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A critical review on integration of virtual labs to enhance access to stem education for girls during and post Covid-19

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Article info

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ABSTRACT

Practical activities are extremely important in teaching sciences as they aid the students in comprehending scientific concepts through participatory learning. However, most Kenyan public schools lack well equipped laboratories. Additionally, the diminishing resources resulting from post-COVID effects offer no beam of hope. Disruption from COVID also poses critical challenges of handling physical devices in times of such pandemics. To address this, the Integration of Virtual Labs to Enhance STEM Education for Girls (IVLESTEG) project was conceptualized to enhance girl's access to Science, Technology, Engineering and Mathematic (STEM) subjects in Kenyan secondary schools. The aim of this research study was to critically appraise the current technology models in relation to girls' access to STEM education with the overall objective of exploring the potential of e-learning in promoting participation of female students in STEM subjects in Kenya. Upon development and implementation of learning in the V-labs, quasi experiments were conducted to determine the effectiveness of use of V-Labs in enhancing the participation of female students in STEM disciplines in secondary schools. Schools were randomly chosen and classified as either experimental or control sites. This method allowed for comparison of performance in STEM subjects of the female learners who were exposed to learning in the V-labs and those not. The findings will contribute to the development of a framework for appraising models for ICT use in STEM teaching and learning processes for girls that can inform practice, policy and research.

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Introduction

Background to the problem

Education has been hit hard by the Covid -19 pandemic, with millions of learners out of school due to school closures. Interruption to education has long term implications especially for vulnerable groups including girls. Young and adolescent girls are twice as likely to be out of school and face greater barriers to education and vulnerabilities as their male counterparts. This calls for innovative approaches to complement the ongoing emergency interventions the government has adopted like radio and online learning as short term measures. According to WHO (2020), Covid- 19 is likely to be a persistent endemic disease. Therefore, education systems need to put in place integrated contingency measures to mitigate and manage challenging situations in future.

Laboratory is the place where students can grasp the practical knowledge and experiences (Župerl and Virtič, 2013) to examine a scientific phenomenon (Kurbanoglu and Akin, 2010). Laboratory experiments promote and enhance students' understanding of concepts and promote the learning outcomes that have been taught in the classes. Experimentation is therefore one of the key concepts in Science, Technology, Engineering and Mathematics (STEM) education that involve students actively and help them acquire scientific knowledge and technical skills in a meaningful context. Studies on seismic shifts in the online distance learning models adopted in the last two decades in Kenya indicate marked technological growth on the computer-based technology (CBT) and techniques that support the Learning Management Systems (LMS) (Findik-Coşkunçay et al., 2018). In the early 90s the Japanese International Corporation Agency (JICA) introduced CBT SchoolBox™ on MS Dos platforms (Fujitsu, 1992) in Kenya through a joint partnership with International Telecommunication Union (ITU). One novel feature of the CBT was enabling the embedded art clips while using free-hand drawing tools, coupled with some form of student-teacher interactions, self-paced learning and assessments with prompt results (Odoyo, 2015). In the mid 1990s then came Authorware Professional™ version 3.0 (Macromedia, 1993) and then version 5.1 were launched on Win95 and Win98 (Macromedia, 1998) respectively. The LMS Window versions have thereafter evolved drastically over the last two decades. The most recent cloud computing technologies in HEIs e-Learning models are the Internet based Canvas and Moodle online platform as a service (PaaS) that are running on Windows, Android and iOS operating systems (OS) platforms (Gleason, 2019). Table 1 is the summary of the milestones for the last two decades.

In developing economies traditional classroom learning has continued to confine students and teachers to physical locations for years, resulting in banking education systems where students only receive, and repeat knowledge acquired, while limiting the students' natural creativity and problem-solving abilities that would enable both teacher and students to be subjects of the educational process(Freire, Ramos, & Macedo, 2014; Ohei & Brink, 2019). The limitations on conventional hands-on laboratories include time constraint due insufficient time for the laboratory sessions (Iskandar, Mahmud, Wahab, Jamil & Basir, 2013) limiting students' access to the lab and perform experiments. Scarcity of time for experimentation also makes it difficult for students to perform and complete assignments; some struggle with the procedures and unfamiliar laboratory procedures and techniques related to the experiments. (Tho & Yeung, 2016). Given the complexity of some STEM experiments, the slow learners also need more time to understand or and implement the idea than fast learners (Khattar, Luthon, Larroque & Dornaika, 2016). Consequently, needs of slow learners should be taken into consideration if STEM is to be important for economic growth and development.

