Addressing Digital and Innovation Gender Divide: Perspectives from Zimbabwe

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1 Introduction

Digital technologies influence and shape every sphere of our everyday existence—from education and health to agriculture, transportation and communications. While technologies hold the promise of unprecedented opportunities for disenfranchised communities, conversations around women's access to digital technologies in Africa remains a topic for debate. Access to digital technologies in most of Sub Saharan Africa is limited to the passive use of mobile phones—one reason for this being the lack of, or inadequate level of digital skills. Sadly, these mobile devices are hardly used to enhance any form of computational thinking or innovation. Long-standing issues such as lack of education and exposure, employment and income, entrepreneurial support and unfavourable policies significantly lower women's ability to fully exploit opportunities presented by digital technologies. In addition, it is argued that lack of access to digital skills reinforces the digital gender gap for women in Africa, hence, the need to reflect on the different issues holding women and girls back from advancing in the technology sector.

Regardless of the high incidence of mobile phones that saw 20 million new mobile subscribers added in Sub Saharan Africa between 2017 and 2018 alone, digital skills remain very low especially amongst women (GSMA 2019). The Broadband Commission set up by UNESCO identified three tiers of digital skill levels—basic functional skills, generic skills and higher level skills (West et al. 2019). Digital literacy skills[1] have been recognised as imperative for sustainable development. Despite efforts to

[1] Digital literacy is the ability to access, manage, understand, integrate, communicate, evaluate and create information safely and appropriately through digital technologies for employment, decent jobs and entrepreneurship(. It includes competences that are variously referred to as computer literacy, ICT literacy, information literacy and media literacy (Nancy et al. 2018 p.6).

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close the digital skills divide, evidence still shows that the digital gender gap is growing (West et al. 2019). In Africa, there are increasing efforts to bring together players in the women in STEM movement to share ideas and experiences, collaborate and build a unified voice. Such programs include the TechWomen[a] program and ESkills4Girls.[b] Furthermore, regional grassroots-led policy and practice initiatives such as i4Policy[c] and Alliance for Africa's Intelligence (A4Ai)[d] are gaining ground in building that unified voice and pushing for policy reforms at the continental level based on the mantra 'a prosperous Africa for us by us' challenging the notion of externally driven policy initiatives.

This chapter highlights various ways in which women and girls can be enabled to leverage digital technologies and contribute to achieving Africa's Agenda 2063 and the Sustainable Development Goals (SDGs). The discourse focuses on initiatives that promote the participation of females in science, technology, engineering and mathematics (STEM), and also in information and communications technologies (ICTs). The chapter is structured as follows. Section 1 introduces the topic and arguments, Sect. 2 articulates key issues identified in the digital gender divide literature and Sect. 3 includes a case study of STEM/ICT initiatives in Zimbabwe. Section 4 discusses the similarities, differences and tensions identified in research and practice from the case studies and Sect. 5 provides recommendations for policy practice.

2 Focusing on STEM Skills

The African Union (AU) published an ambitious strategy called Agenda 2063[2] which aspires to build a prosperous Africa based on inclusive growth driven by all, especially, women and the youth (AUC 2015 p.1). The Agenda lists science, technology and innovation (STI) amongst the 12 identified priority areas stressing that technology is an enabler for attaining continental development goals (African Union 2014 p. 8). To support Agenda 2063, the AU also produced a 10-year strategy called Science, Technology and Innovation Strategy for Africa 2024 (STISA-2024) whose mission is to "accelerate Africa's transition to an innovation-led, knowledge-based economy." (AUC 2014 p.11). Both policy documents emphasize that building a robust Science, Technology, Engineering and Mathematics (STEM) workforce is a critical component of achieving the "Africa We Want" (AU 2014). This position concurs with Atkinson and Mayo (2010) who state that science and technology (S&T) based innovation is impossible without a workforce educated in (STEM). These actions signal a policy shift from a constricted focus on poverty reduction which lacked consideration for the key role that STI could play in alleviating this poverty (Chataway et al. 2005).

[2] Agenda 2063 is "Africa's blueprint and master plan for transforming Africa into the global powerhouse of the future. It is the continent's strategic framework that aims to deliver on its goal for inclusive and sustainable development and is a concrete manifestation of the pan-African drive for unity, self-determination, freedom, progress and collective prosperity pursued under Pan-Africanism and African Renaissance" (AUC 2015).

2.1 *Why the Need for STEM Skills?*

Extensive scholarly work, research and policy documents attest to the significant role that STEM plays in driving innovation, which in turn contributes to economic growth, competitiveness and employment creation (Rosenberg 2004; Ismail 2018). Predicting trends in the 21st Century, the World Bank reported that economic progress would be driven by the ability to innovate and to relay that knowledge (World Bank 1998). Amidst a rising population and dwindling resources in Africa, achieving significant economic growth that is both inclusive and sustainable requires thinking of creative ways to produce more from the limited resources (Rosenberg 2004). This ability to 'think of creative ways' can be enhanced through acquisition of STEM skills, particularly in the younger generation, women and girls included. This inclusion of women and girls in STEM education and skills development is essential to progress in STI, fostering economic growth and achieving the SDGs (Daniels et al. 2017). Atkinson and Mayo (2010) use allegories that as factories are to industrialisation, so is STEM labor force to a technology economy; thus emphasising the need for STEM education.

