks, they were singing ABC songs in the village, and within five months, they had hacked Android to enable the camera, pre-disabled to save power."

Case Study 2: The experience of OLPC in Rwanda[17]: President Paul Kagame of Rwanda is reputed to have stated in his launch of the new Ministry of Youth and ICT in 2011 that "*Never again will Rwanda experience the horrors of the 1994 Genocide, and to avoid its recurrence, we will educate our children….".* The Government of Rwanda followed this up with the introduction of One Laptop Per Child (OLPC) as a key strategy – provide a child-friendly laptop to all the nation's children, so that they can use technology to learn at home and in the classroom.

The strategy has not been without challenges:

1. "*Regardless of its immense contribution to promoting the use of information and communication technology in education and improving critical thinking in young learners, the One Laptop per Child (OLPC) programme has for long been stained by issues of poor management, the Auditor-General's office says*" March 19 2015;
2. Massive affordability challenges; infrastructure deficiencies (electricity, broadband connectivity); knowledge deficiencies (for educators and parents); maintenance and support facilities; geographic remoteness and

[16] MIT 2012 article: One Laptop Per Child in Ethiopia: https://www.technologyreview.com/s/506466/given-tablets-but-no-teachers-ethiopian-children-teach-themselves/
[17] Rwanda 21 April 2017: The Metamorphosis of the OLPC Programme: https://allafrica.com/stories/201704210058.html

isolation; and many more combined to frustrate the strategy. With a GDP per capita of just US$820, and an OLPC price tag creeping up to US$200 per unit by 2018, the ambitious initiative has had to be reviewed.

3. "*In most schools, laptops are still kept in boxes and store rooms and have not been put to use, while 42 out of 67 schools visited had laptops in boxes"* the report noted. This experience resonates well with South Africa's own Gauteng Online R3billion school computerization experience (see also ITWeb July 2011 article here).

4. Rwanda's ambitious ICT4SDG4 has not been halted by these numerous challenges. On the contrary, it has been strengthened through a pragmatic approach to whittling away at the problems that beset it. A new partnership with "*Microsoft to roll out digital education has re-energised the debate by local and international observers on the progress of technology-enabled learning in the country*".

   A key outcome of Rwanda's e-Learning review is based on "*Studies (that) show that technology-enabled learning is more usefully unleashed within a broad institutional environment, such as in what is termed "blended learning", that should ideally include the pupil's family and teacher, in addition to the classroom and the student's peers*".

5. Two excellent online video documentaries outline the start of Rwanda's ambitions ICT4SDG4 strategy in 2008, and how Rwanda's experiences, both the successes and failures, are being acknowledged and cautiously considered by neighbouring countries, e.g. Kenya's discussion of its own strategy based on the experiences of its neighbour Rwanda.

Case Study 3: Baltimore County's $147 Million Tech Program Has Produced Little Change in Student Achievement:

Report by Liz Bowie, The Baltimore Sun / December 13, 2018. "*It's been four years since students from 1st to 12th grade received laptops and other technology, but scores on standardized tests remain flat.*"

- At the start of the 2014 school year, Baltimore County handed laptop computers to all grade 1 to grade 12 learners, for both home and classroom use. The stated objective was to transform education and improve outcomes.
- The report four years later: "*Despite the saturation of technology, Baltimore County ranks near the bottom of the state in passing rates on standardized tests. The scores are generally flat for students in grades three through eight, many of whom have had the computers for at least three years*."
- Following intense introspection by all stakeholders, a decision was taken to continue to support the initiative while focusing more on improving the direct role of educators: "The devices are just the delivery mechanism, ……. the underlying instructional message should be the same."
- The report makes reference to a 2016 nationwide analysis which concluded that educational technology – one laptop per child - does boost achievement in math, English, science and writing, but cautions that "*computers alone don't increase academic performance and must be accompanied by other changes in teaching*."

3.6. Section 3 Conclusions:

There is no doubt that in this 4IR information and technologically-driven age, that the use of all technologies, especially the ICTs, is mandatory for national competitiveness and growth through education. The errors of judgment made by many countries, including South Africa, is the overdependence on technology as a panacea for all educational challenges. Technological use in the classroom by educators and learners, outside the classroom by learners, their parents and peers, and solid pedagogical development and educator education and training are mandatory. Combining them all in a single ICT4SDG4 strategy is strongly recommended by most educators and researchers. The key issues covered in this section are:

- The complex compendium of "skills" listed in section 3.2 are all required, simultaneously, for survival and growth in the still emerging 4IR. Can any of these critical skill sets and required personal attributes be "taught" in traditional classrooms? Clearly, South Africa needs to think beyond the confines of curricula, standardized tests, and memorized pre-set answers to instil these capabilities in the minds of the nation's children if the nation is to survive and prosper in the 4IR.

- Section 3.3 outlines and briefly discusses the current pronounced ICT4SDG4 strategy of providing laptop computers for all learners in South Africa. Clearly, this strategy is well-intentioned, but given the global knowledge about ICT4SDG4 accumulated worldwide, is such a strategy on its own enough? "*If we want students to become smarter than a smartphone, we need to think harder about the pedagogies we are using to teach them. Technology can amplify great teaching but great technology cannot replace poor teaching"* (page 2 of footnote 2).

- Section 3.4 reviews the global knowledge base of the most critical challenges faced by the ICT4SDG4 development sub-sector. From this brief review, it is clear that much more research is required at the global and national levels; there are far more unknowns than there are known facts about the impact and use of ICT in education. What is certain is that the world is undergoing irreversible and rapid technologically-driven socioeconomic changes, and the world's education systems need to change to address these changes. The knowledge acquired to date on ICT4SDG4 has exposed significant opportunities, and threats, of the impact of technological changes on educational systems and their outcomes. Given the massive deficiencies of South Africa's educational systems as shown in Annex 1, both the opportunities and threats resulting from the use of ICT in the nation's educational processes must be a central theme of the nation's ICT4SDG4 strategies.
- Section 3.5 raises other factors beyond the issues covered in preceding sections. These include the suitability or lack thereof, of the devices used by educators and learners alike. The advantages and disadvantages of tablets, smartphones, laptops and desktops PCs are briefly reviewed. The section also briefly reviews the known challenges of ICT connectivity, challenges that result in the massive ICT access inequalities illustrated in the charts of paragraph A1 of Annex 1. The best endeavours of South Africa's ICT4SDG4 strategies will be severely undermined unless equal, perhaps even greater attention is given to the alarming ICT access gaps portrayed in the charts of Annex1. Connectivity lies at the heart of ICT4SDG4 – access devices for educators and learners are rendered almost useless if the information and knowledge they are intended to access remains out of reach of educators, learners, parents and community peers.
- Section 3.5.3 examines one of the most debilitating outcomes of South Africa's educational processes, the national failure to impart crucial reading skills to the nation's learners. The discussion summarizes the opportunities and current limitations of ICTs in this vital educational outcome, with supporting case studies from South Africa's peers Ethiopia, Kenya and Rwanda, and from Baltimore County in the USA. Intuition demands that we acknowledge and accept the immense potential of ICT in education, but we must also acknowledge their limitations. Much work remains to be done – a greater level of introspection, planning, and research-based implementation of how best to leverage ICT for improved educational outcomes. This must be the primary focus of South Africa's ICT4SDG4 strategies.

