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Bundesanstalt für Materialforschung und -prüfung

ISEE AFRICA

INNOVATION – SCIENCE ENGINEERING – EDUCATION

30 January to 1 February 2019
Nairobi, Kenya

funded by
VolkswagenStiftung

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Dr. Dipl.-Ing. Wolfram Schmidt

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Meike Barucker-Sturzenbecher

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Authors
BAM, Z.8 Medienteam
BAM, 7.4
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Preface

Innovation, science and engineering are driving forces to mastering the global challenges of the next decades. The basis is education. ISEE stands for Innovation, Science, Engineering and Education. This book summarises the presentations, discussions and statements that were made during the ISEE-Africa conference held in Nairobi in 2019 from January 30 to February 1.

The ISEE conference is a gathering of international researchers, scholars, and students, who came together to discuss jointly relevant topics related to better education for the engineers and architects of the future.

Today, we know that the climate change is real. Many regions in the world are already suffering significantly, and the only way for humanity to overcome the challenges is to develop more sustainable technologies to the benefit of the entire global society. However, sustainable technologies require for deeper understanding, more conscious thinking, and smarter engineering. The only way how this can be achieved is to educate the developers, the decision makers, the engineers of tomorrow in a more knowledge driven way, and to equip them with the assertiveness required for the implementation.

In this book, topics of construction and sustainable materials are linked to educational challenges. It addresses teachers, academic and political decision makers, and change drivers. The specific objective is to be critical, thought-provoking and inspiring. This way, we do hope that the book can deliver credible solution strategies for enhanced education for a new generation of decision makers with higher awareness of global and environmental challenges as well as innovation potentials.

We wish you an inspired and good read.

Prof. Funso Falade
University of Lagos and AEEA

Dr.-Ing. Andreas Rogge
Bundesanstalt für Materialforschung und -prüfung (BAM)

Prof. Robert Tchitnga
Université de Dschang, University of Ulm

Dr. Wolfram Schmidt
Bundesanstalt für Materialforschung und -prüfung (BAM)

Contents

Motivation

Civil engineers and architects today are exposed to a rapidly changing world. Due to the digital transformation, global value and supply chains, and the urgent need to build environmentally friendly, their professional specifications have little in common with their profiles in the past, and the future will bring additional and different challenges.

> "On a global scale, there is no better alternative to concrete but better concrete – locally there might be thousands.

Due to its tremendous global demand, cement and concrete construction contributes significantly to the global carbon emission, but there is no available mass material on earth that would have a lower environmental footprint. Therefore, on a global scale there is no alternative to concrete but better concrete, but locally there might be better alternatives depending on the boundaries. Hence, in order to understand the implications and to find and apply more sustainable technology solutions contemporary education is key. It is, thus, of highest importance to consider the changed framework for civil engineers, architects, and, today also materials scientists in their education, since these disciplines are highly responsible for the global climate, global networking, and global societal developments.

While the demand for contemporary engineering knowledge, research and education is global, there are regions in the world, where quick implementation of modern education can have much higher leverage than in other regions. This is particularly the case in developing and rapidly emerging economies of the global South, where cement and concrete construction is at the onset of a steep incline. Due to the tremendous impact of cement and concrete based materials on the global climate, the World cannot wait until the maximum production capacity is also reached in these regions before more environmentally friendly technologies are implemented.

> "In order to find and apply more sustainable technology solutions contemporary education is key.

This, in spite of their low contribution to the global climate change, gives a high responsibility to the developing economies of the global South, but at the same time, if new ways can be found to educate

more conscious engineers and architects for the challenges of the future, there is a tremendous potential as well.

Africa has potential to develop and implement best practice solutions, avoid earlier mistakes, and skip technologies of a past era. Africa is young, innovation driven, creative and open-minded, and there is a high affinity for new media, modern processes, and social businesses. Therefore, the starting position in Africa is better than for any other region in the world.

> "Africa is young, innovation driven, creative and open-minded, and there is a high affinity for new media, modern processes, and social businesses.

Construction innovation from Africa, can spark innovation all over the world. However, for innovation driven and sustainable construction technologies to emerge, the next generation of civil engineers and architects need awareness of the challenges, alertness about innovative and sustainable technologies and deeper understanding of their fundamental backgrounds.

To date, all over the world most civil engineering and architecture curricula often do not ideally prepare the students for the global responsibility that comes along with the degree. Contemporary teaching content and educational tools are therefore the only way to adequately educate the next generation of engineers, architects, and decision makers to the benefit of the entire world.

In many industrialised countries this could be implemented quickly in the curricula, since infrastructure, staff and tools for more contemporary education are largely available. However, in many African countries this is not the case. Therefore, it is much more important to support dedicated lecturers and professors with contemporary materials that help enhancing the skills of students. And, Africa is emerging rapidly, and construction activities will tremendously increase over the course of the next decades.

The aim of this book is to provide a comprehensive overview of challenges and potentials in construction, and a diversified discussion about modern education requirements and methods, which help to facilitate the evolution of more conscious, future oriented, innovation driven engineers.

This book is thought to be the kick-off for further activities with the final aim to develop more contemporary teaching tools, jointly with international researchers, scholars, professionals, and students.

Dr. Wolfram Schmidt | *BAM* | *Germany*

About this book

In engineering and architecture, the best practice solution is always individual for a given boundary framework and set of tools. This also applies for education: the best way depends upon a huge variety of parameters. What is good in an industrial environment is not inevitably best in a less developed environment and vice versa. Different cultural, historical, and technological backgrounds demand for different solutions.

> "It may be controversial, it may be inconsistent, it may be polarising. This is wanted and on purpose.

Therefore, this book does not want to convince the reader of one specific opinion and does not want to present one specific solution. This book rather aims at presenting a huge variety of opinions and possible solutions in its entire complexity and diversity. The only common focal point is the requirement for innovative, knowledge driven education towards more sustainable, environmentally friendly cement and concrete construction technologies.

Opinions and the people behind are put into the centre. The main objective is to be thought-provoking and inspiring. Here and there, it may be controversial, it may be inconsistent, it may be polarising, since the opinions, articles and statements are published unfiltered. This is wanted and on purpose.

The chapter "Aspects of sustainability, construction, and education" is a collection of short papers written by outstanding personalities from science, academia, and business. The chapter starts with some considerations about current and future challenges and potentials and continues with thoughts about how engineers and architects have to cope with it in the future. Besides the technical aspects, also social and business aspects are put into the focus. Eventually, some tangible ideas are presented, how future curricula could look like along with the challenges in it, in the World, and in Africa.

The chapter "Talking loud" presents the opinions of the authors of the former chapter in a more personal way. In interviews, the authors give direct answers on questions related to challenges and potentials of the future, and the disciplines involved in it.

The next chapter is called "Points of view". A large part of the delegates of the ISEE conference came to Nairobi from all over the world. A tremendous number of people applied for a travel grant, and it would have never been possible to make it possible for all the

applicants to attend the conference. However, it was possible to select the most suitable candidates based on their motivation to contribute to the conference objectives. This chapter gives them a voice. The chapter comprises of short statements about a variety of topics related to global and local challenges, sustainable construction, engineering skills, and contemporary teaching methods in a global and local context. In addition, it is important to address the issue of gender affairs in STEM education as well as to look at language barriers that apply all over the world, but particularly strong between the francophone, anglophone and lusophone African regions.

Then short "Reviews" of the keynotes, the workshops, and the panel discussion are given, followed by various papers, which were derived from the workshop groups, the "ISEE advancements". These papers were written after the conference by participants who volunteered to elaborate in more detail on the topics discussed during the workshops. The papers are seeds for joint future publications and a real tangible output of the conference. They vary in style and

content, but they summarise the major findings of each group.

> "It is important to address the issue of gender affairs in STEM education as well as to look at language barriers that apply all over the world.

The following chapters "Response" and "ISEE compact" highlight the huge variety of individuals and perceptions, as well as the major topics that formed the central themes of the conference.

The next chapter was completely created after the conference, derived from ideas of the attendees. These "Reflections" are short, thoughtful essays by one or more authors on topics that were not in the focus of ISEE but tangent to the central themes. The reflections start with considerations about vertical and horizontal urban growth, followed by a report about a workshop on future cities and education in Mukuru. The next reflections follow up on education aspects by reporting on Brain Drain, different research strategies in different global regions, boundary frameworks for research, and analytical bias. Bias also plays an important role in the next reflection on gender issues and traditions, complemented by considerations about digital smart life and learning in a global network, which is also an important aspect of the last reflection on the responsibilities of entrepreneurs. The pertinence of the chapters is outstanding, although each reflection was unknown to the other authors. This coherence underpins the excellence of the participants and their will to contribute a small part towards a better world.

Eventually, the chapters are wrapped up in a "Summary" and a "Closure" that provides an outlook on future engineering education. The last, but most important section "Acknowledgements" is dedicated to the VolkswagenStiftung, that significantly contributed to ISEE with financial support.