Apart from the limited time allocated for STEM laboratory experiments, there is also the

Timeline	1991	1995	1997	2004	2009	2014	2016	2018	2022
e-Model	SchoolBox™	Authorware Professional v3.0/5.1	International Computer Driving License	Black Board LANs	Massive Open Online Courses	Moodle v.3.0 Big Blue Button (BBB)	Piaza e-Mode	Canvas e-Mode	Moodle App v.5.0
OS Platform	MS-Dos	Windows 95 Windows 98	Win 2000 Windows XP Linux	Windows XP Linux Windows 7	Windows XP Linux Windows 10	Windows Linux	Windows Android iOS	Windows 10 Android iOS	Windows 10 Android iOS
Infrastructure	Stand Alone PC	Stand Alone PC	Stand-alone PC hosted by K-Place Internet	Stand-alone PC running on LAN servers	Online Internet Intranet	Online Internet Portable Devices	Online Internet Smart Devices	Online Internet Smart Devices	Online Internet Smart Devices
Courseware Features	Courseware Development Graphic Clips Drawing Tools	Courseware designs by Macromedia Inc. tools	Interactive Courseware ICDL Material	Interactive Large Touch Screen Boards	Free Online Adaptive Course Material	Interactive compatible with BBB for Webinar	Group users Management compatible with BBB	On-demand Applications Compatible with BBB	Highly adaptive for Online exam Management
Management controls	Installation Diskettes Passwords Unlimited	Packaging CDs Physical Key Limited	Online Subscriptions, Group License	User IDs Password	Online User sign-in IDs Password	User IDs Password Freemium	Online User Private IDs Password	Freemium PIK Timer Voice/Video add-ons	Freemium PIK Time Voice/Video add-ons
e-Learning Opportunities	Installations Highly volatile Clip Arts	Graphic Animations Multimedia Presentation	Highly Scalable Remote Exam Management	Campus LAN Access Management Controls	Unlimited Multipoint Webinar Conference	Open Source world-wide Interactive Webinars	Use of Smart Devices 24/7 Individual Group users	Reusable Learning Objects Screen Share Media embed Cataloging	Open Educational Resources Recordings Backchannel Communities

Table 1: *Milestones of e-Learning Models in Kenya (Republic of Kenya. (2021)*

problem of limited resources in conventional laboratories in schools. Due to this insufficiency, students are divided into groups to carry out a forced work on laboratory experiment groups that in most cases together but sometimes, limit not every student in the groups has contact with the experimental equipment and conducts the laboratory experiments together with other group members. In addition, students thus rely on laboratory assistants or teachers to demonstrate and solve their laboratory problems (Nafalski, Nedić, Teng & Agadzhanov, 2016). Due to these aforementioned limitations, there is a need for an innovative, sustainable and practical approach to learning of STEM subjects by the already marginalized girl child.

The current challenges in teaching and learning STEM subjects require the development of technologies, creation and adoption of E-Lab/ remote laboratories. Remote laboratories provide remote access for users who may conduct the experiments without time and location restrictions (Garcia et al, 2017). Remote / E- laboratory is a web-based laboratory that allows users to access experimental devices online (Sauter, Uttal, Rapp, Downing & Jona, 2013). Importantly, a single experiment setup can be shared by a manageable number of users – thereby alleviating the logistics challenges associated with administration of conventional laboratories in terms of experiment hardware, space, time, and technical personnel. The impetus for the development of Virtual Lab technologies is to remove the barriers to students' independent and exploratory work in all sorts of laboratories for the purpose of explaining the real world.

Problem Statement

Developing relevant skills in STEM is critical for achieving the Sustainable Development Goals (United Nations, 2016). However, there is a serious skills shortage in STEM areas such as engineering and technology that limits the capacity for African-led development and increases dependency on foreign expertise (African Union, 2014). Further, according to a recent World Bank report (World Bank & Elsevier, 2014) although African universities have made progress in the amount and quality of their research outputs in STEM subjects, the continent continues to lag behind much of the rest of the world as does Africa's share of innovation in science and technology (UN, 2016).

In order to address the shortage of STEM skills, the recent Africa 2063 Framework Document (AU, 2015) has set out an ambitious vision for an African Renaissance with STEM at its heart. The vision is that at least 70 percent of all high-school graduates go on to have tertiary education, with 70 per cent of those graduating in subjects related to sciences and technology.

The aim of the Virtual Lab Initiative is to facilitate the use of online laboratories and inquiry learning applications for STEM education in schools to reduce the Gender parity gap, during and after the pandemic. The Virtual Lab Initiative will provide the ecosystem for teachers, where they can find various online labs and create customized Inquiry Learning Spaces (ILS) for Girls. The Virtual Lab Initiative will first conduct training for teachers in the country on the topics of Inquiry-Based STEM Education in schools and the use of the Virtual Lab Ecosystem specifically modeled for the girl child. The online labs will provide the girl child with an online environment to conduct specific scientific experiments. Remotely operated labs will offer an opportunity to experiment with real equipment from remote locations. The Virtual labs will simulate the scientific equipment. Data sets present data from already performed lab experiments.