4. ICT4SDG4 in Higher Education and Training.

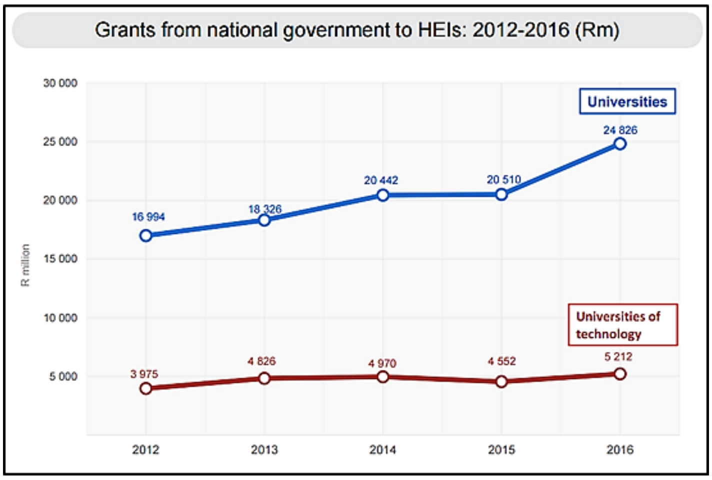
The Fourth Industrial Revolution has and is unleashing an even more socially significant revolution in the world of work and the role and value of labour. This new revolution demands exceptionally high economic, technological and social skills, and the wisdom to understand and respond to all aspects of the revolution. The 4IR demands deep fundamental changes in education from childhood to old-age retirement. The most important phases of education have been recognized as the early cognitive formative years, pre-school early childhood education (ECD), and basic education. This formative period prepares young learners for higher education and lifelong learning, and yet too many developing and some developed countries, continue to seek international acclaim through a skewed focus on their HET results alone. Graduation levels, research and patent outputs, accreditation status, are popular measures of the quality of universities and education as a whole in many countries, but these indicators tend to ignore the most basic building block for national success, the basic education outcomes that shape these HET success indicators.

Prioritizing HET above basic and vocational education has led South Africa into an environment in which obtaining a university degree, and the honour and status that go with it, far outweighs the value of the knowledge acquired and the ability to use it. This perception is demonstrated in numerous high-level public consultation forums and media advertising for HET. In too many conferences, forum and panel discussions about the 4IR or even the SDGs, the dominant questions concern the acquisition of the degree itself, or the bureaucratic process leading to its award. The specific topic under discussion is often relegated to networking discussions or isolated interventions by the more informed practitioners and presenters. The 4IR world demands that this must change. The technological changes, their opportunities, and the new societies they create, occur at a much faster pace than any of the traditional HET institutions and their processes can match. Invention and innovation will still be influenced by original advanced level research, but much more of that research can now be automated by its own outputs, the growing population of AI self-learning machines that can replicate themselves fairly easily in automated AI controlled fabrication facilities. More innovation occurs at the interface between users and equipment manufacturers and vendors than it does in academic research laboratories.

The statistics presented in A2 to A5 of Annex 1 suggest that South Africa's global ranking in the quality of its HET is severely hampered by weaknesses in the nation's basic education, irrespective of the relatively high standing of its universities. With just 4% of the nation's learners graduating after a gruelling 18 years of education, it is unlikely that

South Africa's global HET rankings will improve significantly in the near future. The small population percentage of internationally acclaimed success stories, which include the global icons Elon Musk, Mark Shuttleworth and Siyabulela Xuza in the STEM disciplines, are examples of South Africa's intellectual potential, which must be tempered by the realization that too few successes in an environment of massive mediocrity and failure can fuel inequality further. Small successes in a sea of mediocrity or worse can become a pyrrhic victory.

E-Education for the 4IR: Virtually all South African universities and research institutions are actively engaged in research related to the 4IR. South Africa is also engaged in the complex time-consuming programme of rebuilding and repositioning the nation's technologically-oriented universities and TVETs to address the challenges of the 4IR. The extremely complex process is underway, but a greater sense of urgency, and more investments, are needed to prevent the 4IR realities from overtaking the lengthy timeframes needed and expected. The critical question is: Are there any other innovative initiatives that can partially fill the gap while the long-term development processes unfold? This ICT4SDG4 initiative is one such programme which attempts to mount a parallel programme of action that addresses directly the learning needs of children from the ±55% population who live below the national poverty lines.



Source: https://www.southafricanmi.com/education-statistics.html

The adjoining chart illustrates both the depth and complexity of the challenge of raising South Africa's universities of technology and TVET colleges to the same levels and expectations of the traditional academic universities. Applied universities or universities of technology, and vocational training institutions are becoming central components of the 4IR. Grassroots level innovation and entrepreneurships are becoming vital responses to the 4IR, as it succeeds to replicate itself through automation of high-level skills such as software creation and even manufacturing.

This urgent need for South Africa to raise the expectations, roles and statures of the nation's universities of technology and its TVET colleges towards the same level of excellence as the traditional academic universities cannot be overemphasised. This will entail massive increases in investments in universities of technology and TVET colleges, to reverse the stark investment disparities depicted in the adjoining chart, and to improve South Africa's 4IR readiness.

The following concluding section summarizes examples of critical HET challenges facing the modern world. These examples suggest a strong sense of urgency for South Africa to address the known, poorly defined, and unknown challenges the country faces for the 4IR transition. The primary objectives must be to prepare students for jobs that don't yet exist, using curricula and pedagogies that have yet to be imagined, technologies that have yet to be appropriated and understood, economic and social structures that have existed only in the minds of philosophers and political ideologues.

4.1. China: Report by the World Bank, September 8, 2018: The Chinese Government has over the last two decades embarked on major reforms of its HETs, a combination of "top-down" and "bottom-up" approaches to narrow the divides between academically oriented HETs, universities of applied sciences, and vocational training institutions (TVET). All this to better respond to the demands of the evolving 4IR. This World Bank report provides vital insights into the Second *Africa-China-World Bank Education Partnership Forum* held from August 31 to September 8 2018, with African representation mainly from the East Africa Skills for Transformation and Regional Integration Project (EASTRIP). The Forum examined China's vocational education transformation model, drawing vital lessons from it, and preparing for intensified assistance to the African countries from the World Bank and its partners in the World Bank "Partnership for skills in Applied Sciences, Engineering and Technology (PASET)" initiative.

4.2. Germany: MIT Technology Review, June 22, 2018: **Rebuilding Germany's centuries-old vocational program**: Germany is an acknowledged global leader in engineering, technology and innovation. But, even with this lofty reputation, the country has embarked on fundamental changes to its world-famous ***Ausbildung*** vocational training process. The driver for change is simply the changing technologically-driven 4IR world. This article by the equally renowned and highly respected Massachusetts Institute of Technology (MIT), traces the root causes that drive a highly successful country to change its equally successful vocational training methods and philosophies, heeding the warning by ancient Greek philosophers that *hubris inevitably leads to nemesis*. The article provides an excellent case study of Germany's world-leading automotive industry as it prepares for a very different world of autonomous vehicles, and the immense complexity of the technologies that enable such autonomy with total security and safety for users and equipment. The ICTs and the full range of AI technologies are vital for this and all other technological industries, and the underlying education and training that guarantees their successes.

"*To confront the challenges of an AI-driven century, the program has added a newly blended approach, for the lucky few who qualify - it as an elite dual-studies track that confers both a bachelor's or master's degree and a traditional apprenticeship credential*". This is one of the concluding comments from which South Africa can derive excellent guidance.

4.3. Five Ways Finland Gets Vocational and Technical Education Right, By Guest Blogger on November 14, 2016: https://blogs.edweek.org/edweek/global_learning/2016/11/empathy_and_differing_perspectives_leading_through_education.html. What can South Africa learn from its many institutional partnerships with Finland on how best to structure its integrated HET programmes and strategies?

4.3.1. In Finland, vocational education is a choice. It is not a destination for young learners who are judged (through pre-set tests and examinations) to be deficient in any aspect of the learning process. Both academic and vocational educational streams lead to successful career pathways freely chosen by learners, without perceptions of superiority of one stream over another.

4.3.2. "*Vocational school is highly respected and seen as the more practical, well-defined, and more secure path for many students*."

4.3.3. A very wide choice of academic and vocational "degrees" ensures a balanced knowledge society in which actual or perceived competition between the STEM disciplines and the humanities is deliberately suppressed.

4.3.4. Finland has built over time a very strong shared national vision for the nation's sustainable growth with social stability. All segments of the economy and society collaborate on delivery of a balanced educational programme that seamlessly integrates academic and vocational learning and training. This nationally shared vision is viewed by all sectors of the Finnish economy as the guarantee for sustainable growth in the 4IR world and beyond.