We do hope, this book will provide you with a lot of insights, thoughts and ideas, which can contribute to better technologies and more conscious engineering and architecture in the future.

Future challenges of construction engineering and perspectives for Africa

Andreas Rogge | BAM | Germany

The paper discusses the future trends of construction and their implication on technical processes and engineering with a special regard on African conditions and requirements.

General

The technical development of construction industry in the 21st century is strongly connected to two factors: productivity and sustainability. Regarding the needs for adequate housing and infrastructure especially in developing regions like Africa, there is no chance to cover these needs without a disruptive reduction of manpower and time per built unit. Automated construction techniques or industrially prefabricated building elements may actually be promoted in more industrialized countries at first hand, but the exponentially increasing demand in Africa will in a very short time outpace it.

The claim for sustainable solutions for the built environment will shortly overcome the sole demand for reduction of energy consumption or carbon footprint but lead to the complete avoidance of waste and unused materials. Closed loops of material supplies or even of construction elements in a circular economy will be the most challenging task in the future decades and regarding the resources situation in Africa, the continent will inevitably have to take a leading role in it.

Automation to increase productivity

Compared to other industries, civil construction has and will keep a high amount of manual work on site. Nevertheless, reducing the number of small and frequently repeated steps like placing single bricks or reducing time-consuming steps like the erection of supporting constructions, concreting, concrete hardening etc. will be a key factor to shorten the overall construction time. This not only affects the construction process itself but also limits the periods of traffic impairments, infrastructure blockings etc. The potential for automated processes on site like using robots, additive manufacturing etc. may still be small in Africa, especially in less industrialized areas. But a more or less automated prefabrication of constructive elements will become an important issue in building industry. The obvious advantages are a production process under more controlled conditions leading to a more consistent quality as well as speeding up the entire process on site due to use of bigger elements up to the use of modular systems on a room scale. Without doubt, a plant-based production process will also foster innovative solutions of automation.

Another important game changer in future construction will be the exponentially increasing digitalization of construction processes. Combining all information on design and production in common platforms and making them available everywhere, there will be no necessity to start every single project from the scratch again. Lifetime data will allow to better utilize good and bad experiences. The ownership of data and the ability to process the data for further applications will become a key functionality in building processes. However, this will change the entire process chain, replacing project groups working together for single projects to long-term cooperation of project stakeholders with long-term contracts and supply chains.

Sustainability in a circular economy

On the materials level, sustainability stands for the use of alternative binders, aggregates and reinforcing fibers, preferably made of bio-based, re-growing materials leading to a reduced carbon footprint. On a constructional level, recycling materials for reuse in construction, as far as possible also for structural purposes instead of backfilling only, will stay an important issue. The basic ideas for these goals are already on their way but have to be strengthened and consolidated in engineering practice. However, innovative solutions going beyond partial replacement of cement or steel reinforcement require holistic knowledge of the interaction between materials, structures and building technologies. In a developing educational system this new thinking will be far easier to implement as in traditional systems. The African chance of taking the lead in sustainable civil engineering education is huge.

Another aspect in view of sustainable construction techniques is related to the end of lifetime of structures. The decisive advantage of prefabricated building systems in future will be the better possibility of deconstruction and reuse of building elements. Most houses are demolished not due to reaching the end of their lifetime but due to a change in usage. The possibility to remove and reuse elements in new structures or even with the chance to rebuild the same house in another place will become an important factor in terms of productivity as well as sustainability. The reuse of building elements will also become a key factor for a wide acceptance of innovative composite elements which can combine different functions in a very economical way (f. e. structural stability and insulation), but nowadays suffer from problems in recycling when not developing possibilities of material separation.

Africa's chance for leap innovations

The biggest chance for each efficient development will always be to avoid the mistakes and aberrations others have already learned of before. In a digital world with the principal technical possibility to get any information at any place in real time, it must be possible to make use of this chance for construction business in Africa by not only focusing on technical building solutions (which nevertheless is important as well) but by creating innovative tools for getting access to existing knowledge and making use of it in permanent education on all levels of students, site workers, professors and engineers. The ISEE conference and the tools and skills developed together during this week and hopefully in other formats to follow should be important components to pave the African way for a prospering and sustainable society on the fundamental basis of African resources, knowledge and education.

The democratisation of form

Namata Serumaga-Musisi | The Griot Introspect | Ghana

This paper explores the lived experience of the citizen (the Living City) as they navigate the imposed Physical City, questioning the functionality of emulated Western urbanity and our rejection of locally defined urbanisms in the name of modernisation/development. It introduces the philosophy behind the Griot Introspect, a practice in space making facilitated by artists, and defined by community.

The aftermath of vendor stall demolitions at Madina Zongo Junction, Accra, July 2018. N. Serumaga-Musisi, 2018

Many urban spaces remain oppressive in the 21st century, a legacy of colonialism on the African continent. Emerging communities, economies and structures that should have taken hold in the immediate post-colonial era were and continue to be marginalised into informality by the imported, globalised 'template' that we continue to aspire to. This is reflected in the hierarchical tension between spaces such as markets and malls; as well as between modern African hybrids such as Mobile Money kiosks, and banks.

Cities take the form of a rigid, insufficient mould, rarely meeting the needs of their fast growing, dynamic populations. The inhabitants, unphased by this rigidity, continuously shift and adapt, flowing through and filling the gaps created by imported urbanity, thus highlighting its failures, particularly in spaces where they are not allowed to flow.

As urban creatives living in and observing these spaces, we find ourselves with the unique opportunity for introspection. A new equilibrium must be sought.

From the Series, Whose Utopia Is It, Anyway? N. Serumaga-Musisi, 2018

The age of multiplicity

The urban dweller of the post-colonial age goes through life straddling a razor thin line dividing the perceived modern – too often read 'Western' – and our inherent identity, a traditional, yet forever evolving, breathing identity. Every action is the result of a number of conscious and subconscious decisions based on this fluid identity and the global – and therefore no longer foreign – identity.

Nowhere is this multiplicity so clearly expressed as it is in our cities. We live out our urban lives in an infrastructure constructed and designed by and for a different age and inhabitant. The functionality of the Physical City must often be questioned as we face the violence of navigating this alien structure imposed on our reality by authoritarian figures, in the name of ambiguously defined modernisation and development.

The Living City, on the other hand, tells a different story; inhabitants act as fillers, flowing through rigid infrastructure, challenging all restrictions and channels - daily recreating and reinforcing more dynamic solutions to our needs. The most marginalized [by design] of the populace have become a living map of our needs in the hybrid state that is our existence.

With this wealth of dynamic information at our fingertips, our infrastructure should reflect the innovative nature of our inhabitancy of space, yet we continue to import alien models in a misguided effort to prove ourselves worthy in the global urban development discourse. The elite build their towering, shrines to free market hegemony; and we celebrate them, in the same breath delegating markets and other true foundations of economy and society the role of 'informal' (implying temporary, unimportant, mortal); marginalising and ignoring them at best, periodically destroying them and the sustainable ecosystems they house at worst. We denigrate 'informal' markets and public transport systems, instead building [then abandoning] parking garage markets in commercially dead zones and bus stops for inadequate bus systems, all of which will be altered and repurposed by those they were intended for, before being labelled as problem areas in the next wave of government mandated development planning. We invest in unconnected development plans but do not engage the communities they impact. We reject – in structure but not in function – that which is truly representative of our needs, our way of life, identity, and take on outdated versions of models that continue to grow outside of us, thus guaranteeing ourselves a back seat in our own development.

In appreciating the innovative measures taken to ensure an [uncomfortable] urban equilibrium, one finds the opportunity to facilitate a more inclusive development dialogue that transcends generation, class and borders. This dialogue must be founded on a period of introspection, allowing us a moment to reflect on space in all its embodiments, in the understanding that the Physical space cannot be at odds with the Living, that for the Living space to manifest itself in intentional design, we must engage all aspects of our psychological, mental and virtual space, and that for us to truly engage, we must empower the primary informant in this dialogue – the citizen. We must take the development narrative and return it to those who live it.

Plug and Play: The Griot Introspect was invited by Mmofra Foundation to conceptualise and create plug-in educational play spaces for the children of market vendors in Accra's Mallam Atta and Nima Markets. The team collaborated with the resident communities to identify needs and locations before creating the installed interventions.
N. Serumaga-Musisi, 2018

Empowering the interstitial

There exists a disconnect between the imported urban ideal and the lived reality. The world of the 'informal' is possibly the only mediating element, the organic space where the needs of the citizen take priority. What if we were able to use these ecosystems as platforms for development dialogue and implementation? What if communities were the driving force behind development?

To begin this process of recalibration we must engage, deconstruct and analyse the thought behind the making and inhabiting of space, freeing it from the exclusive circles of academia and enriching it with the lived experiences of the majority. This is easily achieved, as the tradition of disseminating information and engaging in dialogue in shared spaces, beginning with the griot, continues to be manifested in, among others, mobile community radios, market preachers, singers and actors.