2.1.1 Skills Gap—Bridging the Supply of STEM Skills in Africa

Reports estimate a shortfall of five million scientists and engineers in Africa, 80% of new students opt for non-STEM studies instead (Hooker 2017 p.14). Several issues contribute towards this STEM skills deficit and they vary in source and scope. The skills gap could be attributed to a mismatch between industry requirements and educational focus indicating the need for closer collaboration between industry and academia. Another mismatch is the failure of STEM education to address local development needs, thus not bringing value and impact to the society. Therefore, there is a need to redefine school curricula so that students can acquire skills which are transferable, versatile, resilient and useful to the society (Ismail 2018). Most Africans are engaged in the informal sector where women constitute about 70% of the workforce, but, studies and policy responses focus on formal jobs (Madzwamuse and Kouakou 2018). Current discourses on innovation and emerging technologies such as Artificial Intelligence (AI) are a good example of this disconnect. As policy responses towards the fourth industrial revolution (4IR) are being tabled, they should incorporate these realities to avoid deepening already existent digital inequalities (Madzwamuse and Kouakou 2018).

2.1.2 The Gender Gap in STEM/ICT—From Skills Gap to Gender Gap

The corresponding relationship between technology and society indicates that technologies themselves are not gender neutral and must, therefore, be tailored to become relevant and useful to all, including women and girls (Harwood 2011; Rajahonka and

Villman 2019). This process of 'tailoring' the technologies requires attainment of education and skills by everyone, in ways that ensure that women and girls are not excluded. The level of education in a society has an effect on technology uptake, hence, women's lower uptake of technologies can be attributed to disparities in education and income levels in favor of men (Benhabib and Spiegel 2005). Sadly, women constitute two thirds of illiterate adults worldwide and the majority live in developing countries (United Nations Statistics Division (UNSD) 2015). The magnitude of the gender gap in STEM is highlighted in the next section. The AU has, however, published several policies in an attempt to redress this gender gap in STEM. These policies include the Addis Ababa Action Agenda, the Nairobi Declaration and the AU Strategy for Gender Equality and Women Empowerment under Outcome 1.3 (Technology & E-inclusion) (West et al. 2019; AU 2018). These policies demonstrate willingness by the AU to address the current gaps.

2.1.3 Why is the Gender Gap in STEM Topic Important?

The United Nations Education, Scientific and Cultural Organisation (UNESCO) states that access to STEM education is a human right (UNESCO 2017 quoted in Ismail 2018). However, evidence shows that across the world only 30% of female students pursue STEM related higher education studies (Ismail 2018). The figures are much lower in fields such as engineering and computer science, which range from 7 and 17% respectively (UNESCO 2015). Women currently represent only 30% of ICT workers in Europe and have created only 9% of ICT applications (Rajahonka and Villman 2019; Petray et al. 2019). Women are, thus, underrepresented in creation and design of solutions which considerably lowers their contribution towards innovation and economic growth. Researchers forecast that the STEM gender gap will adversely affect the future of women's work if action is not taken to capacitate women and girls in STEM forthwith (Madzwamuse and Kouakou 2018). Modern jobs are highly integrated with digital technologies and thus, demand competencies in STEM to fully exploit the opportunities they present (Madzwamuse and Kouakou 2018).

What could be the reason then for the STEM gender gap? Contrary to common belief, studies indicate that girls are not technophobic. Instead, they outdo boys in using digital tools such as blogging (referred to as pink content), but, are overtaken in the use of more complex digital technologies (Hayes 2008). This preference of one over the other necessitates further investigation given that digitalization has been proven to increase opportunities for women in business and self-development (Rajahonka and Villman 2019).

> Women and girls are 25% less likely than men to know how to leverage digital technology for basic purposes, 4 times less likely to know how to programme computers and 13 times less likely to file for a technology patent (West et al. 2019 p.4).

The above statement shows that the number of women engaged 'with' technologies drops significantly as we move up the value chain of digital skills. To add another layer, women and girls in rural areas have lesser access to digital technologies and hence lower uptake than their urban folk. The correct reading of a country's STEM competencies should, thus, reflect the rate of diffusion in rural areas where the majority stays (The World Bank 2008). In Africa, where 60% of the population lives in the rural areas, more attention should be given to the internal diffusion of technologies (UNECA 2017; The World Bank 2008).

2.2 What Are the Causes?

According to Yu (2017), hindrances that limit the uptake of STEM by women and girls can be placed into three categories—the development of interest; the acquisition of skills and penetrating the workforce. Barriers to entrepreneurship (monetizing STEM) could be included as an additional category since women face various impediments in technology entrepreneurship. The list is not exhaustive, but, focus here is placed more on factors that are in line with the mandate of this paper.

2.2.1 Barriers to Developing Interests

Fewer women occupy leadership and influential positions in the STEM sector which makes it difficult for girls to access and relate to female role models and consider STEM as a career of choice. Only 24% of all jobs in the digital sector are occupied by women and in developing countries men have 2.7 times more opportunity to work in the digital sector than women (West et al. 2019; Petray et al. 2019). Patriarchal cultures entrench gender inequalities, limit access to facilities and resources for women and girls. As a result, girls and women are similalrly exposed to violence online as offline, effectively intimidating and sealing off the space for girls, who would otherwise, explore opportunities there. Patriarchy also reinforces financial dependence and imposes power and control over women's decisions thereby throttling choices into and/or to remain in STEM (Yu 2017; Madzwamuse and Kouakou 2018).

