Project Report Date: March 23, 2021

Enhancing the Quality and Equity of Access to STEM Education in Rural Kenya by Optimising Transition Rates from Primary to Secondary School

Education 4.0 roadmap to national innovation capacity

ABSTRACT

The GraFA EMPOWER Good Governance and Social Entrepreneurship Programme at the TU Bergakademie Freiberg, Germany, empowers doctoral students from less developed countries with project management skills to undertake projects that can impact local communities in their home countries. Following the training conducted over the 2018–2020 period, the inaugural EMPOWER cohort undertook various community-facing projects. The findings of the Kenyan project on quality education (SDG 4) are hereby presented, based on comprehensive key informant interviews conducted in 2019 across eight Kenyan basic-level schools in the counties of Homa Bay, Kisumu, and Nairobi. The overall goal is to support educational investment and policy decisions in an evolutionary and participatory manner, taking care of gender-differentiated needs. The findings show wide differences in budget requirements between rural and urban schools and between public and private schools. To deliver on the main study objective of enhancing the quality of STEM education in Kenya by optimising transition rates from primary (Standard 7 and 8) to secondary school, findings on the high-leverage points were: increased investment in learning resources, especially laboratories and libraries to facilitate fascinating and practical STEM education; quality teacher training, motivation and exposure to enhance STEM teaching; enhanced annual budgets for gender-differentiated needs, with sanitary and extra maintenance requirements raising the estimated annual budget per girl, learning materials inclusive, to 750 USD — far above a boy's estimated annual requirement of 410 USD; improving the trained teacher-pupil ratio; overcoming cultural barriers to gender equality in STEM education; and structured STEM mentorship for talent management and career development. The learner's budget requirements captured in the survey excluded transport and boarding facilities.

Nashon Juma Adero

A GraFA EMPOWER Good Governance and Social Entrepreneurship Project carried out at the TU Bergakademie Freiberg, Germany

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EMPOWER PROJECT 2018 - 2020

Enhancing the Quality and Equity of Access to STEM Education in Rural Kenya by Optimising Transition Rates from Primary to Secondary School

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EMPOWER Project Summary

The EMPOWER Good Governance and Social Entrepreneurship Programme is coordinated by the Centre for Advanced Studies (GraFA) at the Technical University (Mining Academy) of Freiberg, Germany. It empowers doctoral students from less developed regions of the world with the project management, social innovation and entrepreneurial skills they need to positively transform the course of development and societies in their home countries through frugal, participatory and sustainable means and mechanisms. Policy change is key to achieving the intended transformation, hence the principal focus on actionable and evidence-based proposals that can win the attention and active participation of policymakers.

The EMPOWER project presented here was accomplished within the first EMPOWER cohort (2018–2020). It addresses quality education (SDG 4) and the urgent need to address quality and equity in STEM education outcomes without leaving any gender or district in Kenya behind. The overall goal is to support educational investment and policy decisions in an evolutionary and participatory manner, taking care of gender-differentiated needs. The project seeks out the high-leverage intervention points to optimally improve the average Science, Technology, Engineering and Mathematics (STEM) performance by 50%, with gender parity, and consequently accelerate the achievement of at least 95% transition rates from primary to secondary school in a pilot rural district in Kenya, by 2025. The compelling philosophy and thesis of the project is that to be effective and impactful, transition rates must be evaluated beyond mere numbers; the metrics must include the quality of performance where it matters most for national innovation capacity, hence the performance in STEM subjects and the STEM preparedness of learners as they join advanced education and training levels.

A classroom model has been used for taking stock of recommended class contact hours for Grade 7 and Grade 8 learners, total class size for each grade, gender parity, teacher-to-pupil ratio, per capita learning and sanitary resource needs for the female pupil and male pupil, additional costs for teacher motivation, and extra maintenance costs. Primary data captured directly from a sample of Kenyan schools representing the diversity and extremities of STEM education challenges have informed model parameterisation. By minimising the difference between resource inputs and the demand levels that the standards of quality and equity of

access place on STEM education, under given policy constraints, the final data-driven model from this study should inform optimal cost-efficient options for enhancing STEM learning outcomes at the critical transition stages.

The decisive metrics for calibrating the strategies and policies towards realising the project goal have been generated from three pilot counties in Kenya: Homa Bay, Kisumu, and Nairobi. The data informing the metrics were collected from key informants, who were the head teachers of five primary schools and three secondary schools. The schools represented all the key categories in Kenya: rural, urban, public and private schools.

