Electrical and Computer Engineering: the Path to Africa's Digital Skills

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Outline

- On engineering as a development tool;
- Differences in Electrical and Computer Engineering programs in US, Asia and Africa;
- Measuring student learning, quality of faculty teaching, and quality of engineering curricula;
- Summary and some recommendations for reform.

Accelerating the Economic Development of Africa

- Engineering is key to African development because is creates industries that provide stable and well-paying jobs, and is critical for civil infrastructure;

- Not all engineering types will contribute equally (depending on the development stage of the country);

- African nations must choose according to their priorities, but above all,
  - *Electrical and Computer Engineering* must be one of these choices; because
    - It has profoundly changed society, and
    - Is fundamental to the 5^{th} Industrial Revolution;

  - Bootcamp-style training in aspects of Electrical and Computer Engineering, while useful, cannot substitute for proper in-depth and and rigorous training – the wellspring of innovation.

The Modern Engineer

- The qualifications of a modern engineer to function effectively have significantly changed from what they were 15 to 20 years ago;

- Engineered systems today are highly sophisticated, comprising of integrated sub-systems from multiple disciplines; this means:
  - Engineers must be trained to have breadth and depth in their chosen discipline;
  - Possess strong foundational knowledge in the basic sciences that include 3 or 4 of:
    - Mathematics, Physics, Chemistry, and Biology;
  - Acquire a working knowledge of computer systems, embedded computing hardware, programming skills at both a high-level language, and firmware level; and finally,
  - Be skilled at working in interdisciplinary teams;

- Most engineering curricula at African universities are not adapted to train a modern engineer.

Structuring an Engineering Program Responsive to Labor Needs

- A sustainable and relevant program should be responsive to industry and to other employment needs.

	Primary Sector	Secondary Sector	Tertiary Sector
Africa	65%	10%	25%
Asia	30%	30%	40%
USA	5%	20%	75%

Industry Sector	Type of Employment Activities
Primary	Raw materials: agriculture, forestry, mining, other low Skilled labor activities;
Secondary	Manufacturing: automobiles, consumer products (e.g., electronics), industrial products, apparel;
Tertiary	Services: banking, insurance, transportation, retail, hospitality, healthcare, tourism, information technology.

- Majority of industry needs in US and Asia are in secondary and tertiary sectors;
- Need in technical areas, services, soft interpersonal skills, computing skills, team work, and leadership;
- Labor market requires fairly skilled work force;
- Majority of Africans in primary sector of economy.

Data Source: US Bureau of Labor statistics; Brookings Institution, and International Labor Organization

Learning Outcomes of US Engineering Education

- US schools define two main learning outcomes: the second dependent on the first;
- Outcomes calibrated to match needs of industry and other major employers.

Skills	Things students should be able to do by the time the course ends
Knowledge	What students should know and understand by the time the course is completed
Attitudes	Students' opinions about the subject matter of the course by the time the course ends

→

Citizens	Actively involved and globally engaged
Persons	With a sense of wellness and balance
Professionals	Adept at communicating and accustomed to working in multidisciplinary teams
Scholars	Deeply trained in their disciplines