2.2.2 Barriers to Developing Skills

The majority of science teachers are male teachers who sometimes have a preference for working with boys over girls (Yu 2017; Petray et al. 2019). These teachers reinforce gender stereotypes and relegate female students to menial tasks (considered 'girl-ish'). A survey conducted in Vietnam noted that for the Math subject, 65% of teacher interactions were with boys compared to only 35% interactions with girls (Yu 2017). Confidence levels in STEM decrease as girls grow older, dropping more rapidly at tertiary level due to lack of exposure and limited interaction time with technologies for honing STEM skills (Petray et al. 2019; Madzwamuse and

Kouakou 2018; West et al 2019). Another critical dimension is that girls are more modest with professing their abilities as compared to their actual performance which dampens their motivation and resilience (Petray et al. 2019). Here, perception of the system, in general, also comes into play. Students' choices are limited by how they perceive scarcity of resources such as laboratories and materials for practicals and the limited number of schools that offer science subjects at advanced level.

Petray et al (2019), challenge the leaky pipeline[3] metaphor citing it as a problem in itself in that it symbolises a singular pathway into STEM instead of making STEM attractive to all girls, what Atkinson and Mayo (2010) refer to as 'Some STEM for All' (Petray et al. 2019; Atkinson and Mayo 2010; Mosatche et al. 2013). Atkinson and Mayo (2010), instead, propose adopting the 'All STEM for Some' approach which only targets high achievers in STEM. On the contrary, Petray et al (2019) suggest that girls should be engaged from various capabilities and dispositions, giving opportunities to young women to explore their curiosity for innovation (Petray et al 2019). Weak digital literacy in the population limit the impact of technologies on economic activity in that users are less inclined to explore digital technologies for more economically useful activities such as building products and expanding markets (The World Bank 2008). Both approaches, 'All STEM for Some' and 'Some STEM for All' are essential to groom both creators and a market for the created products, respectively. It requires a certain level of competency to use and derive the most benefit from digital technologies.

2.2.3 Barriers to Entering the Workforce

Fewer women occupy roles at the frontiers of technological innovation such as machine intelligence—current predictions indicate that this technology will offer more rewards in terms of growth and compensation (West et al. 2019). Discrimination in the workplace manifests in various forms for women and include gender stereotypes and insensitivities, unpaid care work, unfair hiring processes and inflexible working hours (Yu 2017). Diversity in technology encompasses the ability to mirror the composition of society, for example, race, ethnicity, geography and socio-economic status. The values espoused by innovators are mirrored in the technologies they build, hence, the need to identify and prevent biases in the design, development and deployment process through a diverse workforce (West et al. 2019). A lack of diversity in the choice, manipulation and use of the data in building AI systems is likely to aggravate existing inequalities (Madzwamuse and Kouakou 2018). Organisations can go a step further and ensure that their systems are fully inclusive, moving from mere presence (diversity) to being given the platform to meaningfully contribute.

[3]The leaky pipeline refers to attrition at different stages of education and employment for women in STEM and ICTs despite increased recruitment of diverse students and staff (Watson & Froyd, 2007 in Petray et al., Australia).

2.2.4 Additional Barriers

The rate of female technology entrepreneurship and support given to female entrepreneurs is much lower than that of men, but, the proportion of women in informal business is higher (Madzwamuse and Kouakou 2018; Knowledge @Wharton 2019). In 2018, companies founded by women, globally, received only 3% of venture funds (Thygesen 2019). Digital technologies can lessen the burden to access skills, capital, markets and networking for women. The source of motivation for entrepreneurs differs, therefore, interventions should be tailored. For example, those who embark on entrepreneurship as an alternative for employment have different needs and commitment levels to those who do so to create value (Yu 2017).

2.3 Out of School Initiatives

Several initiatives across the continent have been launched to promote STEM amongst girls. Out of school initiatives (OSIs) are run by different names such as STEM, Coding, Robotics clubs or digital literacy programs. These initiatives are run by individuals, non-profit organizations or corporates through their corporate social responsibility (CSR) arms. They can be run independently or in partnership with relevant government departments. OSIs are set up to prepare girls with the knowledge and skills required for an innovation-led economy. Recruitment of participants is quite flexible based more on the girls' attributes, particularly, imagination and commitment (Petray et al. 2019). Inclusive participation is at the core of these activities ensuring that a girl's passion and curiosity for STEM is not inhibited by her background (Petray et al. 2019). OSIs identify and build on community assets—'resources in which poor people are rich' (Gupta 2013 p.18). These programs involve stakeholders who can influence girls' participation in STEM such as mentors, family, schools and the STEM-related industries (Petray et al. 2019). Hayes (2008) suggests that interventions should be made at the middle school level as it is the time that differences in perceptions about computers heighten.

2.3.1 What Can Be Done to Build Computational Thinking?

The role young women will play in STEM and in the fourth industrial revolution era will be determined to a large extent by changes in the educational system (Madzwamuse and Kouakou 2018). These changes should allow depth in digital design, innovation and engineering skills, incorporate gender sensitive delivery and dispel the notion that STEM curricula is irrelevant to girls (Madzwamuse and Kouakou 2018; Yu 2017; Petray et al. 2019). Adding the fun component is instrumental in increasing girls' curiosity for digital technologies, through for example, access to gaming and suitable games (Madzwamuse and Kouakou 2018; Yu 2017).