The main findings informed the need for increased investments in well-equipped laboratories and practical teaching of STEM subjects right from primary school. The budget requirements captured in the survey excluded transport and boarding facilities. From the survey, an indicative adequate annual budget for learning resources to cater for quality STEM education for the upper primary grades leading to secondary school came to between 250 and 300 USD per learner. The study has confirmed the wide disparities between rural schools and urban schools, and between public schools and private schools in Kenya. The disparities mainly manifest in a wide rural-urban digital divide, cultural bias against STEM for girls especially in rural areas, inadequate exposure to curiosity-enhancing scientific activities, insufficient socialisation of STEM teaching including peer-peer learning experiences, and the level of exposure and empowerment of teachers and trainers to deliver on STEM pedagogy. Assistive technologies are needed to address the special needs of STEM learners with disabilities, who were found in this study to be sharing the same teachers and facilities with ordinary learners. Structured mentorship emerged as a key requirement for STEM leadership and career development.

With the recent launching of a new competency-based curriculum (CBC) in Kenya to replace the old 8-4-4 system, which started in 1985, the study findings from this project phase will further inform the planning parameters for implementing the CBC effectively to enhance STEM education and training. The data and insights from this phase of the project informed the establishment of a STEM-oriented youth mentorship programme, Impact Borderless Digital (IBD), operational since 2019. The uptake of IBD mentorship services surged in 2020 during the COVID-19 global pandemic as online engagements through virtual youth forums enabled borderless outreach and wider impact. The IBD agenda received a boost in November 2020, when the African Centre for Career Enhancement and Skills Support (ACCESS) selected the IBD idea on ***“Addressing youth unemployment by matching lifelong skills development needs with talents and labour market demographics”*** for further development. The long-term vision is to institute the IBD Talent Academy to help sustain collaborative talent management as well as STEM-oriented thought leadership and mentorship.

1. Introduction of the EMPOWER Project Idea

The 2021 World Economic Forum in Davos featured a sweeping perspective on capitalism attributed to the founder, Prof. Klaus Schwab, a German engineer and economist: The world of the future would be pegged on “talentism”, not capitalism. The foresight in this radical statement draws life from the supremacy of human talents as the most important factor of production in a rapidly changing world influenced by knowledge- and technology-led megatrends; capital flows will always be available to support top talents offering transformative solutions, especially in the emerging post-pandemic era. The unrelenting momentum of Industry 4.0 has also birthed Education 4.0, charting a new path for skills development in a competitive and digitally connected world with a borderless global pool of talents and skill sets.

Education, gender and work together constitute a key global issue among the top development agendas featuring in the annual World Economic Forum. Technology, globalisation, demographics including gender dynamics in a rapidly changing labour market, and climate change are together shaping and disrupting the broader global issues related to education, gender and work. If identified early and developed optimally, a country’s stock of young and diverse talents should enhance youth employability skills, job creation, and innovation capacities for an accelerated transformation of economies and societies.

Rural areas in developing regions are largely disadvantaged in terms of human and learning resources. There is a wide rural-urban divide and structural barriers that mainly take the form of a digital divide and associated infrastructure shortages, inadequate supply of human resources (teachers) and learning resources, such as books, laboratories and libraries, and cultural barriers ingrained in traditions and customs that limit opportunities for quality education and aggravate gender inequality.

At mostly 10% and above since 2000, Kenya’s unemployment rate has consistently been above the sub-Saharan average. The youth are the most affected demographic in this country with a median age of barely 20. The 18-35 age bracket makes up a third of the national population. To empower this youthful majority with employability skills and career security in the rapidly changing global technology marketplace, the country requires a skills revolution, a reversal of the inverted pyramid of qualifications where formal education continues to produce “drops of skills in an ocean of academic qualifications”, as once described under this study series on quality education.

Since its launch in 2003, Kenya’s free primary education policy has been recording a mix of isolated success stories and serious widespread challenges. Among the key challenges is the quality and equity of access to the foundational competencies required for Science, Technology, Engineering and Mathematical (STEM) careers. Performance in STEM subjects and transition rates to secondary school have been below average, as low as 30% in rural areas with girls even more disadvantaged. To meet Kenya Vision 2030 and the goal of enhancing national innovation capacity based on an enabling foundation of Science, Technology and Innovation (STI), quality STEM education and skills development must take precedence as a key result area.

The overall goal of this EMPOWER project is to support educational investment and policy decisions in an evolutionary and participatory manner, taking care of gender-differentiated needs. The project seeks out optimal ways of improving the average performance in STEM by 50%, with gender parity, and consequently accelerating the achievement of at least 95% transition rates from primary to secondary school in a pilot rural district in Kenya, by 2025. In this respect, the transition rate will be evaluated beyond mere numbers to encompass the average quality of performance and STEM preparedness as the learners join secondary school and proceed for skills-based tertiary education and training to meet the key demands of changing labour markets.