An established dialogue in which all parties have a voice would allow the urban creative – the facilitator – to explore, engage and record the interstitial that is the informal, setting the foundation for various expressions of collected observations, installations that are living maps of the reality – recorded space as installation. In mapping the experienced space, the creative is able to identify hierarchies, issues, gaps, potential; in the process creating and leaving visual traces of this mapping – installation as intervention. The more permeable our physical, psychological, mental and virtual spaces become through this intervention, the more efficiently the greater community can engage with it, allowing the citizen, facilitated by the creative, to direct the development of their own space – intervention as space.

The aim is to dismantle form, reconfiguring it into a platform from which the previously marginalised can articulate and realise their needs. In doing so, we create the opportunity to claim a new, relevant primary informant in our design processes. In elevating the lived reality, and imagining Physical Cities that complement the Lived, this informant becomes the new form.

The future of cementitious materials and how these can be communicated

Karen Scrivener | Ecole Polytechnique Federale de Lausanne | Switzerland

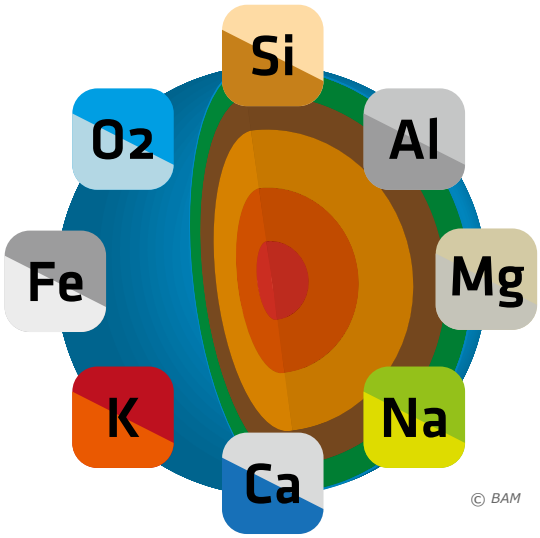
This presentation looks at the prospects for cementitious materials in the future. How this is very dependent on the availability of resources and the technologies we must develop and communicate to reduce CO_2 emissions.

Global challenges

The main challenge facing us is global warming. We have to use all means possible to reduce CO_2 emissions. The role of materials is often forgotten in the debate about alternative energy. Cementitious materials have an important role to play as they currently account for around 8–10% or global man-made emissions. At the same time cementitious materials are essential to house the growing world populations and provide the infrastructure essential for economic prosperity.

The composition of the Earth defines what is possible

Eight elements (oxygen, silicon, aluminum, iron, calcium, sodium, potassium, magnesium) make up 98% of the earth's crust. These elements are overwhelmingly present as oxides and hydraulic materials must essentially come for the lime (CaO), silica (SiO_2) alumina (Al_2O_3) system. This why the well known "Portland" cement has come to be the material produced in the largest quantities by mankind. The constraints of the earth's composition mean this will not change in the future. Nevertheless, we can still make dramatic reductions in the CO_2 footprint of cementitious materials if we combine Portland cement with other materials – notably calcined clay and limestone. Reductions can also then be made at the concrete and structural levels.



How to communicate and implement technologies with lower footprint

This is the big challenge and it needs to be addressed at multiple levels:

- Better targeting of research funding
- Better education of engineers
- Engagement of building users
- Etc.

Some background reading

"Eco-efficient Cements: Potential Economically viable solutions for a low-CO_2 cement-based materials industry" Main authors: Karen Scrivener, Vanderley John and Ellis Gartner for United Nations Environment Working Group. Available at multiple sites via Google.

Construction materials for a sustainable future – Sustainability through diversity?

John L. Provis | University of Sheffield | United Kingdom

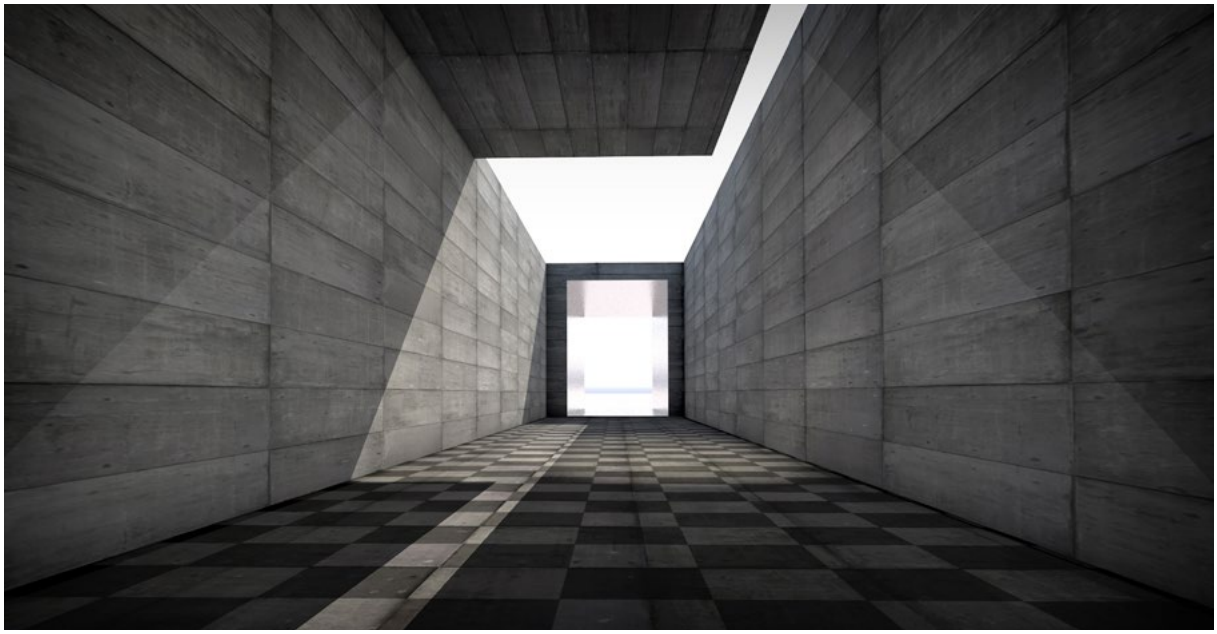
The paper discusses the importance of embracing a local view of materials design, selection and specification, which is essential in achieving sustainable construction worldwide. In particular, the need to design a locally-applicable fit for purpose materials toolkit, rather than seeking a 'one-size-fits-all' solution, is highlighted.

Global challenges and local solutions?

The cement industry is a gigaton-scale commodity products industry [1]; cements are generally specified to perform according to particular standards, with very little to distinguish a product of comparable "grade" (usually defined in terms of 28-day mortar strength) between different manufacturers, or even in different parts of the globe. This means that a Portland cement of a particular type is usually purchased from the most-convenient or most-affordable supplier, and that these two characteristics run hand-in-hand as the cost of transport is a dominant factor in the cost profile of cement-based materials in many locations. This means that there is little incentive for one producer to out-compete another on the basis of technical characteristics of the material, and this has led the global industry – with a limited number of exceptions – toward the development of "one-size-fits-all" solutions, where a near-identical cement is sold to end-users with an extremely wide range of needs and intended applications [2].

This uniformity brings efficiency in supply chains, as the cement manufacturer does not need to know whether the end usage is, for example, in high-rise construction, or in securing an agricultural fence post. Clearly, a material that can fulfil the technical requirements of high-rise construction would be more than sufficient to hold a fence upright – but the question that is more rarely (and largely only recently) asked is: why should we use the same material for both tasks? The environmental footprint of Portland cement is to a significant degree related to the fact that it is engineered for high early strength, which necessitates a high calcium content (leading to more decarbonation of limestone in production), high processing temperature to convert this effectively to tricalcium silicate (alite), and relatively high grinding energy to achieve a high-fineness product which will react rapidly with water. If high early strength is not needed [3], a fraction of this environmental footprint is intrinsically going to waste, as the necessary technical characteristics could have been achieved through the use of a material with a lower environmental footprint.

Such materials are currently produced through blending of less-reactive supplementary cementitious materials with Portland cement, and often at very high volume fractions. This is in many cases an efficient way to valorize waste materials or natural resources, and can also yield concretes with better technical (workability, later-age strength, and/or durability) characteristics than when plain Portland cement is used. However, when a binder is dominated by the reactions and chemistry of the "supplementary" material (rather than Portland cement itself), the question must be asked whether this is in fact the most efficient use of both the Portland cement and the supplementary (now dominant) component [4]. On the contrary, it is highly unlikely that the ideal alkali-source to blend with an aluminosilicate powder to maximize its degree of reaction and the strength and durability of the reaction products, is in fact Portland cement. It is far more likely that a purpose-designed activator [5], specified or blended to match the available aluminosilicate source, will be able to 'unlock' the performance of this material to a greater degree, therefore using this resource more efficiently, and enabling Portland cement to be reserved for use



in cases where it is truly the most efficient, most effective solution.

