Mathematics and Science Education in Africa’s Transformation

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Africa’s Growth: Recovery in Last 20 Years, Driven by Natural Resources
Foreign Direct Investment in SSA: 600% increase in 12 years

Source: UNCTAD (2014)
Note: FDI measured in US$ billions at current prices and exchange rate
• **Innovation**
  • Adoption, adaptation or creation of technologies that are put to productive use by firms
  • New product or use of a new production process

• **Education, Research, ICT:**
  • Education -“Preparation of soil” (Firms need adequately educated and skilled workers to adopt/adapt new technologies)
  • Research and ICT - “nurturing of soil” (Creates and disseminates knowledge that can be used by firms; connectivity)

• **Other Factors are Important**
  • Regulations and competition policy: “Weeding”
  • Finance: “Watering”

World Bank Innovation Policy (2010)
Example of skill shortages:

- SSA: 1 medical school graduate per 117,300 habitants (1 to 54,500 for South Asia – 2nd lowest)
- SSA: 11% of all graduates are within natural sciences and 7% are engineers
- Malawi: 0 veterinarians graduated and only 22 working in the country (2009) due to no veterinarian education (80% of jobs and 80% of exports are from agriculture)
- Angola: 20 petroleum engineers per year (oil and gas is 98% of exports)
Tanzania’s aspiration to attain middle-income country status by 2025

• Through diversification of the economy and more rapid economic growth to create jobs and improve productivity
  • Jobs for 800,000 new labor market entrants each year

• Expansion of employment in existing firms, and creation and growth of new enterprises

• Challenge to develop required skilled workforce to grow new sectors, expand into global markets and innovate
  • given acknowledged education and skill deficits
Tanzania’s challenge: promoting dynamic firms, creating productive employment

Tanzania will have to grow faster to catch up emerging countries...

...But most Tanzanians are employed in small firms

<table>
<thead>
<tr>
<th>Number of employees per firm</th>
<th>1</th>
<th>2</th>
<th>3-4</th>
<th>5+</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>9.8%</td>
<td>7.6%</td>
<td>4.5%</td>
<td>1.8%</td>
</tr>
<tr>
<td>2008</td>
<td>9.8%</td>
<td>7.6%</td>
<td>4.5%</td>
<td>1.8%</td>
</tr>
<tr>
<td>2010</td>
<td>9.8%</td>
<td>7.6%</td>
<td>4.5%</td>
<td>1.8%</td>
</tr>
<tr>
<td>2012</td>
<td>9.8%</td>
<td>7.6%</td>
<td>4.5%</td>
<td>1.8%</td>
</tr>
<tr>
<td>2014</td>
<td>9.8%</td>
<td>7.6%</td>
<td>4.5%</td>
<td>1.8%</td>
</tr>
<tr>
<td>2016</td>
<td>9.8%</td>
<td>7.6%</td>
<td>4.5%</td>
<td>1.8%</td>
</tr>
<tr>
<td>2018</td>
<td>9.8%</td>
<td>7.6%</td>
<td>4.5%</td>
<td>1.8%</td>
</tr>
<tr>
<td>2020</td>
<td>9.8%</td>
<td>7.6%</td>
<td>4.5%</td>
<td>1.8%</td>
</tr>
<tr>
<td>2022</td>
<td>9.8%</td>
<td>7.6%</td>
<td>4.5%</td>
<td>1.8%</td>
</tr>
<tr>
<td>2024</td>
<td>9.8%</td>
<td>7.6%</td>
<td>4.5%</td>
<td>1.8%</td>
</tr>
<tr>
<td>2026</td>
<td>9.8%</td>
<td>7.6%</td>
<td>4.5%</td>
<td>1.8%</td>
</tr>
</tbody>
</table>

Historical growth trajectory, USD 1943 in 2026
Growth needed to catch up Indonesia 2009, USD3374
Growth needed to catch up Thailand 2009, USD5057
Can Tanzania Grow Fast with Such Low levels of Education?