This project has built on the past findings of a 2014–2015 survey on how training emphasis at the basic education level, mostly in Africa, addresses the skills critical to innovation capacity. Talent management and the more critical areas of scientific inquiry, systems thinking, spatial intelligence, creative arts, and communication skills scored low on the training emphasis they received, in the range of 19%–45%.

The critical transition stages coinciding with the onset of the challenging teenage phase of pupils inform a novel approach to identifying the high-leverage points for efficient investment and policy decisions. In the Kenyan context, the critical transition stages identify with Grade 7 and Grade 8 pupils in primary school, who are mostly aged 12–14. At this stage, they make a critical entry into the teenage developmental phase and the last progressive steps to the more demanding secondary school level.

The second section of the report outlines the project merits and lists the likely risks, pitfalls, and proposed solutions. The third section details the expected project impact. The support and partnerships deemed critical to realising the project idea fully are stated in the fourth section. The action plan, in section five, covers the period from February 2019 to November 2021. The last three sections, in a consecutive order, present the methodology applied to accomplish the first phase of the project of data collection and analysis of key metrics, the results and discussion, and the conclusions, recommendations and outlook for the subsequent project stages.

2. Project Merits

What can we change, do more, better, faster, cheaper with this idea?

- Achieve gender parity in STEM learning outcomes
- Increase performance index in STEM learning outcomes in the targeted rural areas
- Ensure economical investment in learning requirements with reference points for auditing
- Systematically empower rural communities through innovation-oriented lifelong learning

Risks or pitfalls

Which possible risks (technical, organisational, etc.) can occur with the idea?

- Lower funds than needed for real transformation
- Insufficient number of STEM teachers
- Change in government education policies and system
- Unfavourable tradition, culture and customs

Proposed solutions

How can we solve impediments or anticipate the pitfalls?

- Sensitisation for more investors
- Look for volunteers and build internal capacity for self-sustenance
- Engagements with policymakers and continuous adjustments
- Community awareness creation

3. Project Impact

What needs to change in order to realise the idea or project? Consider funding, technology and processes, organisation, market approach, etc.

- Increased funding for curriculum books, stationery, special needs for girls and boys, exposure to real-world applications, and teacher motivation
- Optimal teacher/student ratio with modern teaching aids to be achieved
- Economical use of available resources with auditing mechanisms

- Active involvement of key stakeholders including teachers, learners, parents, opinion leaders, and key decision makers in education sector governance

4. Required Parties/Partners

Who or which organization(s) do we have to work with to realise this idea?

- Local rural public schools and their administrators
- German organizations already working in Africa and Kenya, e.g., ACCESS (DAAD/exceed), Konrad Adenauer Stiftung, Friedrich Naumann Stiftung
- Business community and investors
- Youth volunteers to be research and field assistants
- Philanthropists and charity organisations
- Local faith-based organisations
- Community leaders and parents

5. Action Plan

Describe the tasks, who is going to do what by which deadline.

Task	Actor	Deadline
First draft of proposal	Proponent	28-02-2019
Feedback on draft proposal	EMPOWER Team	15-03-2019
Full concept proposal	Proponent	31-03-2019
Identifying donors and collaborators	Proponent team	15-04-2019
Project budget presentation	Proponent team	30-04-2019
Data collection on differentiated class-level needs per student (girl/boy)	Field Research Assistants in Kenya	30-06-2019
Data processing and analysis	Proponent	31-08-2019
Reporting, reviews, and lessons	EMPOWER Team	15-10-2019
Progress report and implementation plan	Proponent	30-11-2019
Founding a structured mentorship programme	Proponent	30-01-2020
Presenting the final report of the initial phase and fostering public-private partnerships for subsequent phases based on initial findings	Proponent, education sector stakeholders, policymakers, philanthropists, donors	30-11-2020
EMPOWER Virtual Conference – project presentation	EMPOWER Team	09-04-2021
Developing a classroom-level model for optimising STEM learning outcomes	Proponent	30-05-2021
Resource mobilisation and instituting the IBD Talent Academy based on the optimal model	Proponent and willing partners	30-11-2021

6. Methodology

An economical approach was applied while the lead researcher was in Germany by selecting the materials and methods that would ensure optimal delivery on the project at minimal cost. The data-collection exercise involved an online survey tool and virtual collaboration with a lean team of young field research assistants in Kenya. The primary data obtained directly from the field would later be used together with secondary data from government statistics and literature on quality STEM education to address the study objectives. The budget requirements captured in the survey excluded transport and boarding facilities.