4.3.5. "*Unemployment is a human and economic crisis, but at worst it can become a breeding ground for criminal and extremist movements. It's the duty of decision makers to encourage confidence in the future, but concrete measures are also needed to weed out youth unemployment.*" Henna Virkkunen (NCP), a Member of the National Coalition Party of Finland, and of the European Parliament. This was stated in a speech outlining Finland's major transformation of the country's vocational training strategy, which, amongst other important changes, allows year-round admissions from one training level to another, and across multiple disciplines[18].

4.4. **Robots hijacking Universities, data to things and things to data, million student university campuses**: A summary of the thoughts of Neil Gershenfeld, founder of the MIT Centre for Bits and Atoms and Fab-Labs; and Martin Hamilton, a highly respected Futurist.

Neil Gershenfeld: (derived from his contribution to the 2015 documentary video "Great Debate, Extinctions":

- Are universities obsolete? Yes! About 50% of them. Their assumptions that (clever) people are scarce, you have to go to universities to find them. Wrong – they are/can be anywhere, everywhere.
- Traditional universities are like old mainframes – you go to them to get processed! Instead of bringing students to the campus, can we take the campus to the students? $100 million and 10 years to build a powerful computer lab that only 1000 people can use. Can we get this lab to build 1000 smarter smaller computer labs around the world, where a few million people can use internet-delivered software tools to make even more and better tools? Can these few million people use the tools design and fabricate things, and send these designs in in bits for others to enjoy? All this is possible through the Fab Lab concept, which also enables massive scalability – MOOCs (Massive Open Online Courses) defeating global knowledge inequalities.
- A Fab Lab in an African shanty town (or Asian, American, Arctic, Spain): "*Amazing kids come to learn amazing concepts that were previously only taught at MIT and the likes. They learn, do, then fall off the cliff*" – they are too smart now and must go to a far-away university to learn what they were learning at home. Fab Lab: a global educational network, learners learn from peers, work groups, local and external mentors, remote "gurus" in remote universities, in any disciplines at any level of competency and knowledge. Fab Labs receive bits of knowledge via the Internet from those who have it and are willing to share it. They convert these bits to atoms – things, using progressively smarter and cheaper computers and 3-D printers. They convert these

[18] Finland sets example with vocational education reform, May 2017: http://www.helsinkitimes.fi/finland/finland-news/domestic/14731-finland-s-vocational-education-reform-an-example-to-follow.html

new smart things back to bits, and send them onwards for others to use. The ancient spirit of creativity and knowledge sharing that led to the successful migration of all humans out of their ancestral African home is back in full force, under the guise of the 4IR.

- The Fab Lab can make anything, and that anything can even more (any) things, and can even grow living anything: Fab Lab makes a biotech lab to grow food! Can Fab Labs address the alarming challenges of hunger as discussed in sections 4 and 5 of ICT4SDG2? Can they recreate the ancient caring societies that challenged hunger directly, together, in unison, with zero social or economic hierarchies?
- Dramatic increase in access to the world's brain power: MIT accepts a few thousand applicants each year, rejects everyone else. The world has a few billion people, six orders of magnitude more than MIT's capacity. Can the universities (the 50% obsolete ones) be broken up (not destroyed) and scattered worldwide to begin to service the billions of candidates that can and want to learn?
- South Africa has introduced Fab Labs (e.g. at CSIR FabAcademy). They have yet to scale up to reach the children and youth in the informal settlements and rural villages where they are needed most.

Martin Hamilton: (Author's interpretation of the article)

- **The fourth industrial revolution: how can universities respond to the rise of the robots?** "*Up to 800 million global workers will be replaced by robots and AI by 2030.*" What can universities do to keep humans employed? Should they be concerned about robots taking over their functions?
- The fear or high expectations of AI is the topic of much public discourse, with some recommending that universities should expand the numbers of masters and PhD graduates in AI. Is this the best response? What possibilities that a handful of very smart PhDs create a few very smart AI machines that distribute their knowledge-bearing bits worldwide to create more AI machines that improve the lives of billions of ordinary citizens, some of whom may become members of that handful of PhDs? Should universities welcome this possibility, or fear it?
- Martin raises the concept of Stanford online education spinout Udacity; free and/or low cost online MOOCS (Massive open online courses) offering Nanodegrees from Stanford's schools of AI, Data Science, Programming, Autonomous Systems, and Business. The demand at launch was massive – 30,000 applicants worldwide almost overnight: "*Could traditional degrees learn from the nanodegree's flexibility and fast pace? "It seems that's what students want.*"
- We know that 4IR technologies will massively replace huge trenches of human labour. Will this impact universities also, AI robots taking over as lecturers, researchers, librarians, janitors, security personnel, etc.?
- "*Universities are a bit like ocean liners – they tend to struggle with sudden course changes*." Can traditional universities keep up with the pace of rapid technological developments and their impact on society, particularly the world of work? If they must change, but how? Most universities in developing nations like South Africa have deep public sector investments and commitments that will in general resist change even more vigorously than the universities' leaders themselves. What will be the overall impact of this resistance to change on the nation's global educational and especially its economic competitiveness?

4.5. The World Economic Forum 2019: As in previous forums, WEF 19 will include extensive discussions on the 4IR and its components and impacts across the whole human value chain. In this ICT4SDG4 discussion, it is useful to recall the excellent coverage of the 4IR at WEF 16: **What role will education play in the Fourth Industrial Revolution?** https://www.weforum.org/agenda/2016/01/what-role-will-education-play-in-the-fourth-industrial-revolution/. The discussions three years ago are still as relevant today as they were then, and will continue to be relevant as the 4IR expands in the years to come.

5. Proposed ICT4SDG4 Strategy: The ICT4SDG4 strategy proposed for South Africa is relatively simple, comprising two separate paths:

5.1. ICT4SDG4 Path 1: A Strategy for the whole national education system:

An ICT4SDG4 component that addresses the whole national education systems, from ECD through to graduation at PhD level. This element of ICT4SDG4 will be extremely complex and costly, depending as it must on the human factor: (i) the diversity of opinion, a symptom of the democratic process preferred by South Africa; (ii) a very wide variation in knowledge and experience by educators and institutional leaders, often divorced from the decision-making authorities, powers and responsibilities assigned to some of these educators and institutional leaders; (iii) a broad spectrum of political and economic ideologies that impact both the institutional structures and the strategies that shape the national educational systems and their outcomes.

The national education system, driven by espoused good intentions, will continue to lurch through different ideas, ideologies, philosophies and outcomes, which include the current round of belief in the recently pronounced "one tablet per child" strategy as a panacea for South Africa's educational challenges. The prevailing deep structural flaws in the national educational systems that give rise to the nationally acknowledged and internationally verified deficiencies can only be overcome over a very long period, decades even, if the lessons derived from the Scandinavian and Finnish experiences[19] apply to South Africa's immense challenges.

The following comments by highly respected South African educators, derived from the video documentary "Some Children are More Equal Than Others" discussed on page 3 of this document, are pertinent:

5.1.1. "*No matter what anyone says in Government, that we are improving the system, until that ideology, that implicit stated ideology (of mere de-racialization of the school system without rebuilding it from the base), is confronted and done away with, there is absolutely no reason to believe that education is doing anything in this country except under-educating our children*": Professor Nomalanga Mkhize.

5.1.2. "*What do the 500,000 grade 10 dropouts do after school? Popular opinion is that they attend vocational schools; research shows that only 1% do that, the remaining 99% join the ranks of the ±50% unemployed youth….*": Dr Nic Spaull.

5.1.3. "*There is this wholescale abdication of responsibility; parents expecting teachers to discipline their children; teachers blaming the principal and school management team for not giving them enough time and overworking them; that's why the kids are failing. The blame game moves all the way up the national educational system hierarchy, no one takes responsibility for the obvious failures. Government continues to refuse to use the principles of "consequence management" for a failing system like this, we don't deserve to be in these jobs*": Loyiso Pulumani: ANC spokesman for the Eastern Cape Department of Education.

5.1.4. (i) "*It is an indictment of our education systems that ten years after democracy, so many of our rural schools still lack decent ablution facilities for our children". (ii) "Children 'bleed' out of the system, there is no other way to put it. If you leave school at the point that many South Africa children do, you will join the ranks of the semi-literate people you will find in the streets". (iii) All of us involved in education are failing South Africa's children*". Dr. Monica Hendricks, Rhodes University.