Inclusion should be mainstreamed in all programs and processes to avoid excluding girls who do not self-identify as the "STEM type"[4] (Petray et al. 2019; Hayes 2008). Schools should shun attributing hierarchies on subjects so that the blending of technical knowledge in STEM with soft skills is not hindered (Petray et al. 2019). Increasing the number of female STEM teachers will reinforce STEM as a female domain and increase girls' interest and confidence in STEM (Madzwamuse and Kouakou 2018; Yu 2017). The media plays a crucial role in sharing, amplifying, linking and making success stories of Women in STEM accessible to girls. Maker movements are a good example of some of the initiatives which encourage practical as opposed to abstract learning (de Beer et al. 2017). Grassroots campaigns such as hackathons and bootcamps, can help secure and sustain interest for girls to pursue STEM by delivering courses which empower girls to address community challenges through learning by doing, tinkering with various components (Madzwamuse and Kouakou 2018; Yu 2017). Field trips also help to connect theory to practice by gaining access to role models in their workspaces (Mosatche et al. 2013). However, mentors' should be trained prior to engagement with the girls to acquaint them with the objectives of the programs and any gender in STEM nuances which they may be blind to (Mosatche et al. 2013).

2.3.2 What About Entrepreneurship?

Entrepreneurial tendencies, like STEM identities, need to be developed early on by connecting science to real-life scenarios where the young women are empowered to identify and solve problems in their communities using technology (Mosatche et al. 2013). Technology and entrepreneurship interventions embed business development while providing access to devices and connectivity. When girls work with technologies created elsewhere and modify such technologies to suit their context, they exhibit some level of entrepreneurship and risk taking (Yu 2017; Rosenberg 2013). These programs should carry some form of incentive to reward both effort and ingenuity. The programs should also incorporate continuous learning and iteration for both the beneficiary and the convener (Mosatche et al. 2013).

2.3.3 Shortcomings/Areas of Improvement

A common challenge amongst Girls in STEM/ICT program initiators is the difficulty in managing impact assessment especially in the long term (Petray et al. 2019). This could be due to lack of competence in the area but mostly lack of funding and the difficulty to keep track of a highly mobile demography. Impact assesments are critical in advocacy work to convince governments to invest in STEM initiatives

[4]STEM identity is defined by Carlone and Johnson (2007) as a way in which individuals make "meaning of science experiences and how society structures possible meanings" (Carlone and Johnson, 2007 p. 1187).

based on concrete evidence. Finding work placements or internships for graduates of these programs is another challenge faced by conevors of these programs. Here, private sector partnerships are critical to offer the women and girls an opportunity to experience and familiarise themselves real world scenarios and increase their chances for employability.

3 Case Study—Zimbabwe

3.1 The Economic and Digital Context in Zimbabwe

Zimbabwe is a country in Southern Africa, known for its high levels 2018 of literacy which currently stands at 94.7% and is a result of policy focus towards education soon after gaining independence from Britain in 1980 (Government of Zimbabwe 2018; Sibanda and Makwata 2017). However, statistics on gender representation in STEM remain low and mirror those of the rest of the world. According to Zimbabwe National Statistics Agency (ZimStat), women constitute about 40% of enrolments in natural sciences but the figures are much lower in computer science (16%) and engineering (7%) (Zimbabwe National Statistical Agency 2016). The government recently launched the economic blueprint 'Towards an Upper Middle Income Economy by 2030' known as Vision 2030[5] and the Education 5.0 model which has a thrust towards innovation and industrialisation and is meant to catalyse the attainment of the vision. Surprisingly, the Science, Technology and Innovation Policy is silent on STEM gender representation measures and lightly mentions encouraging interest across gender (Government of Zimbabwe 2012). Notably, the government has set up 6 innovation centers at 6 state universities country wide to support research and development and they also intend to establish 10 industrial parks in each province (Chaparadza 2019; Government of Zimbabwe 2019a).

Increased interactions, transactions and activities online are shaping and accelerating the growth of the digital economy in Zimbabwe. This is supported by a high mobile penetration rate (87.7%) and increased access to the internet (51.9%) mainly through mobile phones, according to a report by POTRAZ (Potraz 2018). About 97.7% of internet users in Zimbabwe access the internet through mobile phones (Potraz 2018). Also, financial inclusion has increased due to the rapid diffusion of mobile money transfer systems positively impacting the welfare and the livelihoods of previously marginalized and unbanked populations. According to POTRAZ, mobile money subscriptions increased by 12.6% in the first quarter of 2018 (Potraz

[5]The new government is quite aggressive in its approach, and has recently launched Education 5.0 which is centered on the Heritage based philosophy in shaping future technology through innovation and industrialization (Government of Zimbabwe 2019b). The current economic blueprint, Towards an Upper Middle Income Economy by 2030, stipulates that the government will pursue bold steps to empower its entrepreneurs and cultivate innovation at every level (Government of Zimbabwe 2018).

2018). A widening gap in gender representation and skills; poor infrastructure, policy gaps and weak entrepreneurial support is, however, impeding progress in this sector (Johnson 2018). Zimbabwe is ranked 159 out of 190 countries on the Ease of Doing Business (The World Bank 2018). The regulatory environment obtaining in the country is not conducive for innovation, and is a major drawback to the growth of the entrepreneurial ecosystem in the country. It is difficult for start-ups to navigate the challenging regulatory terrains, including from registering the business to managing precarious monetary policies. On the other hand, the government has responded either indifferently or with heavy handedness towards potentially disruptive innovations.