This type of approach will enable construction to be moved from a global industry that treats the world as the average of all local scenarios, to one which considers the worldwide picture, more correctly, as the sum of all local scenarios. From this viewpoint, the particular circumstances (e.g. materials availability, industrial ecology, transport connectivity, ratio of labour vs materials costs, climatic conditions, among others) which characterise each location are no longer deviations from a global average requiring adaptation of invented-elsewhere technology, but rather become key contributors to a global opportunity to develop and use the most appropriate materials in each and every context. It should certainly be noted that alkali-activation is not likely to be the most appropriate local solution in every location worldwide – in fact, this is highly unlikely to be the case. However, in the cases where it is (and similarly, where another cement type, Portland or non-Portland, is environmentally beneficial and cost-effective in meeting technical and societal requirements), it is essential to have in place the necessary toolkit of validated material systems, standards/specifications, skill sets, and most importantly producer and end-user attitudes. The responsibility for laying this groundwork falls upon the engineers who are in a position to be locally influential; "not invented here" syndrome is a major hurdle to be overcome, and the fact that it is an attitudinal, rather than physical or legal, obstruction does not in any way reduce its reality. The requirement for training, education and empowerment of future generations of engineers is thus further highlighted; we simply cannot build the sustainable global infrastructure of the 21st century using the materials, skills and attitudes of the 20th.

References

[1] K. Scrivener, V. M. John, and E. M. Gartner, "Eco-effcient cements: Potential, economically viable solutions for a low-CO_2, cement-based materials industry", UN environment, Paris, 2017), https://wedocs.unep.org/handle/20.500.11822/25281

[2] J.L. Provis, "Innovation in research on new binders", in: Proceedings of SynerCrete'18, International Conference on Interdisciplinary Approaches for Cement-based Materials and Structural Concrete, 24-26 October 2018, Funchal, Portugal, RILEM Proceedings PRO121, pp.3-9.

[3] P.K. Mehta & R.W. Burrows, "Building durable structures in the 21st century", Concrete International, 2001 (March): 57-63

[4] J.L. Provis, S.A. Bernal, I. Ismail, R. San Nicolas, D.G. Brice, J.S.J. van Deventer, "Comparing the influence of fly ash on the durability properties of Portland cement-based and alkali activated slag-based concretes" - 13th International Conference on Durability of Building Materials and Components, Sao Paulo, Brazil, 2-5 Sep 2014, RILEM Proceedings PRO96.

[5] R.J. Myers, S.A. Bernal, J.L. Provis, "Phase diagrams for alkali-activated slag binders," Cement and Concrete Research, 2017, 95: 30-38.

Engineering skill requirements to cope with the local and global challenges of the future

Wolfram Schmidt | BAM | Germany

The paper discusses how the working environment of civil engineers has changed throughout the years, and how curricula need to be adapted towards these changes.

Global challenges

In the 21st century, adequate habitat and functioning infrastructure are critical for global societal and economic stability. In addition, growing urbanisation and environmental pollution cause challenges to societies. With increasing velocity, humanity faces that the current way of living is not sustainable. Thus, habitat, infrastructure, urbanisation, environment and sustainability are definitively among the most striking challenges of the 21st century.

By consulting, planning, building, maintaining, exploiting and processing of global resources, civil engineers contribute significantly to the existence of these challenges. This is a high responsibility, but due to the heavy involvement, together with adjacent disciplines such as architecture, geosciences, chemistry, physics, environmental sciences and economics, civil engineers also hold the key to mitigate these challenges and provide a brighter global future (Fig. 1).

Solutions towards greener, more sustainable and economically viable materials do exist (e.g. [1]), and there is ongoing research on how greener technologies can contribute to better livelihood and economic growth (e.g. [2]), but their level of implementation is limited, a major reason for which is that these approaches require more fundamental understanding rather than standard application.

Global challenges of the 21st Century

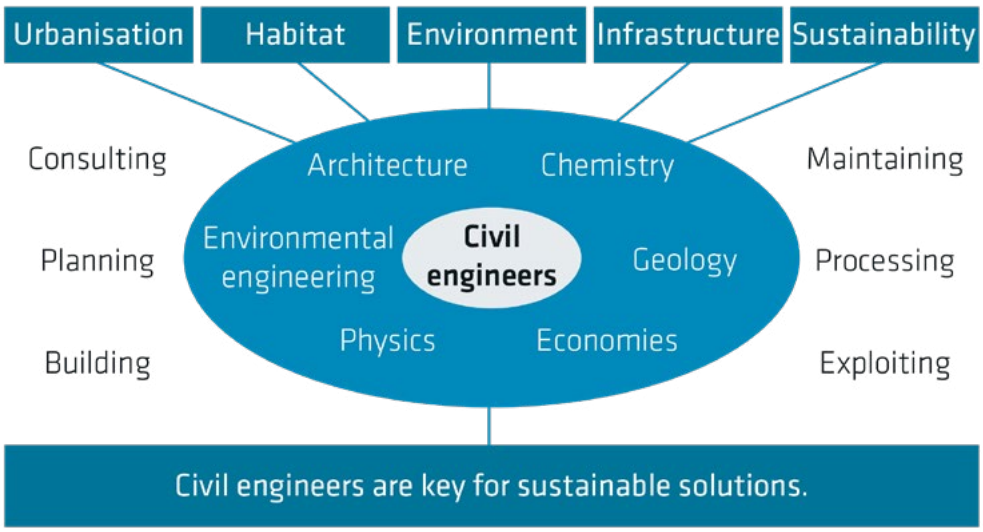


Fig. 1: The role of civil engineers in global challenges

Gap between curricula and real-life requirements

Civil engineering education has traditionally been focused strongly on fundamental mathematics and physics. This may have historical reasons, as the major responsibility of civil engineers in the past was to deliver a reliable, robust and sound calculation, which required a high level of mathematic understanding and reliable calculation skills. Today, with computational tools, the possibilities to calculate and model have increased significantly, but at the same time today no engineer needs to use paper and pen to solve complex equations any more (Fig. 2). Hence, while fundamental understanding of mathematics is definitively still required for civil engineers today, the reliability of the operations can be provided by computational tools.

While the skill to conduct mathematical operations has lower significance today than in the past, the importance to understand materials has significantly increased [3]. In the beginning of the 20th century, construction materials were limited to concrete, steel, timber and masonry, all of them exhibiting limited ranges of performance specifications. Today there is a vast number of materials with a wide range of mechanical and physical properties.