5.1.5. "*A radical overhaul of the education system is needed. That will not happen if the state does it alone. We all need to engage with the challenges, creating power through solidarity*". Professor Pedro Tabensky, Rhodes University.

It is a well-known fact that building consensus, coherence, institutional collaboration and coordination, in a multicultural, multi-ethnic, multi-linguistic, multi-learned, multi-racial, multi-skilled society like South Africa, is extremely difficult – it requires patience and time, and excellent communications, and through ICTs, access to the requisite knowledge. The educational reforms South Africa needs will demand time, patience and commitment by the whole nation. ICTs will continue to play a central role in this reform process, as they do in every other field of human endeavour.

The second part of the ICT4SDG4 strategy outlined below will focus on the poor excluded masses, providing invaluable "living laboratories" to test the long-term strategies for the first part of the broader ICT4SDG4 strategy. The facilities proposed will enable South African scholars to research and test new concepts and ideas in real world situations. Vital ethnographic researches that focus on the human side of the challenges – the victims of the educational development deficiencies, will be enabled. All available and future technologies will be used. The primary focus will be on the economically marginalized population and their children, the base of South Africa's development pyramid.

5.2. **ICT4SDG4 Part 2: A focus on the base of South Africa's development pyramid**.

The urgency to improve South Africa's education systems for the economically marginalized population demands an "All-hands-on-deck" approach. The whole nation must engage in the process of "radical educational transformation" as suggested by Professor Tabenksy. The approach proposed in this ICT4SDG4 strategy is to build massively scalable low technology, low-cost and **affordable** public broadband access facilities in all areas where poor people live. Whole communities, especially their children and youth, must be able to access broadband services for entertainment and learning, for relaxed stress-free engagements with technology, in and outside the classrooms and schools. Their current broadband access possibilities are clearly inadequate – they are unable to access or afford the same levels and qualities of broadband that their wealthier compatriots enjoy for learning, play and work.

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[19] 2011 Swedish Example: The rise, fall and revival of a capitalist welfare state: what are the policy lessons from Sweden? http://www.ifn.se/wfiles/wp/wp873.pdf AND Finland's 40-year history of educational development: https://www.oecd.org/pisa/pisaproducts/46581035.pdf

In building this second part of the national ICT4SDG4 strategy, a word of caution is necessary: the technology or its educational content must not dominate the learning process in any way. Young children must not be "taught coding or programming", they must acquire these vital 4IR life-skills in the same way that they acquire the skills to use language, reading and numeracy – naturally, at their own pace, with enjoyment. A top-down attempt to "teach" digital literacy to poorly education and economically under-resourced adults and children alike has been at the heart of the Telecentre failures (see the discussion of Telecentres in ICT4SDG1). ECD of the technological kind must be central to the process. There is a growing quantity of online learning "games" suitable for ECD that can be applied even in South Africa's poorest communities. The insights of the world's best educational philosophers, which include the likes of Paulo Freire and Noam Chomsky (see "Education for whom and for what?[20]" by Chomsky discussing Freire) must inform the process.

A summary of this strategy is provided in the ICT4SDG1 document of this series, with additional details at http://www.sakan.org.za/SAKANSolutions.html. The key attributes of the proposed network of pro-poor broadband access are:

5.2.1. A minor variation of the traditional Cyber Café model, one that is owned and operated by members of the target communities. The Brazilian LAN-House model is an excellent well-researched model, coined "The Lan-Hose Phenomenon" by several anthropologists and social scientists[21]. This model will need to be modified for South Africa's unique environment.

5.2.2. As part of the national SDG strategy, the primary objectives of the model must include (a) SMME job creation through ownership of the resulting SMME businesses; (b) business models developed that enable sustainable businesses with broadband Internet access priced from R3.00 to R5.00 per hour; most urban cyber cafés are priced at R60.00 per hour. A very small number of cyber cafés located in a few of South Africa's poorer shopping complexes, e.g. Randburg shopping centre, thrive on user charges ranging from R10.00 to R15.00 per hour.

5.2.3. Support by local authorities and municipalities, and all national public institutions, as part of the national poverty alleviation strategies, is essential for success. Support by the whole private sector, including the massive ICT industry, is equally mandatory if businesses are to thrive in a stable high-growth economic environment.
The LAN House development model adopted by Brazil, in which government provided warehouses and set up distribution chains for donated PCs and other required items of equipment, the initial training of favela residents in basic equipment refurbishing, assisting the selected owners to set up the LAN Houses, is informative. This model was described by a Brazilian delegation visiting South Africa in 2010, and is available for download at:
http://www.sakan.org.za/Docs/MultiStakeholder_Forum.ppt.

Given the depth of South Africa's poverty, example Ntombizanele Mbuweni, a single parent who must support a family of five from one Child Support Grant (CSG) of ZAR 400 per month (see Health 24 report of May 2018 on South African Hunger), even R3.00 to R5.00 per hour may be beyond the affordability of some South African families. Can we visualize a children's token system for such access as part of the child social grant system?

5.2.4. A different user focus: Traditional Cyber Cafés are based on attracting users who already have some digital skills: students searching the Internet as part of their learning processes; adults and youth sending and receiving emails; young South Africans applying online for university places and parents searching for school places for their children (both severe perennial challenges); printing CVs and job applications, etc. How can the business models be designed to attract adult Internet novices with minimum education? How can the "new deal" cyber cafés attract youth and children to acquire knowledge-delivering digital skills at their own pace and time? How can the new cyber cafés encourage poor parents to send their young children to "play and learn" in Internet cafés? These will be the focal points of the business development strategies.

5.2.5. Cyber cafés and smartphones: The growth of connected smartphones has decreased the numbers of public Internet Cafés in most countries that have used the growth strategy, e.g. Brazil and China. In South Africa, access via hotspots remains a challenge for poor communities. The planned cyber cafés will provide the widest possible Wi-Fi coverage to encourage especially young users and adults using e.g. WhatsApp, to access their networks as they do hotspots at reduced access prices. In Brazil, at the height of the LAN House Phenomenon, favela children often accessed Wi-Fi at the LAN House, followed by the use of the larger LAN-House PCs to edit the content on their smartphones (often cheap unreliable pirated devices they named called Xinglings).

5.2.6. **Cyber cafés as educational tools**. The failure of Telecentres worldwide and in South Africa should shape the design of the educational strategy. Formalized "teaching" in the proposed cyber cafés should be abandoned in favour of "learning", through online learning games that attract young users. Close coordination with educators skilled in educational online games will be developed, particularly those games with an ECD focus. The success of the Brazilian LAN Houses was the natural inclination towards community engagement and peer-driven learning –

[20] Noam Chomsky Lecture, University of Arizona in 2012: "Education For Whom and For What?": https://www.youtube.com/watch?v=e_EgdShO1K8
[21] LAN Houses: A new wave of digital inclusion in Brazil: http://publius.cc/lan_houses_new_wave_digital_inclusion_brazil/091509

skilled unemployed youth and cyber café owners providing coaching on request to users as needed. The relationship with public schools in the community will be examined. Cyber security considerations will be prioritized, the cyber cafés themselves can provide excellent cyber security education for young children. Children learning how to protect their online experiences may grow up to become Cyber Security experts with hands-on knowledge of the dangers of Internet access and use by the poor.

5.2.7. Can the more successful community-based cyber cafés in very poor communities be migrated in time to become Fab Labs? (see sub-paragraph 4.4). This is clearly possible and most desirable. Fully developed countries have been doing this for nearly a decade now – children learning by designing and building artefacts at child-friendly Fab Labs in numerous countries ranging from their birthplace at MIT: (a) USA, a Fab Lab for 3-year-olds - the "lessons" begin with a recital of "The Three Little Pigs" story, and progress to "designing" and "fabricating" little houses too strong for the bad wolf to "blow down"; (b) Vienna, Austria: First Steps in the Fab Lab: Experiences: Engaging Children; (c) Latin America: EMOSILLA, a digital fabrication project by Fab Lat Kids; (d) Stanford Graduate School of Education[22]: a more formal outline of the Fab Lab concept for learning, coined the FabLearn Labs – child-friendly very high tech labs rendered simple enough for children to grasp and use. While the rest of the world races to ready its children for a 4IR future, must South Africa's ±60% child population living in poverty be left behind again?