Educational attainment lags behind other SSA middle-income countries

Share of high-skilled workers is low relative to its global competitors

**Average Years of Education in Tanzania**

- **Less than primary (12%)**
- **Primary (50%)**
- **Secondary (24%)**
- **Above secondary (14%)**

**Education Composition**

**South Africa (2007)**
- Above secondary (14%)
- Secondary (24%)
- Primary (50%)
- Less than primary (12%)

**Malaysia (2010)**
- Above secondary (20%)
- Secondary (33%)
- Primary (41%)
- Less than primary (5%)

**Vietnam (2010)**
- Above secondary (8%)
- Secondary (16%)
- Primary (69%)
- Less than primary (7%)

**Tanzania (2012 Census)**
- Above secondary (5%)
- Secondary (6%)
- Primary (62%)
- Less than primary (27%)

How much should secondary and higher education be expanded?
There are innovators in every firm size and sector

**Distribution of firms by size and skills categorization**

- **Innovator [46%]**
  - Small (5 to 19): 64
  - Medium (20 to 99): 25
  - Large (100+): 11

- **Exporter [13%]**
  - Small (5 to 19): 34
  - Medium (20 to 99): 46
  - Large (100+): 20

- **Low-Skills Demand [41%]**
  - Small (5 to 19): 71
  - Medium (20 to 99): 21
  - Large (100+): 8

Legend:
- Small (5 to 19)
- Medium (20 to 99)
- Large (100+)
Most firms (even formal sector ones) in SSA countries are not on the technology frontier

- They are not creating new technologies

But a significant proportion are introducing new products and processes

- A critical mass of technically trained and tertiary educated graduates is required to adopt and diffuse technologies
- Technician training is as important as university level education
- Secondary school graduates with foundational skills are required

For specialized skills, focus for critical sectors (agr, energy, manuf)

- Firm level innovation depends on knowledge spillovers; more feasible within a sector
WORLD BANK PROJECTS
Africa Centers of Excellence – Regional Project

Plus country specific higher education and skills projects
Science and Math in School Education (17 ongoing projects + 2 in the pipeline)

<table>
<thead>
<tr>
<th>Teachers</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>➢ In-service teacher training including distance learning</td>
<td>❖ Provision of textbooks and learning materials</td>
</tr>
<tr>
<td>➢ Training of teachers to use teachers guides and subject guides</td>
<td>❖ Provision of school grant</td>
</tr>
<tr>
<td>➢ Provision of teacher guides</td>
<td>❖ Provision of Secondary School Performance Awards</td>
</tr>
<tr>
<td>➢ Teaching strategies to use low cost and effective ICT</td>
<td>❖ Reform of curriculum</td>
</tr>
<tr>
<td>➢ Improvement of pre-service training</td>
<td>❖ Measurement of learning achievements in primary and secondary</td>
</tr>
<tr>
<td>➢ Support to teacher professional development</td>
<td>❖ Building of scientific and technology blocks</td>
</tr>
<tr>
<td>➢ Improve teacher availability in core subjects (including M&amp;Sc) and in rural areas</td>
<td>❖ Scale up and evaluate early literacy program</td>
</tr>
<tr>
<td>➢ Incentive scheme for math teachers</td>
<td>❖ Computer room and laboratories</td>
</tr>
<tr>
<td>➢ Reform of pre-service training</td>
<td></td>
</tr>
<tr>
<td>➢ Support to teacher supervision mechanism</td>
<td></td>
</tr>
<tr>
<td>➢ Reduce teacher absenteeism and improve time on task</td>
<td></td>
</tr>
<tr>
<td>➢ Establish a committee on improving the teaching of mathematics and science</td>
<td></td>
</tr>
</tbody>
</table>
MATH AND SCIENCE EDUCATION OUTCOME IN SELECTED SSA COUNTRIES
TIMSS: Low Levels, Slowly Improving

Average Math Scores

- Botswana (8)
- Botswana (9)
- Chile (8)
- South Africa (9)
- Ghana (8)

South Africa: Improvement in Performance, but 68 percent performing at “Below Low” International Benchmark

South Africa: Science (Grade 8 and 9)

<table>
<thead>
<tr>
<th>Year</th>
<th>Data</th>
<th>Below Low</th>
<th>Low</th>
<th>Intermediate</th>
<th>High</th>
<th>Advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIMSS 2003 (8)</td>
<td>87</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TIMSS 2003 (9)</td>
<td>87</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TIMSS 2011 (9)</td>
<td>75</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TIMSS 2015 (9)</td>
<td>68</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- Below Low
- Low
- Intermediate
- High
- Advanced
The heights of 100 students in a school were measured to the nearest 5 cm. This table shows the results.

<table>
<thead>
<tr>
<th>Height (cm)</th>
<th>145</th>
<th>150</th>
<th>155</th>
<th>160</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>16</td>
<td>40</td>
<td>25</td>
<td>19</td>
</tr>
</tbody>
</table>

Complete this bar chart to show the same information.

- Content Domain: Data and Chance
- Cognitive Domain: Applying
- Description: Uses information in a table to complete a bar graph

For every whole number $n$, are these statements true or false?
Fill in one circle for each statement.