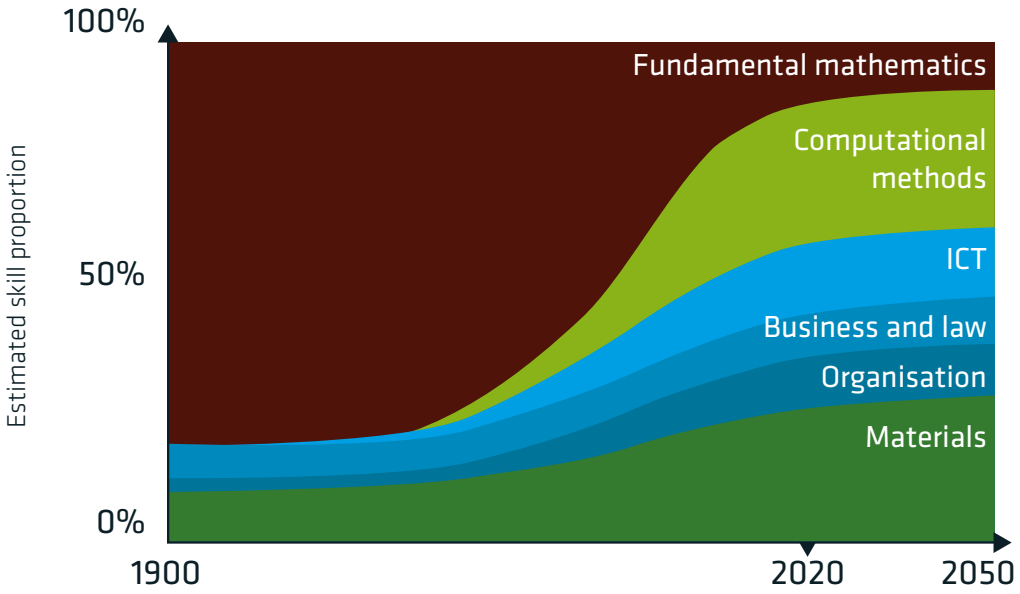


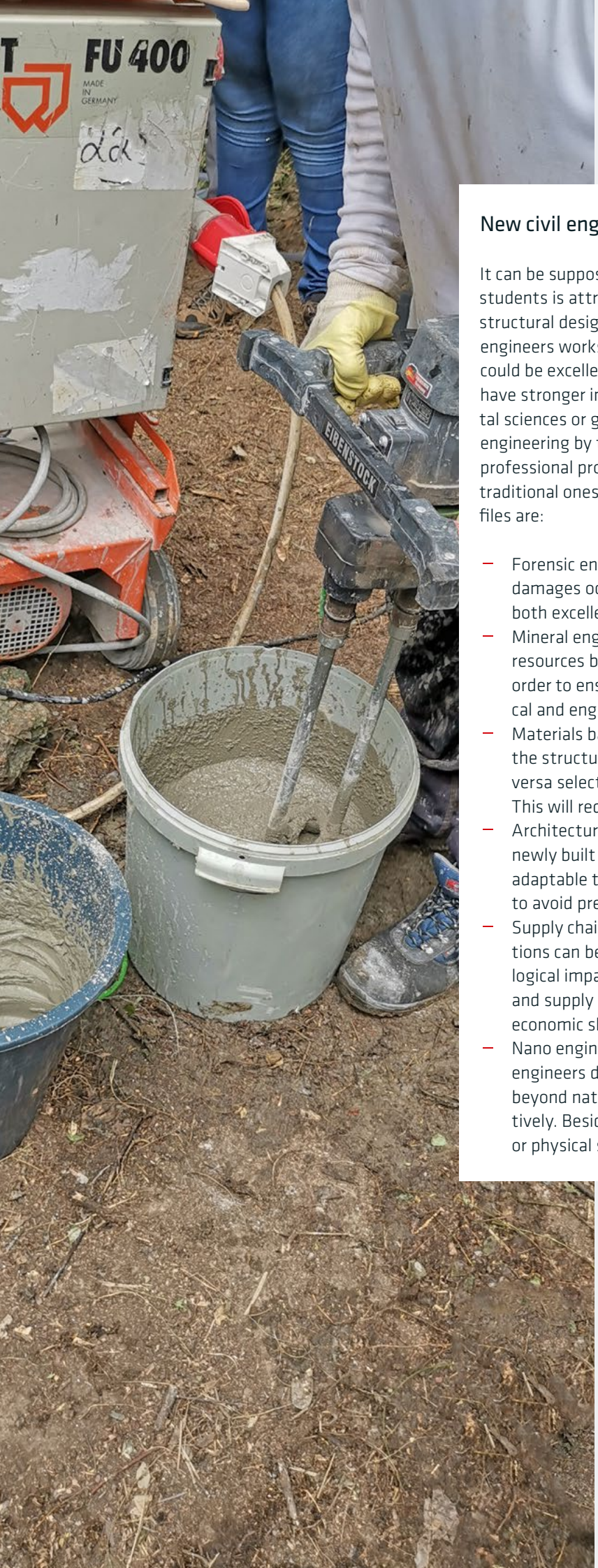
Fig. 2: Skill requirements for civil engineers throughout the last century

Future skill requirements for civil engineers

The working environment for civil engineers has dramatically changed. Specialist knowledge is more and more important, while at the same time individual specialist knowledge alone cannot tackle the challenge of rapidly changing boundary frameworks, more complex challenges, and breakthrough innovation. Furthermore, the working environment has become more global, more digital, more communicative. Therefore, future curricula have to put stronger focus on skills that were formerly often neglected.

Some relevant skills that have to be put more into the focus of educations are:

- Comprehension of the broader context of local problems
- Assemblage of specialist knowledge
- Interdisciplinarity
- Generalising and/or modelling with great awareness of the thresholds
- Language skills and cultural sensitivity
- Communication skills



New civil engineering profiles

It can be supposed that the largest part of the undergraduate students is attracted by traditional civil engineer profiles such as structural designer or site manager, although a majority of civil engineers works in different areas later. Some students, who could be excellent civil engineers in their professional life, but have stronger interest in natural sciences, culture, environmental sciences or geosciences may be deterred from studying civil engineering by the traditional profiles, not knowing that the professional profiles of civil engineers can vary greatly from the traditional ones. Some examples of possible future relevant profiles are:

- Forensic engineers assess structures before or after severe damages occur and develop remedial actions. They require both excellent structural and materials skills.
- Mineral engineers compensate lack of single raw materials resources by blending a large variety of altering materials, in order to ensure steady final materials properties. Mineralogical and engineering knowledge will be required.
- Materials based structural designers who iteratively optimise the structure according to the materials properties and vice versa select materials according to the structural necessity. This will require excellent mechanical and materials skills.
- Architectural engineers take care that structures that are newly built will maintain utilisable, aesthetically pleasing and adaptable to any technological and societal necessity in order to avoid premature demolition of functioning structures.
- Supply chain engineers ensure that the adaption of innovations can be made possible with lowest economic and ecological impact due to evaluation of locally available resources and supply chain optimisation. Besides materials knowledge, economic skill will be required.
- Nano engineered meta materials engineers or bionic civil engineers develop materials and structural concepts that go beyond natural products or are inspired by nature, respectively. Besides engineering skills, a high level of chemical and/or physical skill will be important.

Summary and outlook

The professional profiles of civil engineers have dramatically changed. More scientific skill in the education of engineering can become a booster for an economic, ecologic and societal upward spiral (Fig. 3). Hence, in the light of climatic changes, societal challenges and resource scarcity, contemporary civil engineering education adapted to the challenges of today and in the future may not only be a useful option but possibly a must.

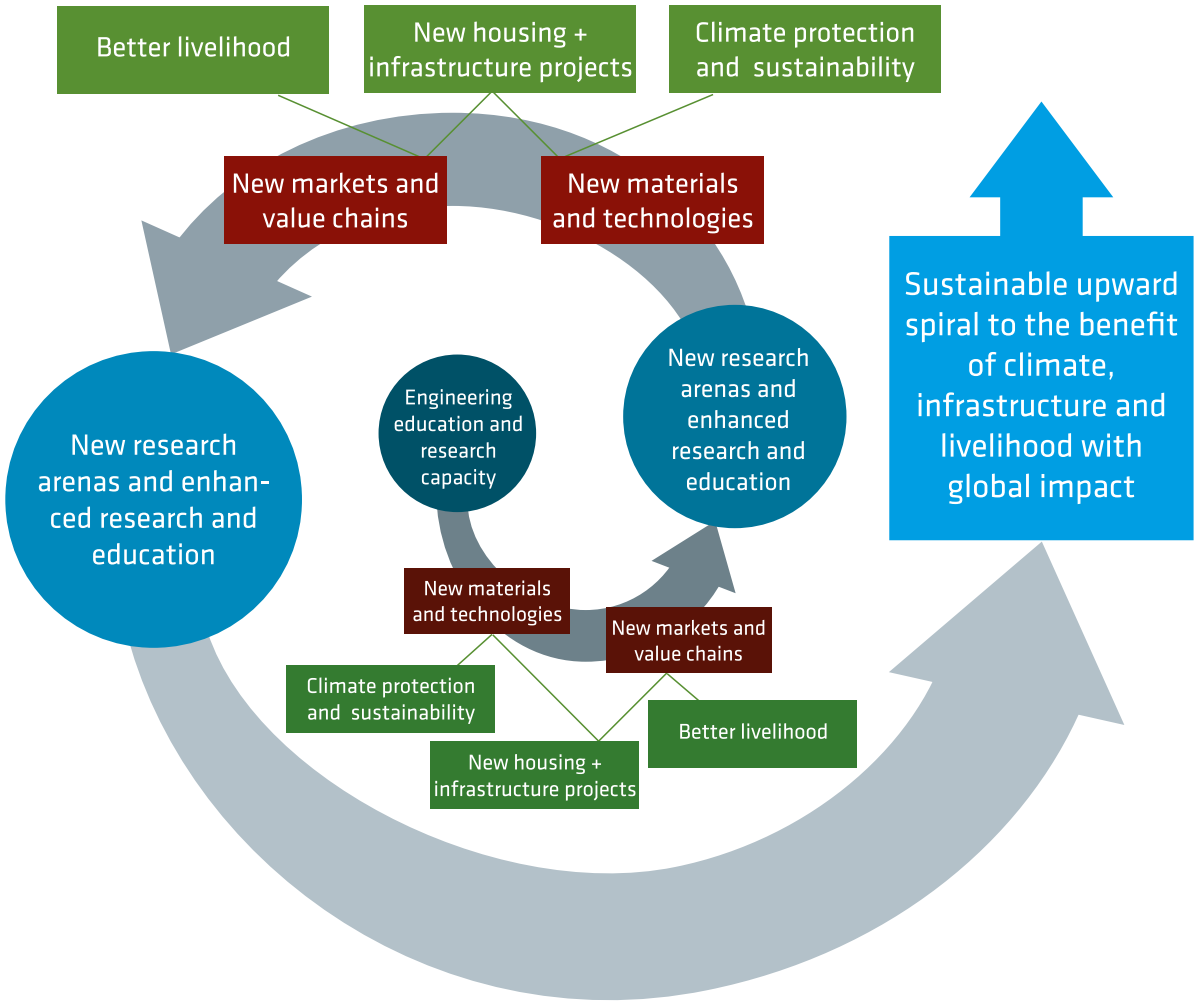


Fig. 3: How engineering research capacity can facilitate positive global developments

References

[1] K. Scrivener et al., "Eco-effcient cements: Potential, economically viable solutions for a low-CO_2, cement-based materials industry", UN environment, Paris, 2017, https://wedocs.unep.org/handle/20.500.11822/25281

[2] W. Schmidt et al., "Materials and technology solutions to tackle the challenges in daily concrete construction for housing and infrastructure in sub-Saharan Africa", AJSTID, 2017, https://doi.org/10.1080/20421338.2017.1380582

[3] W. Schmidt et al., „Education for sustainable use of cement based materials", CCR, 2017, http://dx.doi.org/10.1016/j.cemconres.2017.08.009

The blue-sky research – applied science and engineering inter-relationship in an African context

Ghada Bassioni | Ain Shams University | Egypt

The paper discusses how fundamental research is the real base for innovation and application and needs to be more considered especially in Africa.