5.2.8. The success of the modified cyber café model will depend on public support for its successful launch. Unlike other new innovation start-ups, the cyber café model is well known, uses very simple technologies, and there are enough competencies and skills even in the poorest communities, which include the army of unemployed graduates of any academic discipline (see e.g. documentary video of the Zenzeleni[23] project in rural Mankosi, featuring young Masbulele Siya serving his community). There must be no costly unnecessary pilot studies, the well-known technologies and applications enable immediate large-scale application. Securing the partnerships and support of the full range of public and private entities in all socioeconomic sectors of the country will be the major challenge.

The key concluding questions are: Must South Africa's ±60% child population living in poverty be excluded from the opportunities of the modern world technologies again? Or miss the opportunity to "catch up" with their more economically privileged peers who dominate the Matric success stories? This component of the national ICT4SDG4 strategy addresses these provocative questions directly – a process of technological appropriation and information/knowledge inclusion for the economically marginalized population, owned and operated by community members of this population, providing vital learning opportunities for their children.

6. CONCLUSION: ICT4SDG4

The paragraphs above, and Annex 1 that follows, provide statistical and other evidence of the immense challenges faced by South Africa's education processes, as they seek to drive the nation's development and global competitiveness in this changing 4IR world. The statistics presented in Annex 1 paint a dismal picture of the outcomes of these processes and systems. The discussions in the main body of this document paint an equally dismal picture of the complex range and depth of factors that define the educational challenges. The challenges are clearly a consequence of South Africa's modern history, a history that has failed to instil a common national identity, and to build a common vision for national development, one that is embraced and shared by all stakeholders. The deficiencies in the national educational systems outlined in this document, irrespective of their root causes, are both cause and effect of the failure to build the desired national identity and shared visions for the country's sustainable growth with socio-political stability. The complexities of the latter, growth with socio-political stability, is the primary reason for linking this ICT contribution to the education and learning process to all the UN Sustainable Development Goals pertaining to South Africa. They all need a highly educated, competent and motivated population for their achievement. Radical educational transformation may be necessary, but educational transformation of any kind is a complex and extremely lengthy process.

To counter the extremely lengthy periods required for transforming any national educational system (Finland needed 40 years), this ICT4SDG4 strategy proposes a two-pronged approach – ICTs to assist the high-level national development agenda to reduce the expected long timeframes, and a lower level parallel intervention targeting the poor, and their children, specifically and aimed at short-term measurable results that feed into the longer-term national strategy. The details of this secondary initiative are presented in this ICT4SDG4 document, with key supporting references. It is worth repeating that the strategic focus of this lower-level strategy are the ±60% of the nation's children that live in poverty.

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[22] Stanford Graduate School of Education: Transformative Learning Technologies Lab: https://tltl.stanford.edu/project/fablearn-labs

[23] The ZENZELENI community ICT network video at https://www.youtube.com/watch?time_continue=927&v=YxTPSWMX26M

Annex 1:

Statistical summary of South Africa's education environment and progress.

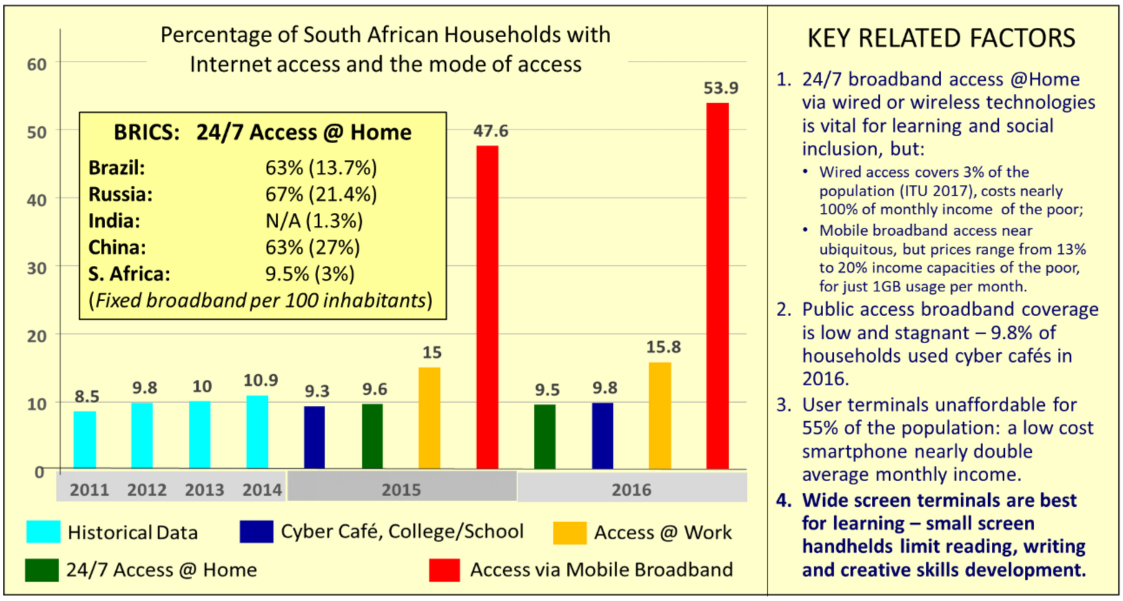
Statistics and related quantitative indicators are very useful for recognition and acknowledgement of the existence of potential shortcomings in the national education systems. They also provide a simple way of measuring the progress of any corrective actions or implementation programmes that may arise. But, the process of development demands much more than statistics. The challenges of equitable education for every child, irrespective of ethnicity, language, social and/or economic class, or geographic location, cannot and must not be defined by statistics alone, the human aspect of education and learning cannot be measured statistically, although statistics remain a useful measure of progress and benchmarking against peers.

The statistics provided in the following paragraphs and charts are merely indicative of a much larger human challenge. They are reasonable estimates at best – the relationships between the start and end of children's education, the dropout rates, failures, and repeat classes, age and maturity variations between children, and the influences of all these complex relationships on the end results, cannot easily be represented statistically with any level of accuracy. The costs of compiling exact statistics are extremely high, comprising extremely costly population surveys and analyses, the costs of which will most likely exceed the value of their contributions to the overall educational development processes.

It is against the above qualifications that the following statistics are provided. The raw statistics are complimented by media and government's own reports on the state of education in South Africa.

A1. Inequalities and gaps in Access to Information and Knowledge via ICT:

Broadband Internet Access in South African homes (%): Children need 24/7 access for development & safety

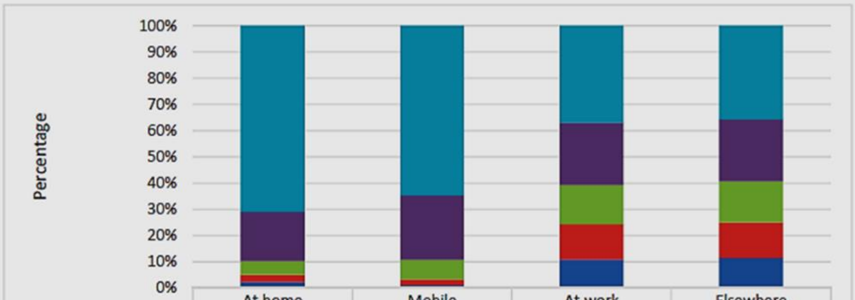


Data sources: (1) STATS SA Household Surveys: (2) ITU World Telecom/ICT Development Report 2018: (3) Country Reports

The low level of household Internet access is further exacerbated by income inequalities: Statistics SA reported in 2015 (see the discussion and impact on page 6 of **ICT4SDG3**) that 71% of households in the wealthiest income quintile enjoyed 24/7 Internet access at home, compared to 2.3% in the poorest quintile, rising to just 5.2% in the third income quintile. This relationship is illustrated graphically in the chart that follows. The major barriers to Internet access at home are: (a) Affordability: fixed "wired" Internet access costs can exceed 100% of the average disposable incomes of the 55% South Africans living below the national poverty line; wireless broadband access costs up to 20% of disposable incomes for just 1GB data access per month (December 2018 published prices); (b) User skills deficiencies: The proliferation of smartphones, growing access via public Wi-Fi hotspots, and free and "Over-the-Top" applications like WhatsApp, are eroding the connectivity challenge. In spite of these advances and new opportunities, differences in the quality of ICT usage between the "information-haves" and the "information have-nots" continues to fuel the growth of knowledge and opportunity inequalities. This aspect of ICT growth is described well by the International Telecommunication Union in its ICT Development Index, summarized for correlation with this series of ICT4SDG documents on page 4 of ICT4SDG.