<table>
<thead>
<tr>
<th></th>
<th>True</th>
<th>False</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n + 4 = 4 + n$</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>$n - 5 = 5 - n$</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>$n \times 6 = 6 \times n$</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>$n + 7 = 7 + n$</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

The answer shown illustrates the type of response that would receive full credit [1 point].

- Content Domain: Number
- Cognitive Domain: Knowing
- Description: Recognizes the commutative property

Percentage of Correct Answers

- Chinese Taipei
- Singapore
- Kazakhstan
- Lithuania
- Turkey
- Botswana (9)
- South Africa (9)
Math: High International Benchmark (TIMSS, 2015)

**Content Domain:** Number

**Cognitive Domain:** Applying

**Description:** Part B - Selects and combines information from two sources to solve a multistep word problem

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**Mobile Telephone**

Kate was going to buy a new Supertex mobile phone. She looked at these two advertisements.

**Company X**

The New Supertex Mobile Phone
Get this great phone free!
250 zeds monthly charge
Calls 3 zeds per minute
Text messages 2 zeds each

**Company Y**

The New Supertex Mobile Phone
Cheap rates for calls and texts!
Buy the phone for 2500 zeds!
Only 30 zeds monthly charge
Calls only 2 zeds per minute
Text messages only 1 zed each

Kate decided to compare how much it would cost to have the phone for a year without making any calls or sending any text messages.

A. Work out the cost of having the Supertex phone for a year from Company X and from Company Y.

Costs: Company X \( \boxed{3000} \) Company Y \( \boxed{3100} \)

B. Kate then estimated how much she was likely to use the phone. She thought she would talk on the phone for 500 minutes in the first year and send 200 text messages. Find out how much she would pay for the phone in the first year from each company. Do not forget the monthly charge and other costs.

Costs: Company X \( \boxed{4900} \) Company Y \( \boxed{4300} \)

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The answer shown for part B illustrates the type of response that would receive full credit (2 points).

- Content Domain: Number
- Cognitive Domain: Applying
- Description: Part B - Selects and combines information from two sources to solve a multistep word problem
Which of the following is the best conductor of both heat and electricity?

A. wood
B. plastic
C. copper
D. glass

- Content Domain: Chemistry
- Cognitive Domain: Knowing
- Description: Recognizes a material that best conducts both heat and electricity

The graph shows the percentage of correct answers by different countries:

- Chinese Taipei
- Singapore
- Thailand
- Jordan
- Kazakhstan
- Kuwait
- Australia
- Botswana (9)
- South Africa (9)
Deer mice live across much of the world. Those living in woodlands have dark brown fur. Those living on sandy beaches have light brown fur.

Why is it an advantage for mice living on the beach to have light brown fur?

It helps the mice blend in with the sand.

- Content Domain: Biology
- Cognitive Domain: Applying
- Description: Explains the advantage for a species of mice to have coloring matching its environment
NEW REGIONAL INITIATIVE FOCUSING ON MATH AND SCIENCE IN SECONDARY SCHOOLS
Dependence on international consultants, no long-term capacity building.
Raising cognitive achievement in math and science requires evidence-based action to address impediments at multiple levels: classroom, school and system

- **interventions at the classroom level**: pedagogy; teacher knowledge and skills; incentives for teachers and students; learning materials; physical conditions in classrooms;

- **interventions that matter** aim to strengthen **teacher effectiveness**

  - **positive impact of adaptive instructional methods on student learning** (e.g. computer based)

  - **use of structured instructional materials when teachers’ content knowledge and pedagogical skills are weak** (IE in India and Philippines; digital technology to standardize both content and pedagogical procedures)
Research on Improving Mathematics and Science Outcomes (2)

- **Interventions beyond classrooms**: Incentives and Accountability Framework

- **Characteristics of high performing systems**: (a) clear national commitment to high standards for learning; (b) an expectation that all students can meet the high standards; (c) teacher accountability; (d) institutionalization of effective instructional practice; (e) Balance between accountability and autonomy; and (f) policy coherence

- **Focusing on teachers and their work**: including institutional infrastructure beyond classroom
MS4SSA Integrates

- Improving mathematics and science learning outcomes in SSA countries needs to integrate key elements around a central focus on improving teacher effectiveness

  1) Focus on supporting teachers in classrooms: need of structured approach, with easy to use materials, student centered pedagogical method, and continuous formative assessment

  2) Focus on building capacity in Africa for training teachers
MS4SSA Integrates 3 Interlocking Elements ...
... with Three Interlocking Partners

International Technical Partners:
- WPI and NJCTL;
- International Advisory Committee

World Bank

African Institutions
- Regional Nodes
- Country Institutions
Adapt to Local Context and Build Capacity on Continent