Research Questions

The project aims to address the inadequacy of empirical evidence on how to integrate Virtual Labs to enhance access to STEM education in secondary schools in Kenya.

Therefore, the CLR review aims to answer the following four research questions:

i. What is the status of Gender parity access to STEM education using technologies in Kenya?
ii. What is the baseline information on use of technologies and e-learning to enhance STEM education for girls in Kenya?
iii. What are the gaps that exist in the interventions available to promote use of technologies to enhance STEM education in Kenya
iv. Which recommendations can fill these gaps that influence use of technologies/ virtual labs

Literature Review

RQ1: What is the status of Gender parity and access to STEM education using technologies in Kenya?

Equity in gender education particularly in STEM education is critical globally (Penner, 2015), especially when it comes to developments of global agendas (Cheryan, Plaut, Davies & Steele, 2009). As such, literacy in STEM education is invaluable for industrial, manufacturing and economic developments, and in global competitiveness as exhibited by the widening gap in developments between developed and third world countries (Singh, 2011; EiGE, 2017). However, despite the importance of STEM education in economic development worldwide, the number of women in STEM fields particularly at the degree and graduate level is small (Rosenthal, London, Levy, & Lobel, 2011; Boateng, 2015). Indeed, the 2016 Gender Gap Report indicates that women continue to be underrepresented in the STEM fields, with the global gender gap standing at 47%. This report indicates that globally, 30% of male students graduate in STEM related subjects compared to only 16% of the female students (ADEA, 2019). This untapped human resource unfortunately significantly reduces to a greater extent the number of STEM workforce as women comprise half the world population (Dasgupta & Stout, 2014).

Under the auspices of FPE, the ratio of enrolment of boys to girls in primary schools has stuck at 0.51: 0.49 since 2012–2016. However, FPE has not focused on reducing the gender disparity between boys and girls in terms of performance in exams (Grant & Behrman, 2010; Lucas & Mbiti, 2012). The performance of girls in the national KCPE exams was found to be lower than that of boys (Lucas and Mbiti, 2012; Republic of Kenya, 2012a). This disparity was particularly larger in STEM subjects (Republic of Kenya, 2012b). Despite the fact that gender parity is being achieved in the performance of English subjects (Wasanga et al., 2011), the gap is still wider in mathematics at the primary level where boys outperform girls (Kenya National Examination Council, 2018; Wasanga et al., 2011).

The high admission rate of students in primary schools due to FPE is replicated in the secondary school. Even though FSE has seen many students join secondary school, disparity in enrolment rates between genders widens in secondary education with about 51.6% of the enrolled students being male and 48.4% being female. The greatest disparity in enrollment is witnessed among the poorest quintile groups that records about 33.1% and 25% male and female admission rates respectively (UNESCO, 2013; Mumiukha et al., 2015; Amunga et al., 2010). Besides low enrolment rate for girls in secondary schools in some regions in Kenya, there has also been generally poor performance of girls in the end of secondary school national examination known as Kenya Certificate of Secondary Education (KCSE). The most affected subjects are STEM related which has incessantly seen low academic performance among the girls over the years (Kashu, 2014). Studies conducted in Kitui, Kilifi, Nyamira, Nairobi and Kakamega counties indicate that girls perform poorly in STEM subjects in KCSE relative to the boys (Musau et al., 2013; Mackatiani, 2018; Awuor, 2013; Wanjiru, 2019; Yara and Wanjohi, 2011). Indeed records of KCSE results of 2019 indicate that girls outshine their male colleagues in languages and art subjects; a trend that has been traced from 2016 (Obiria, 2019). In secondary schools, the core STEM related subjects include Mathematics, Chemistry, Physics, Biology among other sciences that guarantees students to much sort-after luxuries courses like Medicine, Engineering, Aeronautics, Astronomy among others. The poor performance of girls in the STEM subjects in KCSE exams therefore means that only a small proportion of them can gain entry into the prestigious STEM courses at the university level.

According to the Kenya Universities and Colleges Central Placement Service (KUCCPS) which is the government body mandated to place students to various university courses, the placement of 57,687 students of 2019/2020 who selected STEM related course, 63 per cent were male while only 37 per cent were female (Obiria, 2019). It is recorded that even female students who initially selected STEM subjects, upon reporting to the university changes to art-based courses in the first week of admission. This is despite the Kenya government initiating policies and law to empower girls and encouraging them to take courses in STEM fields (Wango et al., 2012; Nzesei, 2017). However, some of the reasons and barriers that fuel this shift in Kenya were previously reviewed by Sifuna. The Unesco figures indicate that the number of women researchers in other science fields in Kenya is low. It also shows that only 14 per cent of women are in the field of natural sciences, 11% in engineering and technology while in the agricultural scientists are less than a third of the overall number of scientists (Otieno, 2020). Likewise, Alice Ng'ang'a and others propose that there should be focus on factors that can improve utilization of resources by girls to improve their performance in STEM related subjects (Ng'ang'a et al., 2018). It is in our view that the proposed visual laboratory when integrated in the STEM education will enhance learning of girls in STEM subjects and improve their performance.