In May 2018, the Reserve Bank of Zimbabwe (RBZ) banned crypto-currency trading highlighting two start-ups Bitfinance Private Limited and Styx24. According to the RBZ, the move was aimed at protecting and safeguarding monetary infrastructure and consumers' interests against money laundering and fraud amongst other vices. The Bitfinance company is still operating in other SADC countries (Reserve Bank of Zimbabwe 2018). Tait and Banda (2016) suggest the adoption of adaptive and proportionate regulation to ensure that innovations thrive at the different stages of development.

3.2 Experience Implementing STEM Initiatives in Zimbabwe

In this section, I share briefly on some of the work I have done training and convening women and girls in STEM initiatives in Zimbabwe in the past 6 years. Although mainly based in Harare, the capital city, I have also coordinated programs in other cities and in rural areas. Through these programs, young women go through coding, robotics, digital literacy and entrepreneurship courses to prepare them for the highly competitive world of work and business. The target groups are girls in high school, out of school youth and young women, mainly between 15 and 25 years of age. The programs are engineered to empower and equip women and girls with relevant digital skills so that they can become intelligent creators and users of technology. The main goal of these initiatives is to increase the number of female-led ICT and STEM based startups focusing on the grassroot. These initiatives have been supported mainly through volunteers and bootstrapping as well as partnerships with development agencies, schools, government ministries and agencies and corporate sponsorship, mainly Internet Service Providers (ISPs). The programmes have been focused largely on disenfranchised communities because, being underserved "does not entail poverty of the mind or morals" (Gupta 2013 p.18).

Initially, we implemented a global technology and entrepreneurship programme for girls locally (Technovation Challenge[6]). About 150 girls from Harare and Bulawayo participated. A total of 20 mobile app prototypes were built in that season

[6]The Technovation Challenge is an annual global competition for teams of young girlsto learn and apply the skills needed to solve real-world problems through technology. Available at https://technovationchallenge.org/.

alone. However, we stopped running this annual programme after only two seasons. There are challenges associated with implementing programmes developed in high income countries in less developed countries (see the proceeding section). After the competition, we noticed that there seemed to be no articulate support infrastructure to further develop the most promising prototypes. Eventually, we established an entrepreneurial support hub focusing mainly on the youth and female innovators. Still, gaps in systems, processes and infrastructure to support innovation and technology commercialisation in Africa. More than 1000 women and girls have since benefited from our digital literacy programs. Most of the beneficiaries have gone on to study sciences at advanced and tertiary level. Of the beneficiaries that decided to pursue other fields such as law and hospitality, they showed an appreciation of the enabling and crosscutting nature of digital technologies. Some of the girls have participated in pitch events, where they pitched their business before a diverse audience who included potential investors, gaining valuable feedback for their enterprises. Women already in STEM and ICT participated as coaches and mentors, including male STEM champions.

In addition, we trained 957 smallholder farmers, 727 of which were women, on mobile literacy for an international NGO in support of the rollout of mobile based bundled services. The purpose of the training was to stimulate the uptake and accurate use of the services amongst users, mainly women small holder farmers. Partners included a farmers' union organization for mobilization of beneficiaries, agricultural extension officers and mobile network operators for farming and product queries, respectively. Relatedly, STEM/Coding clubs have been established in some partner schools. One of the accomplishment is that both teachers and students have been trained as STEM champions as part of a project dubbed 'Digital Aspirations." Apart from the coding workshops, the project also had dialogue sessions where topics related to the digital economy where discussed by a diverse panel putting forth recommendations for both policy and practice. Furthermore, a team of students has been selected and trained in the past three years to represent Zimbabwe in the annual First Global Challenge,[7] a global robotics competition for students 14 to 18 years of age. Participants have gone on to present their ideas and results before policymakers[8] advocating for STEM Education policy reforms.

3.3 *Challenges and Opportunities*

After participating in our programmes and gaining interest in STEM, some students complained that their schools did not offer their desired STEM subjects

[7]FIRST Global is an annual global robotics challenge to ignite a passion for Science, Technology, Engineering, and Mathematics (STEM) among the more than two billion youths across the world. Available at https://first.global/.

[8]The Deputy Minister of Higher and Tertiary Education, Science and Technology Development and the Parliamentary Portfolio Committee on ICTs between September and November 2017.

at advanced level such as computer science. Also, some schools randomly designate subject areas in the lower classes which makes it difficult to change subject areas at a later stage, for example, a student designated to a commercials class would not be allowed to opt for sciences at advanced level. Implementing global programs locally is a good starting point but has its own set of challenges. First, the programmes use platforms that require a higher bandwidth of internet connectivity, which means internet access on its own is not enough but the quality of the connection too. In the first year the schools brought students to a central location (hub) for training sessions but complained that the programme was stretching their transport budgets. In the second year, we pivoted and as trainers travelled to the schools indeed. This stretched our capacity and the poor internet connections at the schools did not help much. Volunteer mentors could not faithfully commit to weekly meetings over a 12 week period without any form of incentive or support, either from us or their respective employers.