Information Inequalities skewed by income inequalities

Figure 18: Percentage of households with access to the Internet by type of access and per capita household income, 2013



	At home	Mobile	At work	Elsewhere
Wealthiest quintile	71,0	64,7	36,9	35,7
Quintile 4	18,8	24,6	23,8	23,6
Quintile 3	5,2	7,5	15,1	15,7
Quintile 2	2,8	2,1	13,4	13,5
Poorest quintile	2,3	1,1	10,9	11,5

Source: GHS 2013

http://www.statssa.gov.za/publications/Report-03-18-05/Report-03-18-052013.pdf

- **Wealthy South Africans enjoy full access to Global information and Knowledge (71%)**
- **Poor South Africans lack access to Information and Knowledge for development – Maximum 5.2% in Quintile 3**
- **Access to knowledge at home is vital for child and youth development**

The best opportunity for ICT connectivity for South Africa's +30 million citizens who survive below the national poverty lines remains public access, for both connectivity and access to and use of suitable transformative terminal equipment. The Internet Café model, which has served South Africa's peer developing countries like Brazil and China well, is eminently suitable for unlimited public broadband access, usable by whole communities in economically marginalized enclaves, including children for Early Childhood Education (ECD) and technological appropriation. Such public access platforms provide a solid foundation for 4IR readiness for the poor. At 9.8% household utilization, the model is grossly underutilized in modern South Africa.

A2. Basic Education: The pre-Matric dropout rate: Basic Education Statistics 2016[24]:

New School Admissions			Wrote the NSC		Bachelor level pass		Diploma level pass		Higher Ed. pass	
Grade R	Grade 1	Total	Number	Drop out %	Number	%	Number	%	Number	%
813496	1208992	2022488	610178	70%	162374	8%	179619	9%	100486	5%
Summary: 22% of Grade R and Grade 1 school entrants in 2004 qualified for further studies in 2016.										

An updated 2018 version of the above will become available as soon as the Departments of Basic Education (DBE) and Higher Education and Training (DHET) publish the official statistics for 2018.

A3. Higher Education and Training: Additional statistics and comments:

Updated 4 January 2019[25]

"Data from the Department of Higher Education showed the number of new graduates that registered at Higher Education Institutes (such as Varsities, Universities of Technologies etc.) coming in at 158 000 in 2013. Thus, assuming all the new registrations were matriculants of the previous year (which roughly totals 700 000), only 22% of matriculants or about 1 in 5 makes it to Higher Education Institutions (HEI) after school. Looking

[24] Basic Education Statistics: https://www.education.gov.za/EMIS/StatisticalPublications/tabid/462/Default.aspx
[25] Education Statistics: 4 January 2019: https://www.southafricanmi.com/education-statistics.html

at it a little differently, only 12% (or around 1 in 9) of school children entering grade 1 will make it to HEI if this trend continues."

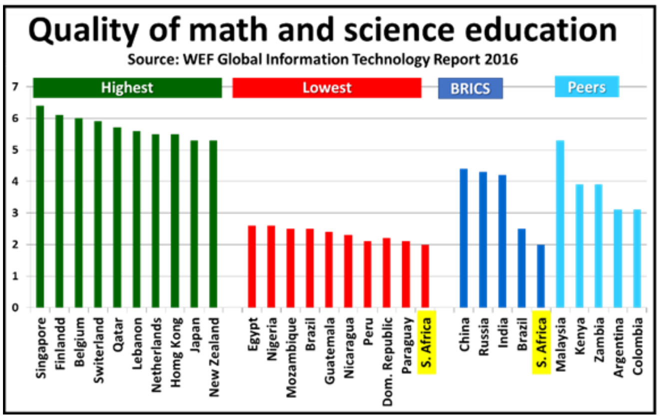
Dr Andre Van Zyl, May 2015. The Director of the University of Johannesburg's (UJ) Academic Development Centre and Head of the South African National Resource Centre, reported as follows:

- "We have space in the higher education sector for approximately 18% of matric graduates, then the system is full," said Van Zyl, adding that it was envisaged this would be expanded to 25% when the two new universities in Mpumalanga and Northern Cape started enrolling an increased number of students (Both universities opened in 2014, and are building capacities, the 18% capacity has increased to 22%).
- Dr Van Zyl stated further that of the 18% matric graduates that enter universities, between 50% and 60% drop out during their first year of study. "And that's why the focus in the first year is important."
- SUMMARY: If 22% of the grade R and grade 1 intakes succeeds in entering university as suggested, and 50% drop out in the first year, and further assuming that those who make it through the first year go on to graduate, then the graduation rate is approximately only 2% (4% to 5% excluding grade R) of the school intake.

Alternative estimates: The Council on Higher Education, October 2017 (Page 2):

- 60% of those who entered Grade 1 wrote Matric; 12% went to university;
- 26% obtained bachelor or diploma passes;
- 12% entered university;
- 6% obtained some kind of undergraduate university qualification within 6 years after matric;
- 4% obtained a degree within 6 years after matric.
- Graduate unemployment levels were reported to be 7.4% for graduates, and 17% for those with other non-degree post-school qualifications.
- STATS SA report for Q1 2018 on graduate unemployment: 33,5% (ages 15-24); 10.2% (ages 25-35); and 4.7% for graduates aged 34-64 years.

A4 Quality of Math and Science[26]: Global Benchmarks:



Mathematics and Science knowledge, and therefore the quality of its education, is the most critical knowledge component for any nation in the 4IR world. The value of early childhood education in maths and science exceeds by far their known value and use in any of the Science, Technology, Engineering and Mathematics (STEM) professions. Getting to understand the relationships between numbers (quantities); shapes (geometry); colours, food, water, plants, soil (science), even as early as 3-years, sets the foundation for critical, creative, logical, rational thinking, qualities that will be invaluable throughout the life of the child.

A5. South Africa's reading crisis is a cognitive catastrophe[27]:

Professor John Aitchison, the author of this highly informative article (footnote 26), is a specialist in adult education and Professor Emeritus of Adult Education at the University of KwaZulu-Natal. He was inducted into the International Adult and Continuing Education Hall of Fame in 2008, alongside global luminaries Paulo Freire and the first president of Tanzania Mwalimu Julius K. Nyerere. Professor Aitchison continues to serve his country well even in retirement. The article presents a powerful comment on the immense educational challenges faced by South Africa, linking these to the nation's political struggle against apartheid. Professor Aitchison traces the link between the global struggle for equality and meaningfulness in education, and South Africa's own struggle for liberation from the yokes of apartheid. Professor

[26] Chart derived from page 249/307 of WEF-GITR 2016: http://www3.weforum.org/docs/GITR2016/WEF_GITR_Full_Report.pdf
[27] The Conversation: February 26, 2018: John Aitchison, Professor Emeritus of Adult Education, University of KwaZulu-Natal: https://theconversation.com/south-africas-reading-crisis-is-a-cognitive-catastrophe-89052

Aitchison infers that Steve Biko's strive for Black Consciousness was influenced by Paulo Freire (1921 to 1997), the internationally celebrated Brazilian educator, philosopher, and author of the influential "*Pedagogy of the Oppressed*"[28].