Global challenges

As national and international financial resources have become defined, there has been a global trend to mainly support implementation oriented science with direct links to the industry on one hand and to neglect basic research on the other. Nowadays, it is almost obligatory to identify potential end users within grants' applications of scientific research proposals. It has become harder to obtain funding for fundamental science projects. These trends have direct impact on young researchers who need to refrain from choosing basic science as their main research focus in order to increase their chances to develop an independent scientific career.

In general, scientists believe that research should contribute to the benefit of mankind and that it should make a difference. It is evident that scientists have contributed excessively to the progress the world has achieved through their various technological inventions and discoveries. Then how should governments decide the balance between hard-nosed research that will certainly have a practical impact and speculative research that may never pay off?

The role of civil engineers in global challenges

Gap between basic and applied research

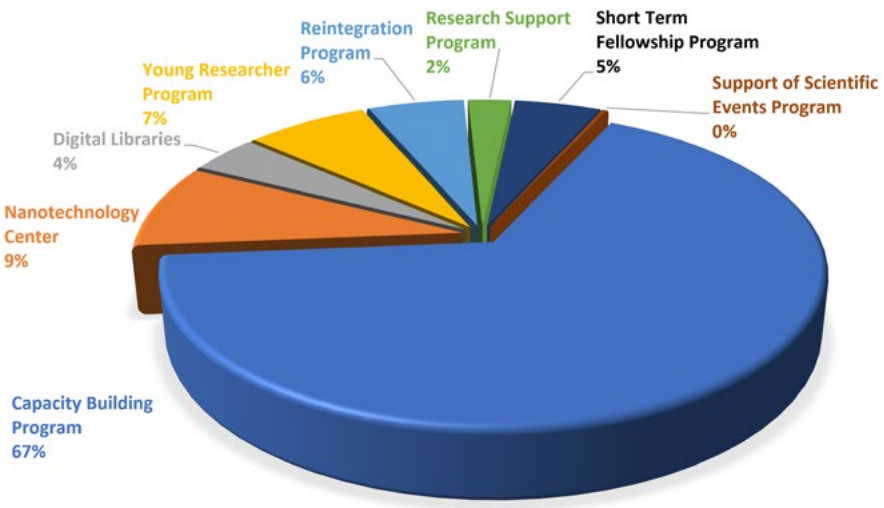
A strong basis for a solid research environment within a continent, such as Africa, is critical for socio-economic development. Various issues that confront researchers in the political, social, and economic context of Africa have been reported [1]. The authors highlight issues of interethnic conflicts, wars, regional fragmentation of African leadership, economic challenges, and international marginalization. Higher educational institutions provide the place where expertise can be generated for fundamental research. Scientists at these institutions learn basic skills for identifying and investigating natural phenomena and scientific problems, as well as interpreting and analyzing data. A great obstacle for Africa's development remains the migration of qualified scientific scholars though – the so-called brain drain [2]. So should scientists in developing countries in general and in Africa in particular focus on practical problems and leave the blue-sky research to others? The interplay between a solution to a particular application problem and the underlying theory is critical to how science progresses.

Capacity building as a fundamental step towards success

In Egypt, and as in many other African countries, scientists vary in their choice between basic and applied research. It is mostly the opportunity provided whether stepping into the supervisors' shoes or whether it is a fellowship abroad that can either drive a researcher to either direction. At an early career stage Egyptian scientists are rather flexible. It is only at a later stage, mostly after obtaining a Ph.D., that scientists become more focused. The Egyptian government provides support mostly through its main funding body, the Science and Technology Development Fund (STDF) [3]. The STDF has been found in 2007 as a governmental entity that helps building capacities in terms of infrastructure and human resources with an annual budget of $100 million. It is under the umbrella of the Egyptian Ministry of Higher Education and Scientific Research and is therefore considered as the focal point to solve national challenges from an R&D perspective. The STDF has several programs that particularly tackle challenges associated with emerging technologies. The STDF is also keen to sponsor events like workshops, conferences and training sessions that particularly focus on collaboration between academia and industry. Programs that deal with basic research exist yet are of lower budget. About 30% of the annual research budget of STDF goes to fundamental research. It is clear from these statistics that the appeal to demand driven research might be better heard in developing countries as it tackles national challenges that have certain priority over basic research. Scientists living in isolated islands who practice "science for fun" might have fewer chances to receive financial support than those who are aware of societal needs.

Outlook

While basic research can be funded within an implementation oriented project, collaboration with other groups from developed countries is certainly an option. International cooperation is based on the idea that high income countries should be supporters rather than prime movers; this was considered to be a meaningful basis for aid only if developing countries possess their own primary scientific resources [4]. How fruitful collaboration with the developed world can be has been questioned in early years, especially with increasing "scientific colonialism". Many young scientists from Egypt and other African countries prefer joining an established research body in a developed country rather than struggling through their own way in their home countries. Over the intervening years "brain drain" from developing countries has been tackled by calling the developing world "a permanent desert for research" [5]. The quest to invest more in young scientists who are motivated and who can have an impact in their countries is a plea to encourage reintegration on a long-term basis.



STDF Capacity Building Grants Statistics

References

[1] E. Maloka and E. Le Roux. eds. 2001. Africa in the Millennium: Challenges and Prospects, African Century Publication Series No. 3, African Institute of Southern Africa, Pretoria.

[2] Nature, Vol. 535, 14 July 2016, page 231.

[3] Science and Technology Development Fund Homepage: www.stdf.org.eg, Accessed 2018 Dec 11.

[4] Nature, Vol. 230 March 12, 1971, pp 87-90.

[5] Nature, Vol. 280, July 26, 1979, pp 262-263.

Research, research networking, and the role of Africa in the international research community

(with specific reference to civil engineering materials)

Mark Alexander | University of Cape Town | South Africa
Gladwell Nganga | Ministry of Transport and Infrastructure | Kenya

The paper discusses the concepts of 'research networks', and looks at these in the context of civil engineering materials research in Africa, mainly. It also discusses factors needed for 'research success', and suggest how African researchers and an African research agenda can move ahead strongly in the future. I write largely from personal reflection and experience, appropriate to engineering and technology in my own field of civil engineering materials.

1. Research landscapes and research networking (mainly in civil engineering materials)

A 'Research landscape' within a broad research field, exists as the array of research activities occurring across different individuals, institutions and entities, geographically and discipline-wise; hence, it is a high-level view of the broad sum of research efforts within the given field. 'Research networking' refers to the arrangements and collaborations, formal and informal, that exist between these research individuals and entities.

Internationally, research landscapes and research networking share certain similarities but also exhibit differences across different disciplines and global regions. For example, medical research is often strongly driven by pharmaceutical industry interests, while climate change research may be driven by political interest groups (although not exclusively!) The similarities and differences are linked also to research support, and importantly to the value placed upon research by society.

In general, the research landscape is 'richer', and also more complex and diverse, in developed countries than in developing countries (but this is not a value judgment!) Africa, being largely a developing continent, tends to have less developed research networks and the research landscape is sparser. However, Africa is actually making great strides in the international research arena, and this is covered later. The conceptual sketch given in Figure 1 attempts to capture the nature of research networks. However, it cannot capture the fact that research is a dynamic activity, since it continually uncovers new knowledge or new understanding, which impacts on further research, often changing its focus and scope, so that the ultimate end-point can be very different from the original goal. Similarly, research groups or units, and research networks, can be very dynamic in that there is constant change, and priorities also change with time. This is essential to good research. Researchers by nature tend to be individualistic, pursuing their own ideas and impacting their respective fields. This may be constrained by prescribed research agendas, for example industry- or government-directed research, but in the more independent academic research institutions, researchers have considerable freedom to pursue their own ideas. This adds to the dynamism of research, but may dilute its impact.

Referring to Figure 1, the 'success' of the individual researcher is affected by intrinsic and extrinsic factors (using a concrete metaphor!) shown on the figure. How the researcher is influenced by, or actively influences, these factors, impacts on 'success', which however, is a rather subjective term, difficult to measure objectively, since it will depend on measurement criteria. Obvious measures are research outputs (publications, patents, graduates, etc.), but there must be consideration of impact. For example, a single ground-breaking publication could have a huge impact in the chosen field (think of Powers on cement in the 1950s).