6.1 Data collection in primary schools

Questionnaire-based data collection was conducted over the period January–July 2019 by engaging youth in Kenya and using a virtual collaboration tool (WhatsApp) for quality control while in Germany. The questionnaires were automated in a subscribed “Collect” application with geocoding capability and administered using smartphones. The exercise targeted head teachers as key informants. Rural and urban primary schools and rural secondary schools were identified for data capture in three Kenyan counties: Homa Bay, Kisumu, and Nairobi. The interview questions probed the key challenges facing STEM education in these settings. The maps in Fig 6.1 show the geographical locations of the primary schools that participated in the data collection exercise, both in terms of their national and county contexts.

To address the main concern of transition rates into higher STEM education, the last two grades in primary school (locally referred to as Standard 7 and Standard 8) that preceded secondary school in the 8-4-4 system of education at the time were selected. These two grades were deemed the most strategic points of entry into the higher learning stages of STEM education. To compare the education challenges in terms of the rural-urban divide, a mix of urban and rural schools was targeted.

The questionnaire engaged the identified key informants on the following key result areas of STEM learning outcomes:

i. Gender-differentiated resource requirements for quality science and mathematics education in terms of annual budgets for learning materials, sanitary needs and extra maintenance, monthly teacher motivation, and teaching contact hours for science and mathematics subjects

ii. Quality enhancement proposals for STEM education including extra-curricular activities

iii. The influence of language, literacy and communication skills on the formal teaching of STEM subjects in primary schools

iv. Socialisation of STEM education in the learning environment

6.2 Data collection in secondary schools

Rural secondary schools were also targeted in the survey so that the teachers could share recommendations based on their experiences on the degree of preparedness of the learners joining them from primary schools. The secondary schools were all drawn from Homa Bay County, a step that was dictated by the need to approach familiar home ground as a pragmatic approach to overcoming the bureaucracy associated with getting key information from secondary schools in Kenya.