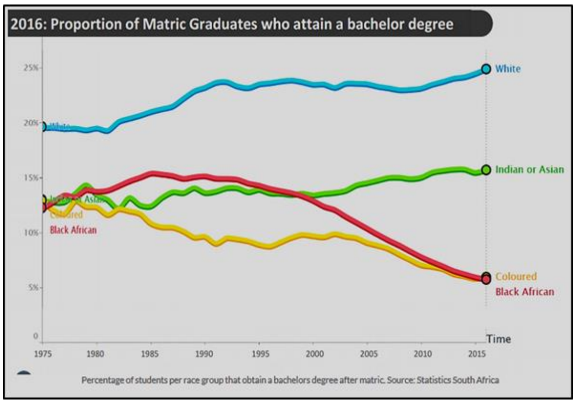
South Africa's reading crisis discussed by professor Aitchison, exposed by the "Progress in International Reading Literacy Study (PIRLS)" report for 2016, is summarised by Dr Nic Spaull, a South African Educator and Researcher at the University of Stellenbosch (Nic Spaull Dec. 2017):

- **8 of 10 SA children cannot read:** 78% of SA Grade 4 students cannot read for meaning. They could not locate and retrieve explicitly stated information or make straightforward inferences about events and reasons for actions.
- **SA scores last in reading of 50 countries:** South African Grade 4 children have scored the lowest mark in the latest 2016 round of the Progress in International Reading and Literacy Study released today.
- **SA lags far behind other countries:** While 78% of SA Grade 4 kids cannot read, in America this is only 4% and in England just 3% cannot read. However, the study also included middle-income countries. In Iran only 35% of Grade 4 students could not read for meaning and in Chile it was only 13%.
- **Massive provincial differences in percentage of Gr4s who can read:** 91% of Grade 4 children in Limpopo cannot read for meaning with equally high percentages in the Eastern Cape (85%), Mpumalanga (83%), Gauteng (69%), Western Cape (55%).
- **Declining number of SA students** reaching high levels of reading achievement: In 2011, 3% of SA Gr4 students reached the High International Benchmark. In 2016 only 2% reached this same benchmark.
- **SA boy's scores seem to have declined between 2011 and 2016:** The average Grade 4 girl in SA scored 341 in 2011 and 347 in 2016 (unlikely to be statistically significant). The average Grade 4 boy in SA scored 307 points in 2011 and 295 points in 2016.

The key question that must be derived from these alarming statistics is: "*What can South Africa do to forestall this looming educational catastrophe?*" Followed by: "*How can ICTs help to overcome this immense national challenge through ICT4SDG4?*"

A6. The ethnic/racial characteristics of education and its outcomes in South Africa[29]:

The provocative nature of this statistic, resulting as it does from a particularly deleterious socio-political history, has a direct impact on South Africa's educational outcomes. Irrespective of the urgency to find solutions, extreme caution and sensitivity is needed if the adopted corrective actions do not exacerbate the already complex social order. Given the provocative nature of this statistic, a verbatim copy from the source, https://www.southafricanmi.com/education-statistics.html is provided:



"*White students' parents are more likely to afford better primary and secondary schooling, and more likely to be able to pay for tertiary education, hence the higher percentage of white students obtaining bachelor's degrees after matriculating. With around 25% of white students obtaining a bachelor's degree after matric, Indian/Asians come a distant second with around 15% while both Coloured and Black Africans sitting around 5% of students obtaining a bachelor's degree after matric. Concerning to see is the decline in the percentage of Coloured and Black African students obtaining bachelor's degrees after school. Again, part of this is due to a lack of funding from these race groups, making it harder for students from these groups to enter a higher education institution. And this is part of the reason for the whole #feesmustfall campaign that swept across South Africa.*"

The historical trend lines illustrated in the chart suggest a call for urgent action if racial strife is to be avoided, but as suggested above, such urgent action must not be allowed to create unintended consequences in which "the cure becomes worse than the disease". The primary focus of attention must be the upliftment of all learners towards the highest possible levels of achievement, irrespective of their ethnicity, race or gender. Failure to do this can lead to racial strife, social disruption, and economic stagnation. Even without the provocative race-based divisions, a small segment of very high achievers in the face of mass underachievement

[28] Paulo Freire, "*Pedagogy of the Oppressed*", posted online by Princeton University at: https://commons.princeton.edu/inclusivepedagogy/wp-content/uploads/sites/17/2016/07/freire_pedagogy_of_the_oppresed_ch2-3.pdf

[29] South African Market Insights: Education Statistics: Last updated: 9 January 2019: https://www.southafricanmi.com/education-statistics.html

will further fuel socioeconomic inequalities, leading to the same social disruption and economic stagnation, irrespective (see the 33-country Hechinger Report[30] on innovation and inequality in education).

A7. Investment priorities in Higher Education and Training (HET):

The 4IR is about building machines with enough "artificial intelligence" to replace human labour. The resulting efficiency gains are vast:

- The only continuous input is energy, electrical energy from the grid in most cases, with batteries for backup and mobility/portability. Developing alternative renewable clean energy sources for this purpose is essential, and can/must be a component of this ICT4SDG4 strategy, fully integrated with SDG7 - *Affordable and Clean Energy*. ICTs can play a major role in the success of SDG7, and will be discussed in a forthcoming ICT4SDG7 document.
- The only human interventions will in time narrow down to the few very highly skilled humans who design and build the AI and related 4IR technologies and systems, and those humans that serve these machines. The new "boss" of the unfolding 4IR world may be a robot, with only a small amount of help from humans.
- Machines will not strike for higher wages, shorter working times, overtime payments, maternity and sick leave and its pay, longer paid vacations, recreation and food breaks, or even sleeping time.
- Even the software designs at the "heart" of the AI machines can and are being automated. AI machine learning was first discussed more than seventy years ago, leading to very basic AI machines that were able to compete against e.g. the best human chess players, and win. Today, AI-driven self-learning software development machines are able to design complex software in the architectural/civil engineering (CAD/CAM), environment (climate change and weather), health (DNA analyses and search for new medicines) much faster than the best software engineers who created the machines in the first place.

Are these 4IR advances the harbinger of a world run by robots which does not need people? The answer is emphatically "NO!". Machines and the technology that drives them have always been designed to make life easier for humans. The 4IR presents an opportunity to eliminating large swathes of mundane wholly unrewarding labour and work, freeing humans for better qualities of life. The 4IR can release human creativity and energies to create a more equitable world; less poverty; no hunger; self-esteem. New highly rewarding forms of work are already available or under development in the 4IR world, but much more are needed.

The national education process, supported by ICT4SDG4, must sooner rather than later address the above aspect of education for and within the 4IR world and its successors. Through our education systems, we must create future jobs that we don't know about, to solve the massive social problems that we know today, and the future social problems that we know nothing or very little about. What pedagogical tools, and especially what *curricula*, are required for this massive uncertainty? One answer to this complex conundrum lies in the 10 future skills listed in sub-paragraph 3 on page 8 of this document. South Africa's educational systems and processes must prepare future adults to solve yesterdays, today's and all future social problems that arise from human progress. They are summarized in all seventeen Sustainable Development Goals, and ICTs as enablers of development, can serve them all, beginning with this ICT4SDG4 strategy.

Of greater immediacy is the need for skills to build the 4IR, and service the new forms of work that arise from it. Not all learners in the national education and learning process will graduate and rise to the levels of designing or building the higher order components of the 4IR. Even with the expected decline of traditional work resulting from 4IR automation, a large workforce will still be needed to maintain and even expand the current human environment, and to build and service the physical environment needed to support the 4IR world. The skills required range from relatively low-level skills that cannot be automated, to a very wide range of artisan and higher order engineering and technical professions. High quality vocational education and training through e.g. universities of technology and Technical and Vocational Education and Training (TVET) colleges remains a critical component of the nation's HET processes. This component also needs radical transformation and improvement.