RQ2: What is the Baseline information/status of use of technologies or e-learning to enhance STEM education for girls in Kenya?

Although developing countries in Africa face serious challenges (e.g., shortage of electricity), there is a strong commitment to facilitate ICT in education at all levels (Farrell & Isaac, 2007; Hennessy et al., 2010; Olson et al., 2011) and models to develop ICT educational policies are available (Zlotnikova & van der Weide, 2012). In Kenya, a national ICT Master Plan has been adopted that includes education and health as priorities of social change (Kenya national ICT master plan 2017.2014). In addition, the Kenya Education Network (Kenya education network.2014), a separate national education and research network, is working to promote ICT in education and research at institutions of higher learning in Kenya.

In 2018, the government formulated a five-year National Education Sector Strategic Plan education plan (NESSP, 2018–2022), which included priority areas for investments in higher education in line with Vision 2030's overarching goal of making Kenya a competitive economy. Building on the positive results of the Economic Transformation Agenda implemented over the NESSP gives priority, among other key areas, to technology innovation to boost economic growth and to vocational training and higher education with the aim of helping young people find jobs. Specifically, the plan proposes as one of its key objectives to increase access to STEM programs to 60 percent of the student population.

Digital Literacy Programme (DLP) that has currently earned a brand name "DigiSchool" was borne out of the Kenyan Government's vision to equip pupils with relevant skills needed in today's digital world. Some of its key objects were to equip public primary schools with appropriate ICT infrastructure to support teaching and learning; and to develop capacity of teachers, education managers and other stakeholders with necessary ICT skills. The programme was designed to introduce public primary school children to the use of digital technology and communication in learning. Currently,.

RQ3: What are the gaps that exist in the intervention /projects/programs to promote use of technologies to enhance STEM education in Kenya

The narrative in Table 2 maps the 21st century skills frameworks currently that positions common features of competence alignment in terms of foundational, transferable and technical skills. The table includes the addition of competence sets for primary and secondary tiers of educational delivery that form part of the Kenya Institute of Curriculum Development (KICD) new proposal for curriculum reform in Kenya. However, challenges faced in the process of change, such as, the current world-wide COVID-19 pandemics and high pace of advances in technology make the implementation of distance learning technologies within the anticipated short time quite difficult (MOE, 2012; Kare-Silver, 2011; Gleason, 2019; Ndeda, Ogara, & Abeka, 2018).

Key among the challenges is the lack of a standardized policy framework for guiding the school boards on ways of evaluating evidence-based incentives for the students as well as the facilitators in these institutions (Faloye, Ajayi, & Raghavjee, 2020). For instance, a student who is enrolled in the school program, face-to-face or online, expects a certificate award at the end of her term year. Meanwhile, the online instructor expects an equitable remuneration for the extra efforts s/he has put in organizing and conducting the program. The school boards are in a dilemma on how to arrive at a universal award and payment scheme to apply across the boards. Efforts to come to a consensus on which model to adopt have been highly illusive over the years (Gleason, 2019).

The KICD new curriculum proposal is based on a needs assessment study conducted among national stakeholders (Juang, 2016). The issue is that the current curriculum is 'widely criticized for being expansive, heavily loaded in terms of content and too examination oriented, which when combined puts pressure on learners' (Wanzala, Daily Nation, March 31, 2016). Central to the proposal at secondary level are '4C' 21st century skills sets (communication, collaboration, critical thinking and creativity), digital and language literacies identified by Kenyan teachers and principals as 'skills you should be able to possess in order to be a good decision maker… and to be creative and