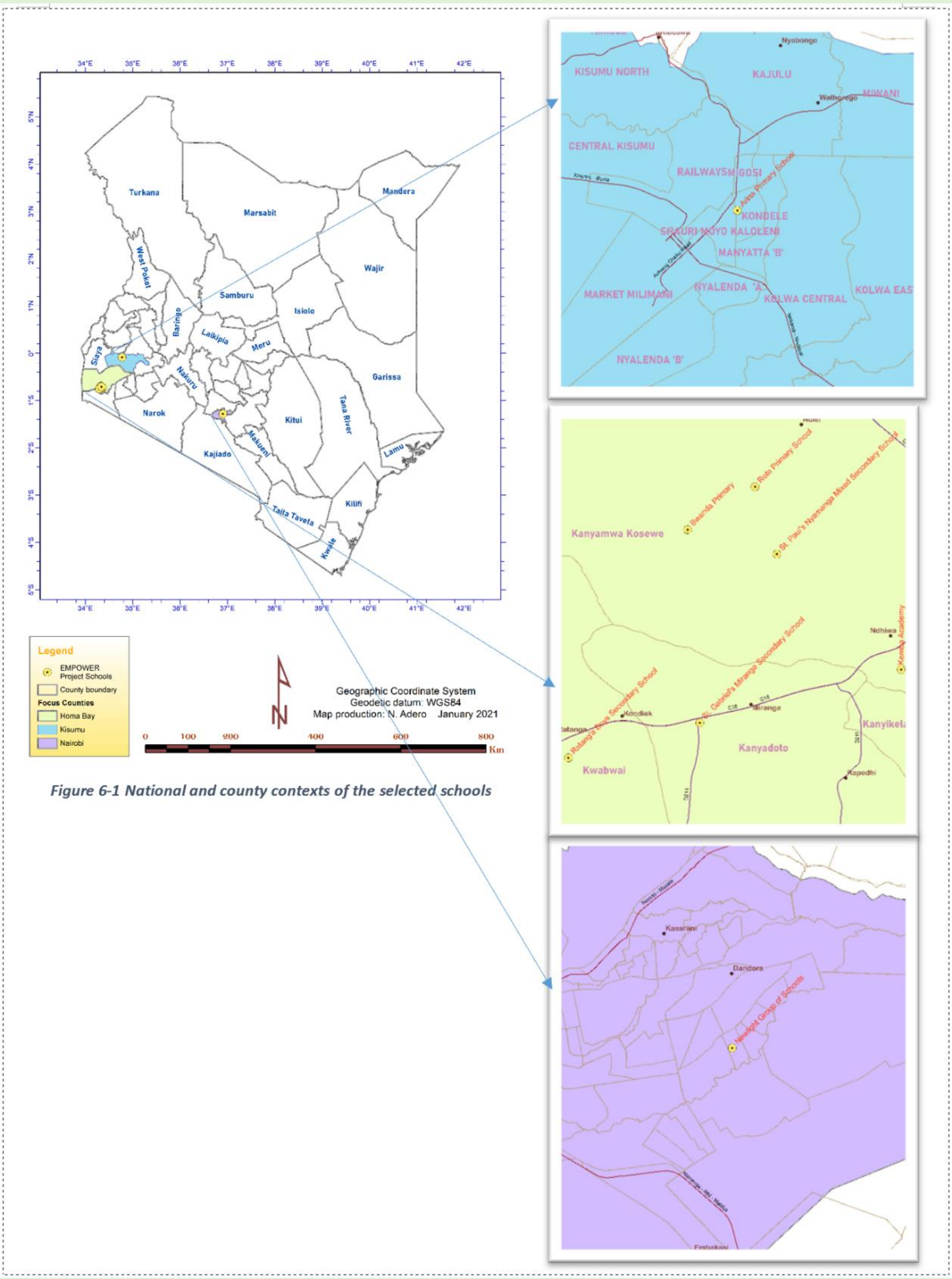

Figure 6-1 National and county contexts of the selected schools

The questionnaire engaged the identified key informants in secondary schools on the following key result areas of quality STEM learning outcomes:

i. Degree of preparedness of the learners transitioning from primary to secondary school in terms of their competencies in STEM a scale of **1 (mostly poor), 2 (mostly average), and 3 (mostly excellent)**

ii. STEM learning capabilities of the students on a scale of **1 (mostly poor), 2 (mostly average), and 3 (mostly excellent)**

iii. Students admitted with special needs and the types of needs

iv. Recommendations on how the quality of STEM education can be enhanced right from the primary school level

The two levels of key informant interviews would help address the need for a systems change, which includes new models for addressing the root cause of the problem. Such a systems change would involve policy change, a pervasive adoption of new methods in the education sector, and inculcating a new learning culture. Ultimately, a framework change is feasible as a long-term goal with the subsequent transformation of mindsets, resulting in a transformed worldview in society in favour of STEM-driven development in a technologically advancing era.

7. Results and Discussion

A total of eight schools were represented in the detailed interview seeking out answers to the four questions on STEM education in upper primary school (Standard 7 and 8). Five head teachers, of three public primary schools and two private primary schools, responded to the four interview questions as key informants for primary schools. For comparative cost assessments by geography, three rural and two urban primary schools were selected. The urban schools are in Nairobi and Kisumu. By name, the schools were Rota Primary School (rural, public), Bwanda Primary School (rural, public), Arina Primary School (urban, public), Kemba Academy (rural, private), and Newlight Group of Schools (urban, private).

In the case of secondary schools, three head teachers, of three public secondary schools in rural Kenya, responded to the four interview questions as key informants. The secondary schools were St. Gabriel's Miranga Mixed Secondary School, Ratang'a Boys Secondary School, and St. Paul's Nyamanga Mixed Day Secondary School.

The detailed results and discussions have been presented in the following sections.

7.1 Gender-differentiated resource requirements across primary schools

The results showed that urban primary schools prescribe up to two to three times the mean annual per capita budget requirements of their public counterparts for learning materials, sanitary materials for girls, and additional payments for motivating teachers. The data portrayed a similar divide between private schools and public schools, the former prescribing double the mean annual per capita budget requirements for learning materials. In terms of sanitary materials, the private schools preferred a mean per capita annual budget that was between 1.3 and three times as much as the one preferred by public schools. The budget requirements for learning materials in Standard 8 came to about 1.5 times the Standard 7 requirements.

Per capita extra maintenance costs for learner needs were reported to be higher in the public schools than the private schools, suggesting the wide gap in maintenance needs in public schools. This difference can further be related to the poorer condition of facilities in public schools than private schools. Generally, the maintenance culture in private institutions is more robust and responsive than in public institutions. Furniture, repairs, male- and female-specific facilities for personal health breaks and hygiene, safety, sports, entertainment and recreation, and general facility management were provided as examples of the factors the respondents were to consider when answering the question on extra maintenance budgets. The detailed budget estimates in US dollars from the survey are presented in Table 7.1.