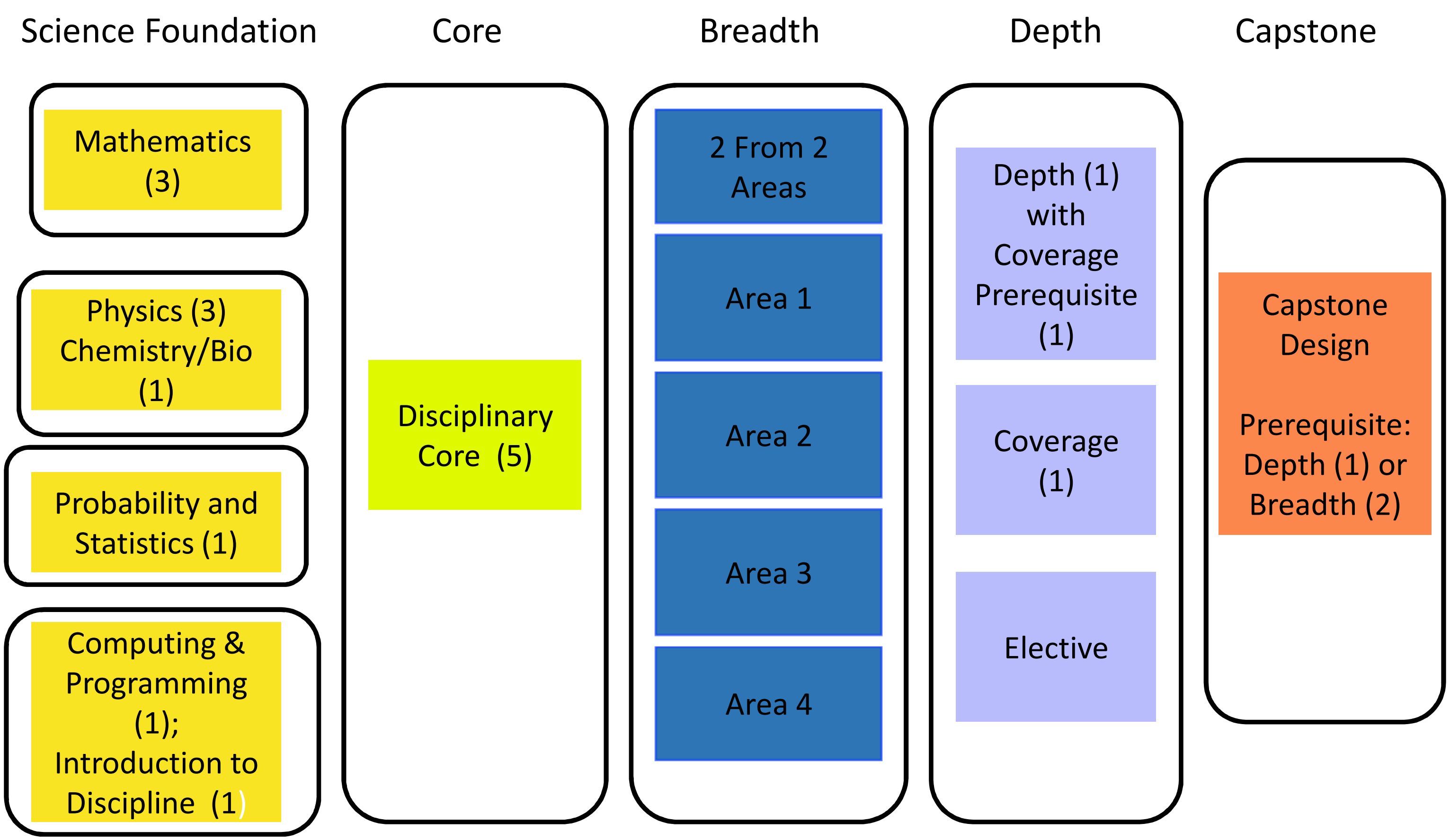
Outcomes of African Engineering Programs

- Most African engineering programs do not explicitly define their outcomes;
- These need to be clearly defined so that students and potential employers in industry understand what to expect;
- Students have no way of inferring what a course or program outcomes are supposed to be;
- Implicit (unstated) outcome is a trained engineer (but with unknown characteristics).

African Engineering Programs relative to Global Norms

- US and Asian programs focus on science, mathematics, and computing fundamentals in first 2 years;
- Most US and Asian engineering programs are flexible, allowing students to choose a major concentration after the common core;
- African engineering program are inflexible and have too many courses – computing is not considered fundamental;
- Some courses in African engineering curricular are dated and not relevant to modern needs or the needs of the nations they are supposed to serve.