World Economic Forum: Industry Agenda – Life Long Learning	**Innovative Secondary Education for Skills Enhancement**	**Kenya New Curriculum Proposal (2016) Skills for Learners – in friendly, inclusive and affordable school environments**
16 Skills for 21st Century	Skills for Employability in Africa and Asia	1st Tier Skills Pre-Primary and Lower Primary (5 years)
Foundational Skills *Student application of Core skills to everyday tasks* Literacy Numeracy Scientific Literacy ICT Literacy Financial Literacy Cultural and Civic Literacy	**Foundational Skills** Basic cognitive skills to think, study and learn Numeracy and Literacy	**Foundational Skills** Numeracy and Literacy **Specific and technical Skills** Digital skills **Socio-cultural skills** Life Skills
		2nd Tier Skills **Middle Primary and Lower Secondary (6 years)**
Competencies *How student approach complex challenges* Critical thinking/problem solving Creativity Communication Collaboration	Cognitive skills Openness to learning Non-cognitive skills Communication: oral and written Work habits: punctuality, application… Teamwork Entrepreneurialism Personal integrity Leadership	**Cognitive Skills** General knowledge **Specific and Technical Skills** Practical skills Technology skills **Social-cultural skills** Values Self-reliance Integrity Patriotism
		3rd Tier Skills Upper Secondary (3 years)
Character Qualities *How students approach their chaging environment* Curiosity Initiative Persistence/grit Adaptability Leadership Social and Cultural Awareness	**21st Century Skills** Skills for work in today's global, 21st century economy Core subjects Life and career skills Learning and innovation skills **Specific and technical skills** Language (mainly English) Basic business skills ICT skills Specific to context – with practical and theoretical perspectives **Character Qualities** Skills collected in packages of 'life skills' considered important.	**21st Century Skills – 4Cs** Communication Collaboration Critical Thinking Creativity **Specific and Technical Skills** Computer and digital Literacy English Language/Literature Home science, Art & Craft, Agriculture and Woodwork **Character Qualities** **Accountability**, Integrity, Responsibility, Peace, Commitment to work, Negotiation, Acceptance and environmental Preservation
Source: WEF, Bailey and Kaufman (2015)	**Source:** Results for development Burnnett and Jayaram (2012)	**Source;** Juang, 2016

Table 2 : *Frameworks for 87st Century Competencies & Skills (Sources: Bailey & Kaufman, 2015; Burnett & Jayaram, 2012; Juang, 2016)*

analyze situations in order to make the right choice where you're faced with difficulties'. Whether the proposal will be realized is another challenge given Voogt and Roblin's (2012) observation that 'it is worrying that the education sector, let alone schools and teachers, do not seem to be actively involved in the 21st century initiatives and in the overall debate about these competences'.

While there are patterns of horizontal consistency across 21st century skills frameworks in relation to curriculum intentions for reform and transform as presented in the Kenya proposal, there remain critical caveats in vertical consistency related to coherence between intentions, implementation and assessment of outcomes. Akyeampong (2016) would concur on the gap between desired competencies that STEM should foster what happens in the actual process of teaching and learning in these subjects'.

Andreas Schleicher, OECD Director for Education and Skills, contends that school systems need to invest more strategically in technology integration for more effective pedagogies that can build student 21st century skills (OECD Blog, 2015b). McDonough and Le Baron (2010) argue that unless technology disrupts 'grammar of schooling' assumptions of fixed knowledge organization and rigid curricular design, 'it will fail to produce meaningful improvement'.

The issues of technology disruption as a prerequisite for school transformation point to multi-faceted dimensions for ICT integration in school systems in the knowledge age. In Kenya Gakuu et al. (2011) advocate the necessity to equip educators and administrators with expertise for supporting whole school ICT development in order to support teachers' pedagogical integration of ICT in classroom practice. Hammond (2013) argues that the need is to build a better understanding of the interplay between the individual agency of the teacher and their school contexts in change processes.

RQ4: Which recommendations can fill these gaps that influence use of technologies/ virtual labs

The project recommends a solution design that integrates and contextualizes globally benchmarked standards and frameworks for ICT use in teacher development and classroom practice inclusive of the Mishra and Koehler's (2006) Technology, Pedagogy and Content Knowledge (TPACK) framework. These combined frameworks will include interventions from *ICT application* (technology literacy) to *ICT infusion* (knowledge deepening) in STEM classroom practices.

The recommendations in Kenya is a particularly timely intervention that is positioned to contribute to national systemic frameworks for ICT integration at a time when the Government of Kenya is embarking on mass deployments of ICT in primary and secondary schools. This intervention can advise educational policymakers and stakeholders on future paths for ICT-enabled educational innovation from national to local levels from policy formulation to classroom practice.

There is an apparent need for deeper research in the area of student interaction for effective ICT integration in schools and classrooms. The issues of what students and teachers need to know and be able to do to integrate technology effectively are highly important for informing policy and practice in teacher education. It is hoped that the research will contribute to the knowledge field in general. In a broader context it is hoped that the contribution might have what Hammond (2013) describes as a 'value for use' factor that is that the research provides useful, usable and relatable knowledge to policy makers, educators, practitioners and researchers affiliated to ICT in education and teacher education.

Methodology

The chapter outlines the post-positivist symbolic interactionism that guided the inquiry's qualitative orientation, followed with an outline of the Design Based Research methodology that was adopted and the rationale for its adoption. The chapter continues by presenting the details of ethical considerations, sample methods, data collection and analysis that were utilized. It concludes by a discussion on considerations of status and validity associated with the researcher's dual roles as designer and researcher in the inquiry.

Theoretical Framework and Research Paradigm

The review looks at some of the frameworks and theories in order to leverage the thinking about integrating Virtual Labs to enhance access to STEM education in Kenya.