Table 7-1 Results of the interview of key informants (head teachers) on estimated budgets for improving learning outcomes for upper primary male and female learners in selected rural and urban primary schools across Kenya

	Budget estimates in USD as of July 2019									
Primary school type	Class 7 annual budget for learning materials	Class 8 annual budget for learning materials	Class 7 Boy sanitary material annual budget	Class 7 Girl sanitary material annual budget	Class 8 Boy sanitary material annual budget	Class 8 Girl sanitary material annual budget	Class 7 teacher motivation payments monthly	Class 8 teacher motivation payments monthly	Boy's extra maintenance annual budget	Girl's extra maintenance annual budget
Public, rural	120.00	150.00	0.00	84.00	0.00	84.00	2.00	3.00	24.00	72.00
Private, rural	250.00	350.00	50.00	240.00	50.00	240.00	15.00	22.00	60.00	240.00
Private, urban	180.00	180.00	20.00	100.00	20.00	100.00	5.00	7.00	36.00	120.00
Public, rural	80.00	130.00	0.00	80.00	0.00	80.00	1.50	1.50	24.00	60.00
Public, urban	120.00	150.00	40.00	240.00	40.00	240.00	6.00	6.00	120.00	600.00
Mean, public	106.67	143.33	13.33	134.67	13.33	134.67	3.17	3.50	56.00	244.00
Mean, private	215.00	265.00	35.00	170.00	35.00	170.00	10.00	14.50	48.00	180.00
Factor	2.02	1.85	2.63	1.26	2.63	1.26	3.16	4.14	0.86	0.74

It was also evident from the pupil numbers that there was a reduction by mostly ten or more in the number of boys and girls when transitioning from Standard 7 to Standard 8. This applied to both public and private schools. In the public schools, however, gender disparity was more evident, the ratio of boys to girls in the upper primary classes being 3:2. The private schools had almost attained gender parity in pupil numbers in these upper primary classes. These observed trends also show the marked influence of differences in the social and economic status of the parents of the pupils, both in rural and urban areas.

The data also portrayed the higher demands on the female learner in terms of budgets for sanitary requirements and extra maintenance, four to ten times of the male learner’s annual budget. The public primary schools gave a mean annual budget for sanitary material of 135 USD per girl (13 USD per boy), lower the mean of 170 USD per girl (35 USD per boy) for private schools. The mean annual extra maintenance budget for a girl in a public school of 244 USD (56 USD per boy) was higher than the 180 USD stated for a girl in a private school (48 USD per boy). The prevailing maintenance culture in public schools trails private schools and this could explain the difference, manifested in maintenance backlogs as revealed in this study.

7.2 Factors of quality enhancement for STEM in primary schools

To enhance STEM education, the suggestions given were:

i. Well-equipped laboratories and research projects
ii. More practical lessons to arouse scientific curiosity among learners
iii. Quality teacher training and exposure for benchmarking purposes

iv. Encouraging peer-peer learning
v. Early introduction of the constituents of the consolidated Science subject in the form of Biology, Chemistry, and Physics

Teacher/pupil ratios, availability of well-trained teachers, and the level of teacher motivation together determine the quality of delivery on taught subjects, more so the resource-intensive STEM subjects. Key statistics from the survey of the primary schools represented the deprived status of human resources across Kenyan schools, which is a setback to attaining quality education targets.

The survey confirmed that teacher motivation requirements were much higher in private schools (10–15 USD monthly per teacher), which was between three and five times the mean monthly requirements preferred for public schools. While the rural schools had 50 pupils or less for each of the two grades (Standard 7 and 8), the urban schools generally had more pupils per class for both grades, typically more than 100 learners. The urban public school in this sample represented the reality of congestion in public schools, with 232 pupils in Standard 7 and 198 pupils in Standard 8. The higher population density in urban centres is responsible for this large difference. For the public schools, lower teacher/pupil ratios of 1:50 and less were common, lower than the recommended 1:35 in Kenya. Shortage of trained government teachers, especially in public schools, necessitated stop-gap measures such as contractual engagement of untrained teachers, paid at less competitive rates for their services by the resource-deprived association of teachers and parents.

7.3 Effectiveness of languages for STEM teaching and contact hours

The teachers compared the effectiveness of the official teaching languages (English and Kiswahili) to vernacular, Kenya being a multi-ethnic nation with more than forty different mother tongues. The teachers confirmed that the learners were more interactive when the official teaching languages were used to teach them STEM subjects. This finding confirms that the upper primary classes had become more accustomed to the STEM keywords, which are available in the official language of teaching as expressed in learning materials.