Structure of a Modern Engineering Curriculum (US/Asia)



Curriculum typically includes a sequence of mandatory humanities courses

Managing Constant Change and Finiteness of Time

Students in US and Asia focus on fundamentals and only 1 or 2 depth areas of specialization

Area 1

Area 2

Area 3

Area 5

Area 5

Breadth

In Specific Engineering Chosen by Student

Foundation

Mathematics

Physics

Chemistry/Biology

Computing

Areas chosen to reflect national needs or industry priorities for the nation

Department core mandates

School or University requirements

Electrical and Computer Engineering Programs

- Electrical and Computer Engineering (ECE) has profoundly changed society, and in the process, impacted all other engineering and science fields (and most other non-engineering fields as well);

- It is a good model for understanding the organizing principles of other engineering disciplines;

- Today, ECE divides itself into three broad core areas that overlap:
  - (1) Electronics, (2) Electronic Information Systems, and (3) Computer Science;

- Most top ECE/EECS programs in the world remain as a single department (or school) rather than separating computer engineering/science from and electrical engineering.

Electrical Engineering and Computer Science

Curriculum builds after 3 or 4 science and 3 mathematics foundation requirements

Depth subjects build on core material

- Advanced undergraduate subjects
- Advanced undergraduate subjects

Three additional subjects taken during 3rd or 4th year

- Discipline elective
- Discipline elective
- Communications

Students choose three **breadth subjects** that build on core material

- Electrical Engineering subjects: Electromagnetic Fields; Cellular Neurophysiology; Signals and Systems; Nanoelectronics; Electromagnetics
- EECS subjects: Machine Learning
- Computer Science: Computer Systems; Algorithms; Software Construction; Artificial Intelligence

Students must take three **core subjects** that build on introductory material

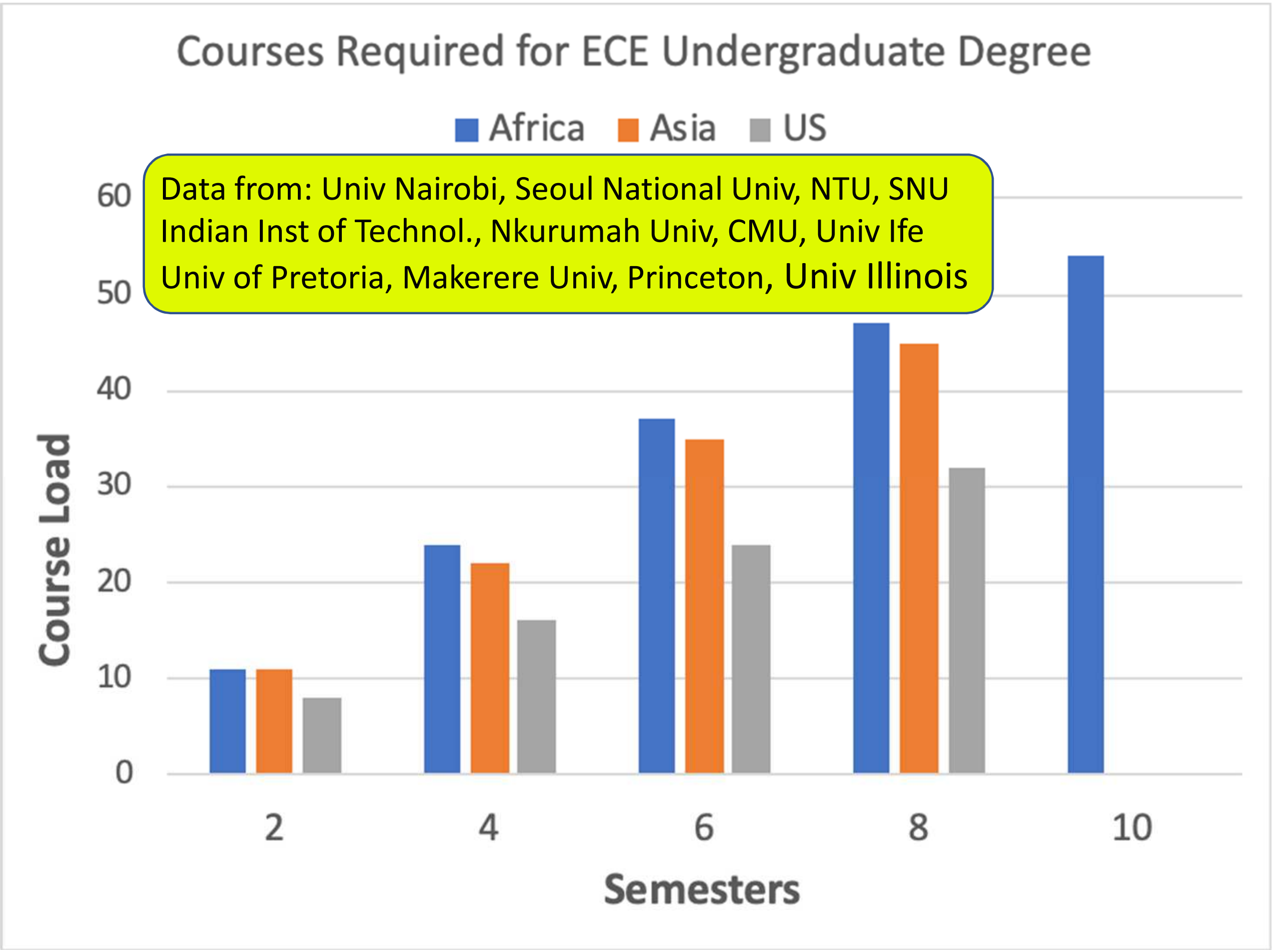
- Electrical Engineering subjects: Circuits; Signals
- EECS subjects: Inference; Computation structures
- Computer Science: Programming; Algorithms