There is a sense in all of the debates of a growing crisis in the education field that is manifested in at least two fronts. On the one hand the 21st century new development policy demands for building knowledge-based societies and economies has presented a parallel urgency for educational research to build understanding of education practice and delivery that is relevant for the new knowledge age (Sugrue, 2008). On the other hand the paradigmatic divisions and plethora of approaches in the eyes of some have rendered much educational research today to be unsatisfactory and fragmented (Hammersley, 2004).

Arising from these ontological considerations are questions of epistemological approaches adequate to address the dilemmas of educational research in general. In the context of this inquiry the questions centre on grounded theory approaches for suitable integrating Virtual Labs themes to enhance girls' access to STEM education intervention (Montesi & Álvarez, 2017). It is an inquiry that is straddled between the research debate dilemmas for assessing whether the intervention is 'something that works' (Nicolopoulou & Cole, 2010) and for creating new knowledge for improving models for ICT integration that are responsive to the needs of a rapidly developing Kenya knowledge-based economy and society.

a) Qualitative Constructivist Orientation

In defining parameters for research into teachers' classroom practices, Groth *et al.* (2009) relate the use of conceptual framework lenses to 'identify theoretical constructs for attention'. The present inquiry drew on the Social cognitive career theory (SCCT), Technology, Pedagogy and Content Knowledge (TPACK), expectancy-value theory (EVT) and Activity Theory (AT) conceptual frameworks and lenses as described in the literature review.

Social cognitive career theory (SCCT; Lent, Brown, & Hackett, 1994, 2000) provides a useful framework for explaining why attitudes, interest, and engagement play a critical role in students' decisions to pursue STEM. SCCT centers on the idea that academic and career choices are based on the interaction of personal (e.g., self-efficacy), environmental (e.g., supports, barriers), and behavioral (e.g., goal implementation) factors (Lent et al., 1994, 2000). Environmental variables are of particular concern to education researchers since these are the malleable factors that school teachers and administrators can influence (Lent et al., 2000). Researchers used SCCT in studies of student persistence and career choices within STEM, and findings support models that incorporate these factors (e.g., Byars-Winston & Fouad, 2008; Quimby, Seyala, & Wolfson, 2007). Factors related to STEM persistence included STEM self-efficacy; familial, peer, and school support; instruction (as barrier or support); availability of role models; and discrimination based on sex, race, or performance.

Along with SCCT, the review also analyses the four-phase model of interest development put forth by Renninger and Hidi (2016; Hidi & Renninger, 2006) with the following phases:

(a) triggered situational interest for particular content, (b) maintained situational interest, (c) emerging individual interest, and (d) well-developed interest.

The review also looks at the expectancy-value theory (EVT) to understand reasons for STEM persistence. This theory states that expectations for and the value placed on success are highly correlated with individuals' persistence in and level of achievement (Battle, 1965, 1966; Eccles et al., 1983; Eccles & Wigfield, 1995; Wigfield & Eccles, 1992, 2000). This theory allows further understanding of why individuals may or may not continue along pathways toward STEM. In recent times, Eccles, Fredericks, and Epstein (2015) have also highlighted the synergies between the four-phase model of interest development and work on EVT.

Where in the past the unequal representation of female students in mathematics, science, and technology used to be explained as a result of a lesser aptitude of women research shows that there is little empirical support for this claim (Barres, 2006; Ceci, Williams, & Barnett, 2009; Guiso, Monte, Sapienza, & Zingales, 2008; Haworth, Dale, & Plomin, 2008; Hyde, Lindberg, Linn, Ellis, & Williams, 2008; Lynch & Feeley, 2009; OECD, 2009, 2010; Spelke, 2005). Moreover, this explanation of presumed lesser aptitude cannot be used to explain the vast differences in female participation rates that exist between countries.

Therefore, the aim of this review is to compliment the previous theories with the recent theories, to describe the gendered study choice patterns, and to critically assess recent scientific progress in this field in order to integrate Virtual labs to generate more interest and enhance access to STEM education for girls in Kenya. A study by UNESCO (2012) asserts that gender roles contribute greatly as a potent and prolific avenue by which manipulations of social perceptions and expression manifest reality. The Social Constructionist Theory (SCOT) explains low female participation in STEM disciplines as emanating from social construction of female students into stereotypically feminine disciplines, societal expectations and gender roles. In terms of gender responsiveness in STEM curriculum, the theory further explains low participation of female students in STEM disciplines (Kulis, Sicotte & Collins, 2002 & Settles; Cortina, Malley & Stewart, 2006a). An individuals' social environment with respect to their socialization, education, peers, culture and family informs their need to aspire towards certain careers and job markets to shape their life's satisfaction. This phenomenon sets a foundation for their career targets. The number of women earning university STEM degrees declines as they move through the educational ladder, a phenomenon referred to as the "leaky pipeline". This can be attributed to the masculinity of the disciplines, stereotypes and associated prejudices.