The weekly contact hours for STEM subjects was determined to be averaging 23–25 hours in the primary schools. The rural schools generally reported more contact hours. The fewer teachers and limited variety in extra-curricular activities and optional subjects such as foreign languages and computer studies in rural public schools could explain the shift of more contact hours to STEM subjects in their favour. Less strict administration of syllabus coverage for all subjects in deprived rural public schools is another possible explanation of this rural-urban variance.

7.4 Socialisation of STEM education in primary schools

To socialise the learning process effectively and stimulate the application of STEM within the immediate environment and society, the suggestions given were:

i. Bringing forward the Science Congress competitions that have hitherto been a reserve for secondary schools in Kenya to start in primary schools, as a way of stimulating interest in STEM, nurturing young talents, and catalysing an early adoption of scientific thinking and a culture of innovative solutions among young learners
ii. School field trips for exposure to practical applications

iii. Drama festivals
iv. Contests on creative skills, arts and craft
v. A pedagogical paradigm shift from binary answer choices to thought-provoking and learner-centred approaches, so as to develop critical thinking and complex problem-solving skills

7.5 Degree of STEM preparedness and learning capabilities of the learners transitioning to secondary schools

The secondary school teachers independently but unanimously confirmed that the students they received from primary schools were mostly average in their STEM preparedness, with some cases of poor preparedness among girls due to sociocultural stereotypes that associate girls with poor STEM capabilities. They attributed the sub-optimal preparedness of the learners to diminished practical lessons, deficiency in STEM learning resources, and the mostly deprived or disadvantaged home backgrounds of the learners transitioning from primary school. Cases of inadequate delivery by the teachers of science and mathematics because of training and resource deficiencies were also cited, which impair the practical teaching and exposure that STEM subjects require for impactful instruction.

7.6 Profile of students with special needs

The secondary schools have been receiving learners from primary schools who have special needs. The most common cases recorded were sensory impairment in terms of vision, hearing and dissociation. Physical handicap and allergies (more of asthma cases) were also cited. To excel in STEM subjects, which are resource-intensive as already demonstrated from the interviews, this special group of learners need assistive technologies. The increasing rate of skills attrition and demands on upskilling and reskilling cycles in the emerging era of Industry 4.0, a skills revolution in essence, make the utilisation of such technological solutions an urgent and critical policy issue to achieve equity in STEM learning outcomes.

7.7 Preparing learners from primary schools better for quality higher STEM education

The key informants (teachers) appealed for a reversal of the systemic and limiting stereotypes and culture against STEM subjects for girls, or science and mathematics in the context of Kenyan primary schools. This requires deliberate awareness creation to socialise STEM at school and in society. Providing adequate learning resources and well-equipped laboratories was also emphasised, appreciating the high demands of STEM subjects. Practical teaching and project-based learning were fronted as critical factors in arousing and sustaining passion and scientific curiosity among the young learners. The teachers also stressed the necessity of adequate syllabus coverage and quality assurance of the same in primary schools to help hand over better prepared learners to secondary schools.

8. Conclusions, Recommendations and Outlook

Addressing the urgent challenges of quality and equity in STEM education in Kenya calls for adequate measures and countermeasures calibrated by three main lessons: a wide rural-urban divide in human resources, learning resources, and infrastructure facilities; the need to incentivise a faster attainment of gender parity in rural areas by increasing the enrolment and participation of girls in basic education while actively socialising STEM education to erode discriminatory stereotypes, gender bias, and similar cultural barriers; and the need to invest more resources, especially in rural areas, to help make the teaching of STEM subjects more practical and field-oriented. Taking the higher average per capita annual budget for learning material (for private schools) and adjusting for the rising cost of living, an additional annual provision to cater for quality STEM education of between 250 and 300 USD per learner is recommended for the upper primary grades leading to secondary school.

Adequate budget for learning resources and sanitary requirements for girls and boys were established to be higher in private and urban primary schools than public and rural primary schools, between twice and three times as much. From the average results from private schools and adjusting for the rising cost of living since 2019, each girl would need about 200 USD annually to meet her sanitary requirements and study STEM subjects comfortably. Each boy would need about 50 USD annually for their less demanding sanitary requirements.

The adjusted extra maintenance needs beyond the ordinary sanitary needs were higher for girls than boys and also higher in public schools than private schools, the private schools recommending about 80% of what the public schools stated. The poorer maintenance culture in public schools than in private schools could explain this difference. For the public primary schools, the range of extra maintenance estimates came to an annual budget of about 200–250 USD per girl and 50–60 USD per boy.