In addition, economic challenges in Zimbabwe have resulted in many industries shutting down. This means that there are less industries to absorb STEM graduates, further reinforcing negative perceptions and choice of STEM as a career of choice. Correspondingly, funding is scarce, therefore, necessitating the need to explore creative ways of sustaining digital technology initiatives aimed at improving the skills of women and girls. For the most part funding from development agencies is directed towards programmatic costs, making it difficult to sustain operations resulting in fatigue and burnout, withdrawal of both regular and permanent staff and susequent closure. Where available, financial support from the private sector is usually directed towards once-off events, instead of long term projects. Both public and private capital is needed to scale initiatives for greater impact.

Work placements for graduates from digital skills initiatives for women and girls are critical. The private sector can offer support by absorbing some of the graduates into the workforce through internships, outsourcing or permanent placements. Longstanding infrastructural issues such as internet connectivity, access to devices, materials and laboratory facilities and reliable electricity remain a major problem.

Despite these challenges, the tech and entrepreneurial ecosystem, though nasscent, is vibrant and growing. Figure 1 below is an ecosystem map for the Zimbabwean entrepreneurial community conducted by Briter Bridges in collaboration with ecosystem players in Zimbabwe. The map presents a picture of the entrepreneurial activities in Zimbabwe listing the startups according to the sector they operate in, supporters and events. The map also indicates that much of the entrepreneurial activities in Zimbabwe are around fintech and blockchain technologies. As the ecosystem grows further, it is imperative that programmes and policy interventions that aim to groom and support more female founded start-ups are established and adequately financed.

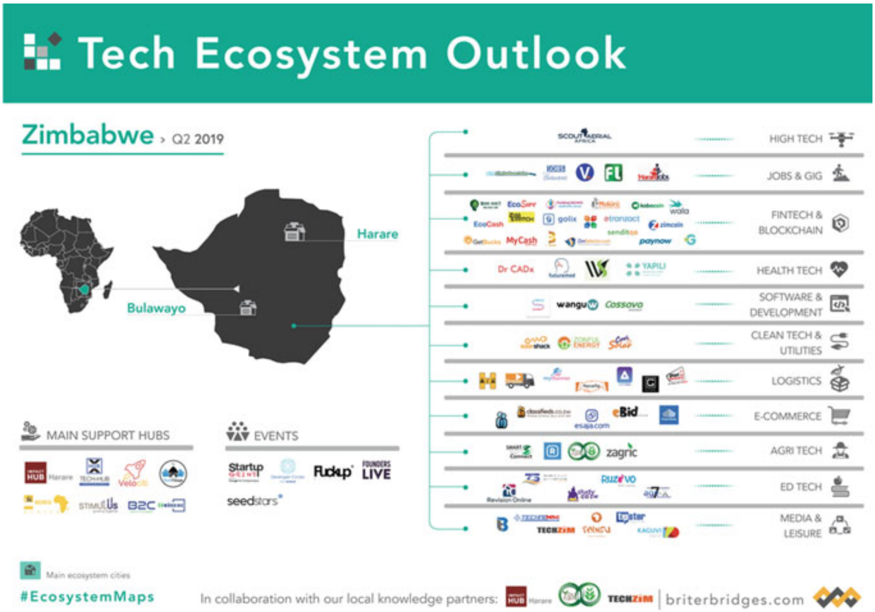

Fig. 1 Zimbabwe tech ecosystem outlook. *Source* brighterbridges.com

4 Discussion

This section discusses the tensions, opportunities and gaps identified from experience working in the Women and Girls in STEM and ICTs, innovation and entrepreneurial ecosystems in Zimbabwe and in the region. Some of the discussion points, are however, transversal in nature.

4.1 *Suitable Policies*

Appropriate government policies and regulations can help bridge the gaps discussed in the preceding sections and bring relevant players together, forming linkages between sectors and supporting innovation at grassroots level (Daniels 2014). I outline some areas where policies can promote the development of STEM and ICT skills amongst women and girls, drawing from my practical experience from running multiple programmes and initiatives in Zimbabwe.

Gender Equality in STEM: Current gender equity programs fail short in addressing the soft barriers such as cultural and social stereotypes and unconscious bias against women in STEM. Women and girls are solution oriented and given a conducive environment they can thrive. Our initiatives do not force STEM on girls; rather, we expose them to different possibilities so that they can make informed choices. Our programmes acknowledge the important contribution of the arts, creative and social studies to technology throughout the innovation process. Teachers play a crucial role in influencing career choices, it is therefore, imperative to bring gender mainstreaming to the education sector. Similarly, parents also play an important role and should thus be considered part of the solution in building STEM identities early on.

Curriculum and infrastructural reforms: Curriculum changes shifting emphasis to the practical element of learning are commendable though the roll out is ill-funded. Access to computer and science laboratories, internet and qualified staff is limited, especially for rural schools. Resource sharing could be introduced, for example between private boarding schools in rural settings and the rural schools in their proximity. There should be some flexibility allowed in choosing subjects to study at the different stages of high schooling. Schools in some areas do not offer science subjects at all at advanced level due to the cost associated with setting up laboratories prejudicing students interested in STEM within their jurisdiction.

Support for grassroots innovators: There is a policy gap on how innovators at grassroots can be supported or absorbed into mainstream innovation system. There is need to shift from traditional state dominated interventions to more coordinated forms which involve a variety of non-state actors. Daniels (2017) stresses the need to 'transform, rethink, or re-imagine innovation' in an all-encompassing, sustainable and solution oriented way (Daniels 2017).