The ideas of gender roles and socialization relate directly to the concept of STEM field gender gap because there is evidence of gender stereotypes related to STEM professions. One of the reasons females are leaving the STEM pipeline and professional arena is because they are barraged with socialized ideas and negative stereotypes (Robnett & Leaper, 2013). These mentalities and stereotypes are communicated to girls at a young age ultimately diminish their interest in STEM fields. It has been debated that stereotypes and stereotype threats are two reasons why women are underrepresented in STEM fields. Socialization also occurs in family contexts. Parents and/or guardians who raise off-springs have an impact on their motivation when it comes to accomplishment in settings such as those structured around STEM related topics (Eccles, 2011).

While socialization may play a role in the leaky pipeline for girls in STEM fields, peer groups and stereotypes of STEM professionals are also under focus. In essence, the child's acceptance within the peer group is one of the key measures of positive/negative school experiences. While socialization and stereotypes at a young age could influence the eventual career path of a student, the few or even absence of women in the field of STEM could also be a contributing factor.

The idea of social segregation of women is directly related to the theory of gender socialization. Women are not generally socialized or taught that they are born with intelligence, while males are socialized with the understanding that they are born with intelligence (Rosser, 2012). Therefore, if stereotypes related to the work culture for STEM professionals is altered or expanded, girls may be more absorbed in the career paths related to STEM. One of the ways suggested to increase girls' perception of STEM professions was through incorporation of women in STEM fields. Additionally, more recent research has found that if women combat the stereotypes associated with their gender and develop a mentality of self-confidence, the gender gap may close faster.

Integration of Virtual Labs, Policy reviews and pedagogical interventions are likely to enhance access of more female students to participate in STEM disciplines.

b) Design Based Research

Design based research (DBR) has been described by many researchers from Wang and Hannafin (2005) as a 'systematic and flexible methodology' which aims to improve educational practice through 'iterative analysis, design development and implementations' that link together the value chain of researchers and practitioners to the 'real world settings' of school and classroom contexts to Anderson and Shattuck (2012) who described a design-based research approach as a research methodology that can bridge the chasm that exists between research and practice in formal education systems and Lewis, Perry and Murata (2014) describing the DBR process in terms of 'cycles of design, enactment, analysis, and redesign' that can enable researchers and practitioners to 'hone an innovation while also building theory about "how it works" and not simply to 'empirically tune "what works"' .The DBR because of its 'how', 'when' and 'why' approach becomes integral to the intervention and frameworks underlying the research inquiry with an added interrogative of 'what' would constitute innovative practice as perceived, observed and applied by students .

The opportunities for focusing the research on the integration of Virtual Labs intervention in the context of enhancing STEM education for girls within the Kenya education system, was also a critical rationale for adopting a DBR approach.

Results Analysis and Findings

Thematic Analysis (TA) taps directly on both observed phenomena and latent i.e. unobserved constructs that address the research questions in this paper (Neuendorf, 2019). Due to social and economic disparities at separate project locations various research teams explored different themes and sub-themes on the emergent views as well as common concerns for effective implementation of specific features of the STEM education within the shortest time allocated to the teams (Braun & Clarke, 2016). The flexibility of TA, also, allowed the researchers to use open-ended questions and other informal ways of gathering the data such as telephone conversations and SMS text messages (Neuendorf, 2019).

RQ.1. Interventions to bridge gender parity and access to STEM education using technology in Kenya

The following interventions have been done to bridge the digital divided

1. The Kenyan Government has implemented legal and regulatory frameworks that drive ICT adoption. The inclusive policies have effectively promoted useful and meaningful content for women via digital platforms to increase access and use of basic services. Progressive policies promote technological innovation as a driver for social inclusion and economic participation of women.
2. Design and implement capacity building programmes for women that include teaching digital skills and individual mentoring that accompanies women through the learning and adoption process in a case by case basis.
3. The government promotes education of women in science and technology fields through scholarships, internships and training programs and consider gender quotas for admission into education programs in order to strengthen women participation in decision making positions and leadership within the STEM sector
4. The government has designed digital procurement strategies that promote increased private supply of ICT services, thus fostering market competition and segmentation in order to lower economic barriers of entry for women. These strategies highlight the fact that nowadays women represent an important and untrained segment of the digital market
5. Low levels of education and skills inhibit women's capacity to access and use digital technologies. These 'old' problems need to be urgently addressed to meet the 'new' dig-

ital challenges. New tools will be needed such as family counselling and innovative new pedagogies in order to overcome not only low-skills, but also traditional practices that preclude the women's interaction with technology

6. Statistical data on digital inclusion are scarce and usually not disaggregated by gender. Disaggregated statistics should be made available. In addition, measures of digital inclusion should be improved to make them comparable across counties. This is particularly important for evaluating the effectiveness of policy measures aimed at improving digital inclusion in general and reducing gender digital divide in particular. More research needs to be done to better understand the dynamics and the underlying causes of the gender digital divides in different counties.