The suggested additional motivational monthly payments for STEM teachers in private primary schools is much higher than in public primary schools, in the range of three to four times. The result for the monthly motivational budget per STEM teacher in private primary schools came to about 10–15 USD. These indicative figures should help inform parameters for progressive educational planning.

The secondary school respondents confirmed the sub-optimal STEM preparedness of the learners in rural areas transitioning to secondary school, calling for measures to enhance practical and skills-based STEM education earlier in primary school. To meet this goal, it is recommended that governments institute robust plans for increased and sustainable investments in laboratories, learners' exposure through field-oriented STEM teaching missions, adequate learning materials, adequate teacher training and their exposure to ensure practical competencies in STEM subjects as technology advances, and structured mentorship.

For equity and social inclusion in STEM, assistive technologies need to be secured and made readily available to the learners with disabilities, who already make up a significant share of modern learners. The rapid pace of technological advances, however, forces all policy reforms in favour of STEM education to be timely and actionable with adequate budgets. The results of this study will therefore continue to be shared with policymakers, educators, and other key stakeholders in Kenya's education sector including local communities. The emphasis remains on timely action and implementing quick wins to reduce STEM education inequalities while meeting the training and mentorship needs of the rising population of young learners.

The outcome of this study has further reinforced the rising need for early talent identification and mentorship in STEM, as confirmed earlier from the 2014–2015 key informant surveys. The outlook from this project was to establish a youth mentorship programme in Kenya, anchored on the philosophy of knowledge-driven impact on society based on refined talents and a mindset of global citizenship for borderless collaboration and intergenerational responsibility in a digitally connected world. The youth mentorship programme was launched in 2019 under the name Impact Borderless Digital (IBD). The decision variables and metrics from this background study will be used to develop, parameterise, and calibrate an optimisation model for efficient resource planning and allocation for quality STEM education including performance monitoring and evaluation.

By March 2021, the following milestones had been realised as by-products of this EMPOWER education project:

i. Drawing on the youth mentorship experience, a book chapter on post-pandemic perspectives on youth unemployment and skills development in Africa has been published in a new book, to be off the printer by the end of March 2021: **Adero, N.J., & Juma, J. (Eds.). (2021). *The Future of Africa in the Post-COVID-19 World.* Nairobi: Inter Region Economic Network.**

ii. Winner of the DAAD/ACCESS (African Centre for Career Enhancement and Skills Support) Idea Competition on ***Employability Promotion at Higher Education Institutions in Africa***, announced on November 27, 2020. The cash award received is supporting research on enhancing employability skills among young Kenyans in the 18-35 age bracket.

iii. This EMPOWER project was used to secure a registration and membership in **The Global Academy** (on SDG 4.1, 4.3, 4.4, 4.7, 4.9) as a Kenyan global change maker.

iv. Fifteen youth forums (IBD Series) – both physical and virtual, had been conducted across Kenya under different topics on Education 4.0, which is the emerging education agenda in the era of Industry 4.0. The delivery mode has been engaging speakers who are mentors and experts in the topics of interest, drawn locally and abroad. The COVID-19 global pandemic has led to a reinvention of IBD series to be virtual and recorded, enabling a ready global connectivity to highly skilled diaspora.

v. Complimentary TV recording of **"Talanta Talks"** on Talanta TV in Kenya has been secured for wider outreach to youth. *Talanta* is the Swahili word for talents. Two such recordings have been made.

vi. Publicity of the IBD programme on Kenya's leading daily, **The Daily Nation**, was achieved on January 17, 2020 under The Personality of the Week feature.

vii. A website for **Impact Borderless Digital** (impactborderlessdigital.com) programme was set up in March 2020, complete with a Facebook page, YouTube channel, and Twitter handle (@ImpactBorderle1) for regular and borderless engagement with youth on topical issues of mentorship and thought leadership.

viii. Participated as a speaker on youth skills in the digital era at the **Inaugural Australia-Pacific Skills Summit** held in Suva, Fiji, June 24–25, 2019.

Subsequent efforts from 2021 onwards will be concentrated on seeking out and fostering sustainable partnerships to expand the pool of mentorship resources towards meeting the needs of Kenya's rising youth population. The long-term vision is to institute the IBD Talent Academy to stimulate collaborative mentorship and continuity in empowering youth with the right attitude, international exposure, and experience they need for knowledge- and technology-led leadership and change agency in a rapidly evolving world. The sentiment attributed to Prof. Klaus Schwab that the world of the future would be pegged on "**talentism**" as opposed to capitalism, with human talents emerging as the most important factor of production, could well be proven to be right on point through the long-term impact of this project.