4.2 Building Capabilities

Our projects are focused on building capabilities in technical know-how, financial management and improved soft skills which are necessary for both employability and entrepreneurship and to narrow the gap between women innovators and their male counterparts.

Technical skills—Movement towards a digital economy requires fluency in the use of digital tools and devices, and more importantly knowing how to create solutions. Making use of locally available resources, social capital and open technology tools and platforms can immensely reduce costs of implementation. Programs should be tailored to allow for both virtual and offline mentorship. Africans in the Diaspora can be incorporated into the mentorship matrix and assist in grooming young women's skills to become both locally relevant and globally competitive. It is essential to be amenable to change and pivot in response to prevailing economic situations. However, scaling of these initiatives still requires government support and therefore, public funds should be availed towards these programmes.

Entrepreneurial skills—Possessing great ideas does not equate to knowing how to build a business case around it. Incubation programs bridge the gap for early stage start-ups, taking them through business development, value creation and investor preparation. Most innovators with a STEM background struggle with understanding and articulating financials for their start-ups. Although it is not necessary to be skilled in every area, a basic appreciation of finances is critical for entrepreneurs. A good starting point would be making business studies mandatory in schools at an earlier stage, fostering creativity and risk taking attributes.

Soft skills: Problem solving, negotiation, creativity, team play, cross cultural management and presentation skills are vital for career and business success. Experimentation, iteration and ubuntu are critical elements embedded in our training programmes. The beneficiaries are equipped with skills to manage both success and failure, organise community outreaches in less privileged areas and do advocacy work.

Policy priorities: Some quarters postulate that digital skills are not a priority for Africa and are therefore, a waste of resources. They believe focus should be on fixing basic needs such as food, health and clean water. There is, therefore, a need to clearly articulate the link between science and humanity and the role that science and technology play in day to day life to get buy-in from policy makers. This requires a multi-stakeholder approach which includes media for improved STI communication, cognizant of the fact that STEM is not a silver bullet. Policy makers should also be equipped with digital skills to so that they can debate on digital issues from an informed perspective. There are fundamental structural and governance issues that need addressing first, more research is required to provide demonstrable proof that STEM and ICT for development (ICT4D) skills are crucial in solving the several challenges faced by the continent.

Data paucity: Published evidence on the importance of girls' education in STEM in Africa is not readily available, forcing researchers and practitioners to infer trends from global surveys. External researchers may fail to articulate the cultural nuances that local researchers are able to pick on. Public funds are vital for research aligned to local needs and agendas and governments should ensure that policies that support the production and open sharing of relevant data are put in place to facilitate access to important data by researchers.

Mismatch in approach: There is a huge mismatch in approach, selection of participants and focus areas between interventions at grassroots level and what is offered in mainstream education. STEM advocates are then misconstrued as driving foreign agendas or failing to appreciate local contexts and priorities. STEM advocates should, therefore, deliberately increase interaction with and involvement of government officials in programme delivery to dispel any misunderstanding and build mutually beneficial relationships.

4.3 Intellectual Property Protection

Intellectual Property (IP) issues are a serious concern for innovators to the extent that potential innovators shy away from sharing their ideas fearing IP theft. The major concern is around predatory corporates whom they accuse of using or stealing their ideas leveraging on their vast resources. IP protection is not a clearly understood area, and is beyond the scope of most STEM advocates and hub managers. IP experts are, therefore, essential for consultancy and advice. Some of the pain points around IP shared by innovators include questions on how to protect their ideas and at which stage they can do that. Teece (1986) states that "If there are innovators who lose there must be followers/imitators who win" rightly pointing out that innovators, in most cases, are not the ones who derive the most benefit from their innovations (Teece 1986). Unfortunately, bigger firms have stronger and more established complimentary assets and will likely prevail over start-ups.

4.4 Impact Measurement

Challenges exist on how impact can be attributed solely to our interventions in an uncontrolled environment and how to find mechanisms to measure and differentiate cases of good and bad impact. Another example is that an entrepreneur (beneficiary) connected to a potential investor can disclose the intricacies of the ensuing deal at their sole discretion. If they choose not to, this critical information will be missing in impact reports. We also make use of impact stories to show intangible impact such as motivation and inspiration, but, it is a challenge to present such stories as evidence before policy makers who demand hard facts and concrete evidence.

4.5 Access to Early Stage Capital

Support to early stage innovators is limited. Venture capital is limited and angel investors are still very few in Zimbabwe, if any, and generally quite nascent in sub-Saharan Africa. Public funds are vital during this delicate level of the entrepreneurial growth phases. Donor dependence severely limits creativity and innovation; donors are mostly driven by their own agendas which may not fit in well with local needs and priorities. Stirling (2014) stresses that innovation democracy encompasses the ability to determine the values, priorities and direction of innovation processes and outputs. Innovators should be empowered to make these choices, particularly female innovators who have to contend with other additional structural issues.

4.6 Access and Affordability

Limited access to the internet and digital devices affects mostly women who may not possess or control their own finances. For instance, Zimbabwe is ranked second for the most expensive mobile data in sub-Saharan Africa (Ecobank Research 2018), faring poorly both in real and income relative measurements. Thus, data charges are exorbitant and beyond the reach of many. This lack of access, severely limits practice time and skills development outside of training sessions.