RQ.2 Intervention /projects/programs in place to bridge the gap and to promote use of technologies to enhance STEM education in Kenya

The following samples of interventions were established to have significant level of success;

1. Adoption of national ICT Master Plan that includes education and health as priorities of social change
2. Promotion of ICT in education and research at institutions of higher learning in Kenya by the Kenya Education Network
3. Formulation and implementation of five year National Education Sector Strategic Plan (NESSP), one of its specific key objectives is to increase access to STEM programs to 60 percent of the student population.
4. Implementation of Digital Literacy Programme (DLP) that has currently earned a brand name "DigiSchool" The programme was designed to introduce public primary school children to the use of digital technology and communication in learning. Currently, the programme is almost 100% complete with over 20,000 out of 23,951 public primary schools having been issued with the devices.
5. The Kenyan government trained over 91,000 primary school teachers on digital learning. For posterity, ICT and Computer Use training was integrated into the teachers training curriculum at the college level.

RQ.3 what are the gaps that exist in the intervention /projects/programs to promote use of technologies to enhance STEM education in Kenya

1. Interventions lack some competence sets for primary and secondary tiers of educational delivery.
2. While there are patterns of horizontal consistency across 21st century skills frameworks in relation to curriculum intentions for reform and transform as presented in the Kenya proposal, there remain critical caveats in vertical consistency related to coherence between intentions, implementation and assessment of outcomes.
3. There is a gap between desired competencies that STEM should foster, and what happens in the actual process of teaching and learning in these subjects' (Akyeampong, 2016)
4. In Kenya the government has been implementing the National ICT strategy for Education and Training developed in 2006 with a focus advocacy on the use of 'innovative practices in the implementation of ICT in the curriculum' (Murithi et al., 2013, p197). There is, however, much hype of the successes of ICTs to both assist education systems achieve their mission for educational reform and to transform and innovate educational practice
5. The positive impact of technology integration in education and on student achievement has not been proven despite thousands of impact studies (InfoDev, 2015); (OECD Blog, 2015b); McDonough and Le Baron (2010).
6. The issues of technology disruption as a prerequisite for school transformation point to multi-faceted dimensions for ICT integration in school systems in the knowledge age. Gakuu et al. (2011) advocate the necessity to equip edu-

cators and administrators with expertise for supporting whole school ICT development in order to support teachers' pedagogical integration of ICT in classroom practice. Hammond (2013) argues that the need is to build a better understanding of the interplay between the individual agency of the teacher and their school contexts in change processes.

RQ.4 What are the recommendations to fill these gaps that influence use of technologies to enhance STEM education in Kenya

1. There is a gap in the Kenyan scenario on effective development for ICT use in the locale of access to classroom teaching and learning processes. The main objective is to track students' perceptions and applications of ICT in practice, and to integrate and enhance access to STEM education using virtual labs while trying to understand the environmental affordances enabling or inhibiting teacher technology use in classroom teaching and learning processes.
2. Virtual Laboratory concept has been expanded to advanced opportunities for integrated teaching, research and promoting cross-disciplinary research **(**Rauwerda et al., 2006). This can be used in STEM teaching.
3. Giving learners reading texts with STEM themes is one of the best ways of building students' literacy skills, including how to read, write, and reason with the language and text, while learning STEM content and cultivating dispositions of science (Pearson, Moje, & Greenleaf, 2010).
4. The learning institution boards require a well evidenced based framework, approved by the Ministry of education, for implementing the e-learning models for students at Vocational Technical Education Training (TVET) centers to realize the Sustainable Development Goals (SDG) agenda four: the quality education while matching the skills gained from competency-based learning curriculum (CBC) with qualifications National Employment Authority (NEA) guidelines. Therefore, youths trained through apprenticeship systems or ones who have undertaken online classes shall be awarded with recognizable certification after completion of their STEM programs (NEA, 2016; Kember, 2016).

Conclusion

Despite the international campaigns for gender equality and equity in STEM Education, the study conducted in several counties in Kenya continue to show that women are not given equal access to education in Kenya. Girls in STEM education in Kenya are still very few. The study identified three main barriers for girls under-representation in STEM education namely; Policy, technology and social barriers. The findings also display various interventions which have been taken to combat the situation in Kenya, affirmative action's such as lower entry scores, remedial pre-university programmes and financial assistance although representation of women is still low. However, the study documents some sustainable interventions which can be used to redress the issue of womens low uptake of STEM Education among others equal opportunity programmes for women is of great impact.

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