Introductory subjects introduce students to breadth of discipline; Teach fundamental skills of the discipline.

- Electrical Engineering subjects: Mathematics
- EECS subjects: Introductory subject
- Computer Science: Programming skills

Electrical Engineering subjects | **EECS subjects** | **Computer Science**

Trends in Undergraduate Degree Course Load



- ❖ African engineering programs require more courses for the BS degree;
- ❖ US and Asian programs require a semester-long or year-long capstone project;
- ❖ African programs rarely require semester-long projects.

Some Courses In African ECE Curriculum Not Relevant

Courses Not Necessarily Needed

1. Fluid Mechanics for Electrical Engineers
2. Mechanics of Machines
3. Power Electronics and Variable Machines
4. Electrical Machines
5. Mechanical Workshop
6. Courses, e.g., with content that includes DOS, Autocad, word processing, and other commercial apps.

More Useful Things

- Focus should on fundamentals that can last a lifetime;
- Provide depth in core material;
- Teach skills that help with life-long learning;
- Impart skills for team-work and collaboration.

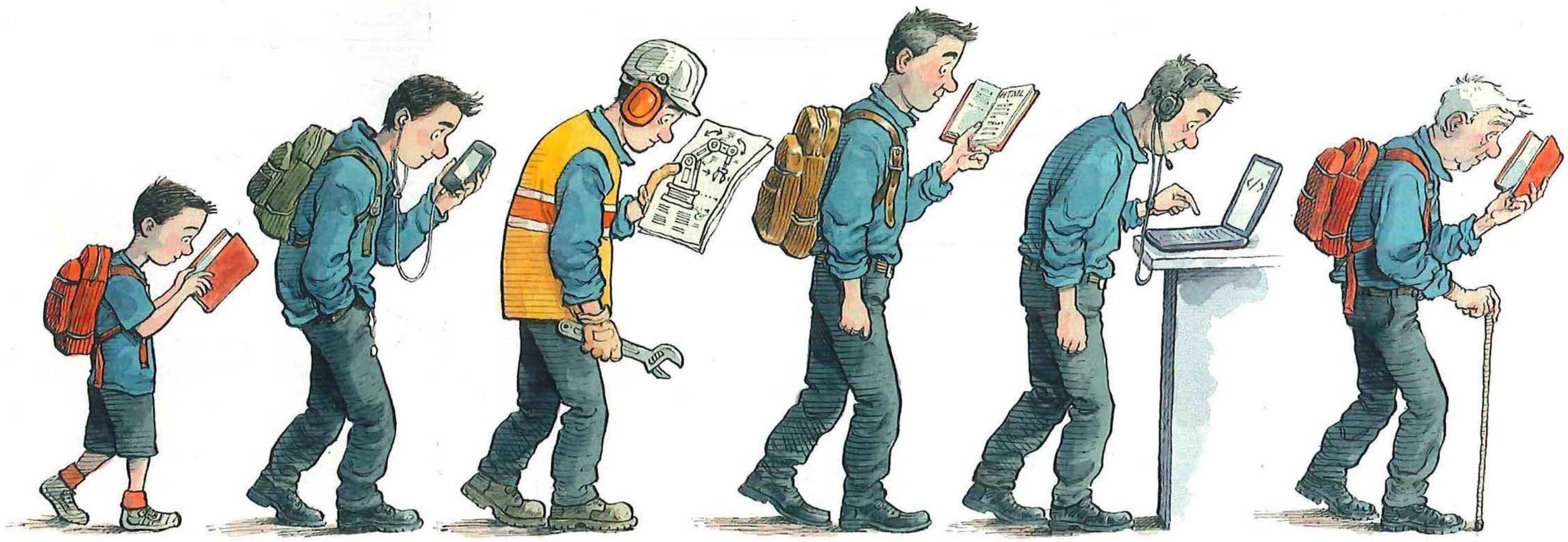
Pedagogical Style Differences

Teaching Mode	Africa	Asia	US
Lecture	Yes	Yes	Yes
Recitation	No	Yes	Yes
Tutorial	No	No	Yes
Lecturer Office Hours	Yes	Yes	Yes

- Most US and Asian universities require lectures and recitations for 1st and 2nd year students;
- All African universities instruct by lecturing, but rarely offer recitations;
- Among US universities, recitations are where material is covered in-depth, and examples problems solved;
- Tutorials are drills for honing problem-solving skills in US universities (conducted by graduate students);
- Additional help available to US students during lecturer's office hours (lecturer required to hold office hours).

Every Engineering Curriculum Should Impart Life-long Learning Skills

- To cope with rapid change in engineering and technology, every course must impart life-long learning skills for a successful career



From *The Economist Magazine*, January 14 – 20, 2017

Learning Experience is Fundamentally Different for Asia/US Students

	Course Project	Non-thesis Research Project	Thesis Project	Internships
Africa	Rare	None	None	Rare
Asia	Required	Encouraged and available	Sometimes	Available
USA	Required	Encouraged and available	Optional	Available

- US and Asian undergraduate students have an abundance of opportunities for hands-on experiential learning on independent or supervised projects;
- African students rarely have these opportunities;
- Projects are essential to assimilating and internalizing engineering concepts.

Assessment of Student Learning

	HW	Tests	Final Exams
African Universities	Yes (10-15%)	Yes (15-20%)	Yes (70 – 100%)
Asian Universities	Yes (?)	Yes (?)	Yes (?)
US Universities	Weekly (15 - 20%)	Yes (35 – 40%)	Yes (50 – 100%)

- Semester-long to year-long capstone or thesis projects are a major assessments tool in US schools;
- Homework, frequent tests, and mid-terms are very important for US students – they can drop a course if not doing well in it after mid-term;
- African Universities heavily weight final exams – students have not mid-point feedback for a decision to drop or not to drop a course.