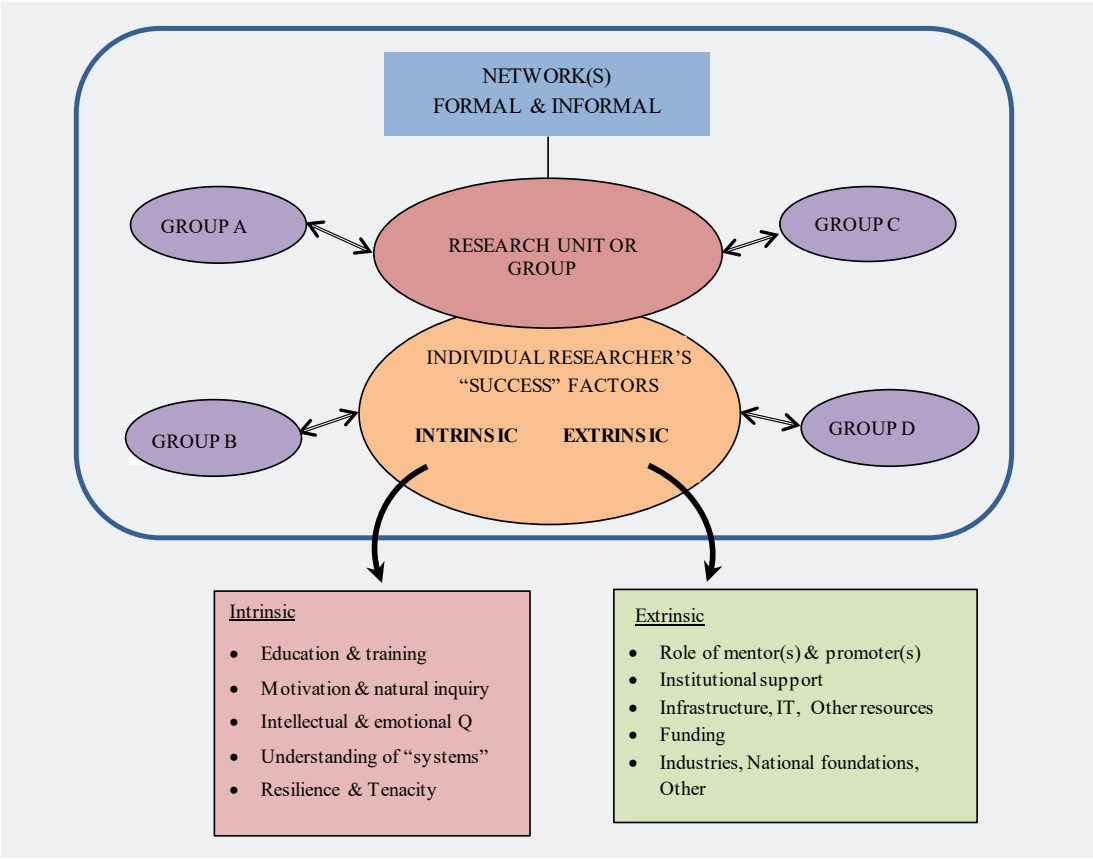


Fig. 1: Researchers and research networks

Researchers tend to build on previous work, theirs or someone else's, and most research progress is incremental. An individual researcher might be part of a research unit, or work independently, as indicated by the overlap in the figure between the entities. Further, research units or groups are nowadays strongly encouraged or even required to be multi- or inter-disciplinary. 'Networking' between the research unit (or individual researcher) and other similar groups or units, local or international, is also strongly encouraged, on the assumption that the benefits of networking or collaboration are obvious (?) and that it is preferable for researchers or research units to interact in networks. These collaborations may be formal or informal, and the research agendas may be clearly articulated or relatively diffuse. However, shared intellectual values and respectful relationships are a vital prerequisite for successful networks and collaboration!

Thus, the challenge for Africa is how to develop strong research units and research networks, and how to foster greater inter-disciplinarity in research units.

2. African realities, challenges and opportunities (and threats?)

2.1 Africa and the share of international research

The general view from outside the African continent may be that research activity is relatively sparse, with limited impact. However, from the UNESCO Report (2015), there is growth in research, both in quantity and impact. From this report, it was observed that research articles published in the continent have risen by 60% between 2008 and 2014. From a study reported in Onyancha (2018), it was observed that there is knowledge specialization as well as research diversity in sub-Saharan African countries. It was also observed that knowledge production in sub-Saharan Africa addresses areas that

Fig. 2: Illustration of unpaid research in Africa

are considered key to economic development, namely agriculture and health. One of the main challenges to research in Africa is funding, where there are cases of researchers working unpaid, sometimes for years (Makoni, 2018). This is illustrated in Figure 2. International funders may provide the funds but they may have a set agenda which fails to address the societal challenges that African countries face (Onyancha, 2018). Makoni (2018) proposes that national research funding agencies should be set up by governments where on seeing the practical solutions to societal problems, they would put in more money.

2.2 Construction materials research in Africa

Some possibilities for construction materials research in the African context is set out below.

2.2.1 Research networks

In Africa, there is a need to develop research clusters and networks in construction materials, that are viable and sustainable. Sound and reliable national infrastructure is essential for economic development (and is notoriously and dangerously under-valued!), and for areas such as human health (think of clean water and proper wastewater treatment!). Formal research networks in construction materials are not strongly evident, but are likely in embryo.

One network model that might be studied and emulated has existed in South Africa for more than 25 years. To quote from Ballim (2018): "... South Africa has made very significant progress in developing its structural design and specification approaches to ensuring improved durability and more efficient materials utilisation for reinforced concrete structures. A particular feature of this development and its relative success has been the supportive relationship that has evolved over the past 30 years or so between university-based researchers in cement and concrete technology and the broad concrete industry. Indeed, our international research collaborators consider this developmental relationship in South Africa to be a

model that they would wish to emulate in their home countries". Ballim is here referring to a SA concrete materials research network that has had substantial impact on the local concrete industry and practice (SAICE (2018)). It continues to do so.

Such research units and networks need to be adequately resourced, and industry must become involved, since public funding is usually lacking. However, industry sometimes, unfortunately, operates with short-term goals and with limited self-interest, by not seeing the long-term benefits of creating a growing band of well-qualified engineers and scientists that can make the best use of their products and technology. This is what good research can accomplish.

2.2.2 Research opportunities and perspectives in Africa

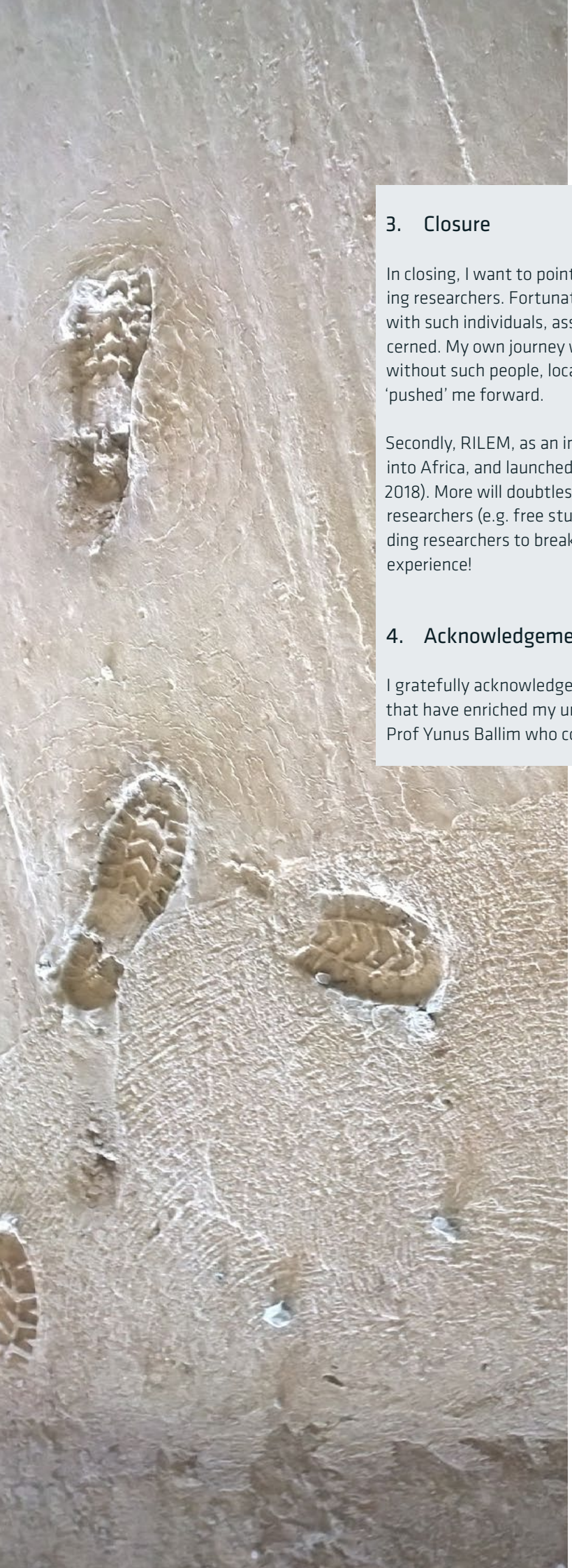
Firstly, the researchers and research units / networks must ensure that research credibility is established and internationally benchmarked, to attract the industry. This speaks to the 'quality' of research, which is not entirely linked to resources, but is closely linked to a strong research culture and a thirst for knowledge. There is every incentive for the current generation of African researchers authoritatively to prove African intelligence and research perspective.