[30] The Hechinger Report of 2015: Schools exacerbate inequality: https://hechingerreport.org/schools-exacerbate-the-growing-achievement-gap-between-rich-and-poor-a-33-country-study-finds/

The chart below, discussed in some detail in paragraph 4 on page 16 of this document, provides the starting point for the detailed analyses and strategic designs needed to transform South Africa's vocational training systems through ICT4SDG4. The current skills distribution in South Africa[31], linked to what South Africa needs to do to increase investments in vocational education and training, are:

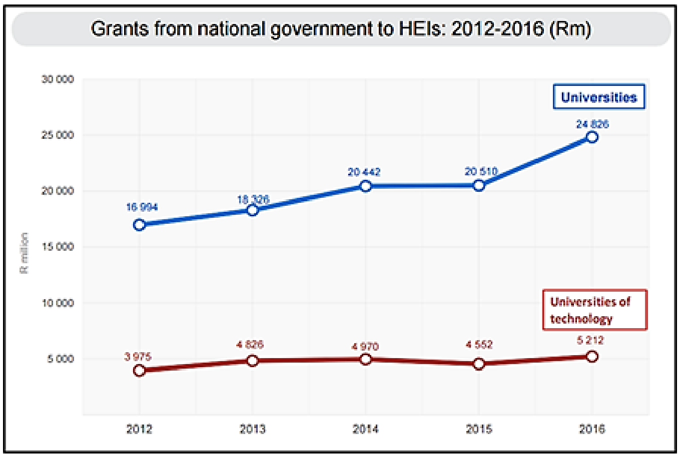
Table A7: Skills distribution in South Africa

• Skilled workforce: 13% • Number (2018): 1.27 million	• Semi-skilled workforce: 31% • Number (2018): 3 million	• Unskilled workforce: 56% • Number: 5.5 million

While detailed analyses of South Africa's 4IR labour force vulnerabilities have not been undertaken, global data suggests that up to 35% of "low-skilled" workers will lose their jobs through automation, from 2020 onwards. Based on recent STATS SA employment data of a total workforce of approximately 10 million, an unemployment rate of 27.7%, and an assumption that the "low skilled" definition applies only to the unskilled workforce of Table A7, a 35% decline of unskilled jobs will result in a rise in the unemployment rate to approximately 63%. The impact on the already high youth unemployment rate (more than 40%) will be severe. With South Africa's strong labour unions supported by a massive (±55%) economically excluded population, such a rise in unemployment could trigger significant societal disruption. Like all previous technological revolutions, the 4IR has the potential of creating new but different jobs, demanding all the new skill sets discussed in paragraph 3 on page 8 of this document. Can these skills, and the jobs that require them, be delivered to the 8.8 million semi-skilled and unskilled workers shown in Table A7 above?

Recommended Response:

Initiate massive increases in investment for improved delivery of vocational education and training for semi-skilled and unskilled workers, and for the future, for all learners at all levels of the school systems.



Source: https://www.southafricanmi.com/education-statistics.html

- Reinforce urgently the ongoing national efforts to improve the nation's TVETs;
- Rebalance the nation's investment in universities of technology without cannibalizing investments in academic universities – both need transformation;
- Broaden the scope of HET to develop the technological skills needed by the 4IR, and the human sciences skills needed to survive the 4IR;
- Examine ways of extending the current initiatives to extend the SABEN network to cover feeder schools in all economically marginalized communities, including rural villages, beyond the limitations of the current strategies and funding methods;
- Develop urgently the pedagogical tools for vocational education and training that are consistent with the needs of the 4IR.

Delivering against any of the above observations and recommendations will not be easy, it will require lengthy timeframes to modernize and refine current strategies, and add new ones to them. Can this slow but essential process stem the restlessness of the ±30 million South African citizens living below the national poverty lines? This question demands that parallel highly visible initiatives in addition to the formal state interventions are provided. The "bottom-up" public broadband access strategies recommended in this ICT4SDG4 South African initiative are one approach that will add short term value to the state's high-level long-term interventions.

A8. Impact on South Africa's unemployment: A major social challenge:

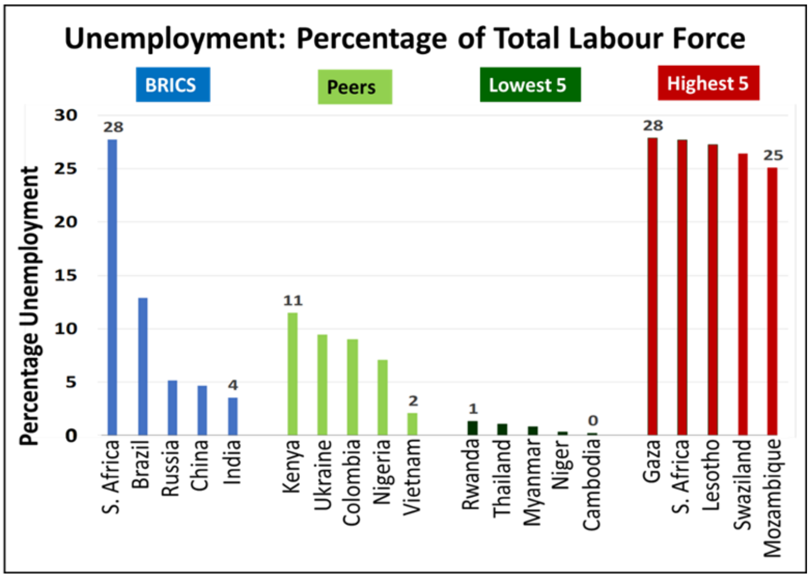
South Africa ranked alongside the West Bank and Gaza, Lesotho, Swaziland and Mozambique as the nations with the highest levels of unemployment in the world in 2017. This must be of concern to all South Africans and their businesses. Education is the best-known antidote to high unemployment levels, but educational

[31] STATS SA and World Bank MARCH 2018: http://www.statssa.gov.za/wp-content/themes/umkhanyakude/documents/South_Africa_Poverty_and_Inequality_Assessment_Report_2018.pdf

reform requires exceptionally long timeframes before results become visible. While national educational systems develop over time to produce 4IR-ready jobs, there is a growing level of anger, frustration and impatience in many developed and developing countries – e.g. the "*New French Revolution*" – the massive 'Yellow Vest' protests against poverty, unemployment, inequality – and the disastrous "*Arab Spring*". This restlessness will not wait for economic growth to "trickle down" to the poor. South Africa has already witnessed the beginnings of this threat. The current round of extreme socio-political instability in all regions of the world, South Africa included, is an example of the growing public restlessness that can be attributed to high levels of unemployment, poverty and inequality. In its annual report to the World Economic Forum of 2019, OXFAM reports that global inequality has grown to a level in which just 26 wealthy individuals enjoy the same wealth that 3.8 billion world citizens are obliged to depend on for survival. In the previous year, this wealthy "family" comprised 43 individuals, and in 2016, it was measured at 61 individuals.

South Africa's employment record, illustrated in the global benchmark chart below, is acknowledged by the nation's leaders, and is a source of great concern across the whole nation.

Unemployment in South Africa compared to the rest of the world



Derived from: https://data.worldbank.org/indicator/SL.UEM.TOTL.ZS?view=chart

This ICT4SDG4 chapter focusses on education, for job creation and much more. The specifics of employment opportunities and the risks of unemployment will be covered fully in the chapter ICT4SDG8 – *Decent Work and Economic Growth*. The chart above serves as a reminder of the immense challenges that South Africa faces. The equally massive challenges faced by the nation's education system are both cause and effects of this massive unemployment challenge. The impact of global changes made necessary by the 4IR, both the opportunities and threats unleashed by this immense technological evolution, complicates both the causes and effects of South Africa's labour and work challenges. Resolving the nation's unemployment challenges will demand exceptional competences in all the 4IR skills discussed briefly in sub-paragraphs 3.2.1 to 3.2.10. Negotiating with the powerful and often aggressive labour unions, strengthened as they are by their contributions to the national struggle for democracy, will demand all those skills, for which educational models and curricula have yet to be developed. These factors will be addressed in ICT4SDG8 still to be developed.

One disturbing feature of the unemployment chart above is that the global unemployment comparisons, and related inequality statistics not shown in this document, are dominated by the Southern African Development Community (SADC). South Africa is a leading member of this economic grouping. Can South Africa's educational reform processes contribute towards similar developments in SADC, and at the same time draw from the positive experiences from this community of nations?