Data from: Univ Nairobi, Seoul National Univ, NTU, SNU
Indian Inst of Technol., Nkurumah Univ, CMU, Univ Ife
Univ of Pretoria, Makerere Univ, Princeton, Univ Illinois

Program (Curriculum) Assessment

	Assessing Authority	External Review	Self-study
Three African Universities	National Board of Engineers (2) None (1)	None (3)	None (3)
Three Asian Universities	Ministry of Education (1), IEEE Accreditation Org (1) National Inst of Engineers (1)	None (3)	None (3)
Three US Universities	ABET (3)	Yes (3)	Yes (3)

- Most engineering programs in US are accredited by Accreditation Board for Engineering Technology (ABET);

- Most engineering departments conduct a self-study and peer review in addition to the ABET review;

- Some African programs are reviewed by National Boards of Engineers; others are not;

- Some Asian programs are reviewed by IEEE (an international Professional Society); others by their Ministry of Education.

Assessment of Teachers

Years after joining	Africa	Asia	US
3 years	?	Yes	Yes
6 years	?	Yes	Yes
9 Years	?	Yes	Yes
Tenure Granted	?	After 6th year	After 6th or 10th year

Evaluation of Teacher and Course	Africa	Asia	US
Mid-semester evaluation	None	None	Yes
End of Semester evaluation	None	None	Yes

- Assessing teachers is one of the most critical aspects of education;
- It provides feedback to the teacher on what to improve; and
- Makes them want to be better teachers, who care about their students.

Need for Reform

- To properly prepare students for the 21st century, African engineering programs need to be reformed:
  - Curricula structure – what major areas (of any engineering) to focus on;
  - Syllabi – what topics to include in a course; and
  - Making computer literacy a core requirement in all engineering programs.
- Curriculum reform is best informed by national and industry needs;
- Computing and computers are everywhere: every program and course must integrate computing into all its activities.

Need for Regular Assessment of African Programs

- Periodic quality assessment must be an integral part of any curriculum;
- Programs/curricula should be reviewed periodically for relevancy (every 4 or 5 years);
  - Assessment should be by an external national/international engineering authority;
- Content of syllabi should be reviewed or fined tuned every semester based on how students performed in course;
- There should be regular homework and more periodic tests which count toward the final course grade; assessment proficiency by a final exams is not fair to the student as it is unrepresentative of what they have learned;
- Professors/lecturers should be evaluated by students every semester in every course;
- Professors/lecturers should be reviewed by peers periodically.

Summary of Critical Recommendations for Reform

- At the faculty level - review and refine approach to how course material is presented every semester (by gauging response and perceived understanding by students in previous semester);
- Department level - carry out periodic curriculum review and updates (every 4 to 5 years); institute anonymous evaluation of faculty teaching by students, and by peers;
- University level - arrange for program review of departments by external panel of experts in the relevant fields; *establish an ECE department if there is none; also establish a general computing program for the rest of the university;*
- Country level – articulate development plans and goals that universities can contribute to;
- Regional level - establish a network that can collaborate on
  - Shared research interests, and shared pedagogical experiences;
  - Developing a regional board that could become an external curricular review board, and a resource for member universities for recruiting external experts as teaching evaluators.

Short-term Actions

- Add tutorials for 1st and 2nd year students (engage 4th year students and graduate students as tutorial instructors – this is a valuable training tool for them, and a potential source of future faculty members);

- Implement regular assessment of student learning (weekly homework, monthly tests, and provide early feedback at mid-term so students know how they are doing); final exam should not be the only metric for final grade;

- Offer semester-long projects to students (reform curriculum to allow this);

- Institute anonymous review of the quality of teaching by students every semester; faculty should study the anonymous reviews and take corrective action when necessary;

Long-term Actions

- Define and articulate a national strategic development plan - then align the teaching/research mission of university engineering departments with the national goals;

- Consider focusing on updating engineering courses for M.S./Ph.D. studies through the PASET Regional Scholarship and Innovation Fund as a recruitment tool for next-generation faculty members who will support the articulated teaching/research mission;

- Develop rigorous assessment criteria for quality of engineering programs;
  - Evaluate quality of program by asking reputable professionals to review, and by surveying employers of graduates to determine level of satisfaction;
  - Evaluate faculty on quality of scholarship (by papers published in prestigious international journals);

- Establish regional accreditation organizations to monitor and review engineering programs (standardize process and align with international accreditation boards).