4.7 The Role of the Media

The media plays an important role in giving STEM the face that students can relate to and see within their reach. The media can be instrumental in doing away with labor concealment, highlighting instead, the achievements made by women as researchers, inventors and entrepreneurs. The Next Einstein Forum[9] has already started showcasing extraordinary African scientists and technologists doing phenomenal work around the world.

5 Conclusion and Recommendations

Promoting innovation and entrepreneurship in Sub Saharan Africa requires building the right STEM and ICT skills set that enable the development and deployment of solutions which address relevant societal problems. Inclusion is a critical component in development—thus the need to improve the computational thinking and entrepreneurial skills of women and girls using digital technologies. Context, space, delivery, positive reinforcement, increased and varied interaction with digital technologies are all critical factors in increasing the participation of women and girls in STEM supported by the right and accessible infrastructure and policy environment. There is need for boldness to challenge and redefine, in the right time, existing educational systems which carry a colonial legacy—systems entrenched for ages require time to distill and dismantle. Multi-pronged policy responses make it difficult to determine what works, what does not and what to drop off completely, therefore it is incumbent upon each community to determine their area of intervention focus. We suggest research on the assessment of the direct impact of the initiatives and programs in women and girls in STEM run over the past ten years at country and continental level, to build a local database for ease of reference and also to inform policy. Comparative research for Women and Girls in STEM has been conducted across countries and regions, but, research focused on internal diffusion and impact Vis a vis the needs of that community needs to be explored. Additional dimensions to deal with include fixing regulatory hurdles and ensuring that potential high growth innovations from the grassroots are not shut out by the system before their potential is fully realised. Another dimension is the establishment of relationships between

[9]The Next Einstein Forum is an organisation working to make Africa a global hub for science and technology and hosts the largest biennial science and innovation gatherings in Africa. Available at www.nef.org.

innovation centers in universities and entrepreneurial hub ecosystems so that the conventional innovation centers can offer guidance and expertise to innovators at the grassroots and in turn receive the innovative edge and agility embedded in these communities. Development partners can use their convening power to create platforms of engagement to bring together relevant stakeholders to co-learn and co-create a way forward.

5.1 Recommendations

5.1.1 Governments and Policy Makers

- Release public funding to support innovation and include support for innovation at grassroots. Run open challenges to solve specific issues in society and encourage young women to participate by setting aside specific funding for them. Support women and girls in STEM programs and allocate a portion of universal service funds towards these programs.
- Introduce subjects that are in line with the demands of the digital economy to prepare student for the future of work. Encourage experiential and hands-on learning activities, for example, introducing robotics as a practical subject. Online safety should be embedded in curriculum from a human rights and security perspective for student to appreciate data and privacy issues online.
- Incorporate ethics and gender components in science curriculum from primary school to raise awareness and equip both boys and girls with the skills to correctly respond to gender dynamics in STEM early on.
- Give schools a level of autonomy in determining additional activities they may want to engage in. Build systems that work, continuously review and do not be afraid to change what does not work.
- Incentivise the participation of role models and mentors through, for example, tax cuts to individuals and companies that run formal mentorship programs to motivate and retain more women and enhance girls' interest in STEM and ICT.
- Train and appraise legislators on current digital trends and give them skills to properly adjudicate on digital matters from a well-informed position.
- Fund research on the state of women and girls in STEM including civic society initiatives and grassroots innovation to understand the state of affairs and make decisions based on evidence.

5.1.2 Girls and Women in STEM/ICTs and Innovation Communities

- Coalesce and build a unified voice for advocacy and become credible access points for policy.
- Identify and train male champions. Some girls testify that their role models are men who have inspired, encouraged and supported them to pursue STEM.

- Promote Afro centric traditional modes of financing that offer solutions which can be adapted to suit the times as an avenue for community support of innovation.
- Engage with government as allies with a common goal not as antagonists.

5.1.3 Private Sector

- Establish formal mentoring programmes specifically targeting girls and young women;
- Support women and girls in STEM and ICT by offering facilities for training and networking, identifying areas of shared value.
- Fund locally grown initiatives as a long term investment towards human capital development.
- Tap into the entrepreneurial capacity of young women by organising innovation challenges in collaboration with Women in STEM communities through, for example hackathons, for specific product or service innovations.

Notes

a. TechWomen empowers, connects and supports the next generation of women leaders in STEM from Africa, Central and South Asia, and the Middle East by providing them the access and opportunity needed to advance their careers, pursue their dreams, and inspire women and girls in their communities. Through mentorship and exchange, TechWomen strengthens participants' professional capacity, increases mutual understanding between key networks of professionals, and expands girls' interest in STEM careers by exposing them to female role models (TechWomen 2019a).

b. #eSkills4Girls initiative tackles the existing gender digital divide in particular in low income and developing countries to globally increase the access of women and girls in the digital world and to boost relevant education and employment opportunities. It is an initiative of G20 members in partnership with UNESCO, UN Women, ITU and OECD (eSkills4Girls 2019b).

c. i4Policy is an initiative by African Innovation Communities through participation and gathering of insights from young entrepreneurs and innovation communities such as hubs to develop a policy vision to support digital and economic transformation in Africa (i4policy 2019c).

d. A4Ai aims to stimulate the adoption of exponential technologies across Africa by empowering a fully inclusive and up-skilled labor force for the jobs of the future, aligning public–private decision makers on best practices for accelerated growth of the ecosystem and celebrating our collective success to ensure proper reporting and increased engagement from the people (Alliance for Africa's Intelligence 2019).

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