Regarding research opportunities, we expect that these are enormous and very exciting. The importance of generating and developing local indigenous knowledge and skills must be stressed, rather than importing them. This is where research plays an indispensable role – the generation of high-level human resources that are truly a national and continental resource.

Some ideas and perspectives are given below.

- Investigation and use of African natural materials for construction, e.g. natural pozzolans, calcined clays, natural fibres, limestones, organic materials for admixtures and additives (RILEM TC-AMC, 2018), and the like; also 'traditional' African building materials, clay, mud, etc. There is a need to develop materials that support energy efficient architecture – e.g. dome structures, improved tensile stress materials, low carbon materials, natural resins with natural fibre as reinforcement, etc.
- Development of African design codes and specifications, strongly informed by local materials, expertise and practice.
- From a philosophical perspective, African researchers can bring a different worldview to their work; a more 'communal' approach, looking for ways to maximise cooperation and leverage progress for the greater benefit of all, in contrast to a strongly individualistic worldview. This could mean that, suitably networked and resourced, African researchers could make major and qualitatively different types of research contributions in the future. Thus, a specific African challenge is to develop an approach where research questions are posed against the backdrop of a shared developmental framework or philosophical approach that can guide ongoing work.
- Following on, collaboration between international researchers and African scholars can offer other continents certain advantages; intra-African collaboration can make a substantial contribution to the development needs of the continent.

So, we must start to create African research networks – drawing on key people and key institutions on the continent. We must put plans in place to find such people, create the networks and make then sustainable, and start to work on African problems relevant to the continent



3. Closure

In closing, I want to point to, firstly, the role of mentors and promoters for aspiring researchers. Fortunate is the young researcher who can locate or be provided with such individuals, assuming they take genuine interest in the person concerned. My own journey would probably never have got off the ground properly without such people, local and international, who genuinely got behind me and 'pushed' me forward.

Secondly, RILEM, as an international 'research network', is actively expanding into Africa, and launched its first 'African Technical Committee' in 2018 (RILEM, 2018). More will doubtless follow. RILEM offers great incentives to African researchers (e.g. free student memberships), and can be one sure way for budding researchers to break into the broader international arena. Such was my experience!

4. Acknowledgements

I gratefully acknowledge many colleagues and students – past and present – that have enriched my understanding of the above matters. I especially mention Prof Yunus Ballim who continually challenges my presuppositions!

References

Ballim, Y. and Alexander, M.G. "Guiding principles in developing the South African approach to durability index testing of concrete". Sixth International Conference on the Durability of Concrete Structures, 18-20 July 2018, University of Leeds, Leeds, UK.

Makoni, M. (2018). Research is often unpaid in sub-Saharan Africa. Nature. doi: 10.1038/d41586-018-07244-w

Onyancha, O.B. (2018). Towards a Knowledge Specialisation Index for Sub-Saharan Africa: an Informetrics Study. Journal of Knowledge Economy. https://doi.org/10.1007/s13132-018-0548-7

RILEM TC-AMC, "Use of Agro-Based Materials as Cementitious Additions in Concrete and Cement-Based Materials". RILEM, 2018

SAICE Magazine (2018), "Raising the durability bar for concrete in civils". Aug 2018, 4,5.

UNESCO (2015). UNESCO Science Report: towards 2030. UNESCO. http://www.scidev.net/sub-saharan-africa/r-d/analysis-blog/africa-analysis-continent science-making-progress.html

Engineering design: an approach towards sustainable site-specific solutions with global considerations

Daman K. Panesar | University of Toronto | Canada

This abstract is focused on the motivation/need to incorporate the engineering design process in engineering education. In particular, the 'Engineering Design Capstone Course' is discussed in context with the design method, course development, delivery, and assessment approaches. The presentation will illustrate the design methodology in context with open-ended design problem statements related to sustainable infrastructure provision. This will open the door for discussion to draw parallels with relevance to the African context.

Background and motivation

We continue to face significant global issues such as climate change, air pollution, energy and resource depletion, waste disposal, and disruptions to the hydrologic cycle. Engineers have a central role in addressing these critical issues while developing innovative solutions to engineering problems. Engineering design education is essential to bridge knowledge of engineering fundamentals to practical application in real life engineering challenges. Engineering design is defined as a holistic, and systematic, approach leading to the development and generation of a material/product/system/technology that performs a desired function that meets its aim without violating specified limitations. Design is one of the twelve graduate attributes that are set by the Canadian accreditation board (Fig. 1). Accreditation metrics for undergraduate engineering degrees are used to measure curriculum content in five categories: mathematics, natural sciences, engineering science, engineering design and complementary studies. Program accreditation enables continual improvement of education, ensures high standards of programs necessary for licensure, and accredited programs allows for recognition by international partners.

Engineering design approach and integration in the capstone course

The introduction and development of the engineering design project capstone course in the civil engineering undergraduate curriculum was motivated by the necessity to fulfill the accreditation criteria. The course is referred to as the Capstone course because it is intended to be a culminating academic and intellectual experience for students in the last term of the senior year. The basis of the course is an open-ended, multi-faceted and interdisciplinary design problem pertaining to civil engineering systems, processes, and/or infrastructure. The problem statement is typically accompanied by some background information such as engineering drawings, design criteria, requirements, constraints and some information about the location or community that the design solution must serve.

Given that the problem is 'open-ended', students have the flexibility to extrapolate the scope of the design solution to include many facets beyond the technical components, such as environmental, social, economic, aesthetic, and safety/security considerations. Since the problem statement is to reflect a real life engineering problem in the field, interdisciplinary aspects need to be addressed. For example, projects dealing with structural design will also consider constructability, materials, building science, and geotechnical engineering etc. Another example is where a projects related to transportation engineering may incorporate public policy, economic, systems engineering, and urban planning aspects.

Fig. 1: Accreditation Criteria: Attributes that undergraduate students need to possess

The steps of the design approach are shown in Fig. 2. Exercising the engineering design process requires students, and designers to not only think at depth of the physics, chemistry and/or the mechanics of the design problem, but also to be equally thoughtful about community needs, cultural norms, the local environmental, and aesthetics. There could be a multitude of aspects, but this is where the student team needs to be able to identify, and manage the scope of the project so that the solution, at a minimum, fulfills the design criteria. The students are expected to demonstrate effective skills in: project management, team work, communication (oral, written and visual), creativity and innovation in order to develop a strong design solution by the end of the term.

Course format: The practical arrangement of the course is a design studio format which is comprised of a 3-hour studio session per week can be used for several activities, such as: discussion / meetings between design teams and the instructor; guest lectures; student presentations; group working session; site visit; debates; presentations; brainstorming activities etc. There is not to be lectures of new material, because students are expected to draw knowledge from previous engineering courses. The number of students in a module can range between 15–20 and each design team is 3 to 5 students.

Skills: Development of engineering solutions requires that the design teams meet the specified design criteria, and work around the identified design constraints. Such finite solutions will not be in any one textbook and so warrants critical thinking, creativity, and innovation. Since there can be an expectation that students develop a unique solution that is innovative, out-of-the-box, and push the envelope, it is imperative to emphasize: responsibility for every design decision; professional engineering ethics and the obligations of holding an engineering license. Communication (written, oral and visual) and teamwork are critical attributes that the students exercise in this course. By the end of the term, the final deliverables are the design report and presentation. The convincing, and well-justified design solution needs to address aspects of sustainability regarding the environmental impacts, economic viability and maintenance and longevity.

Assessment: Due to the 'open-ended' nature of the course, there is no single correct solution. Grading can be subjective since the answer is not black or white. There will however be stronger or weaker design solutions. This depends on the rigor, scope, depth, and breadth that the design team presents. Due to the subjectivity, the assessment of the deliverables, can be facilitated by developing a rubric for each deliverable which specifically reflects the graduate attributes, and expected learning outcomes.

Case study: sustainable infrastructure provision
World-wide, there is a dire need for sustainable infrastructure in rural communities as well as a need for retrofit and upgrade of existing infrastructure. There are many specific scenarios which can serve as effective, multifaceted open-ended design problems that require sustainable, innovative solutions. The application of the design process has potential to be a powerful, methodical approach to systematically address the complexities of the problem, and evaluation of a range of possible solutions at every design stage. The design criteria and practical constraints for some case studies will be discussed including: availability of materials, transportation of supplies, equipment, materials, use of indigenous materials, construction approaches, training and use of local skilled workers, durability of the outdoor and indoor climate, functionality for the local community, and applicability of standards and codes.

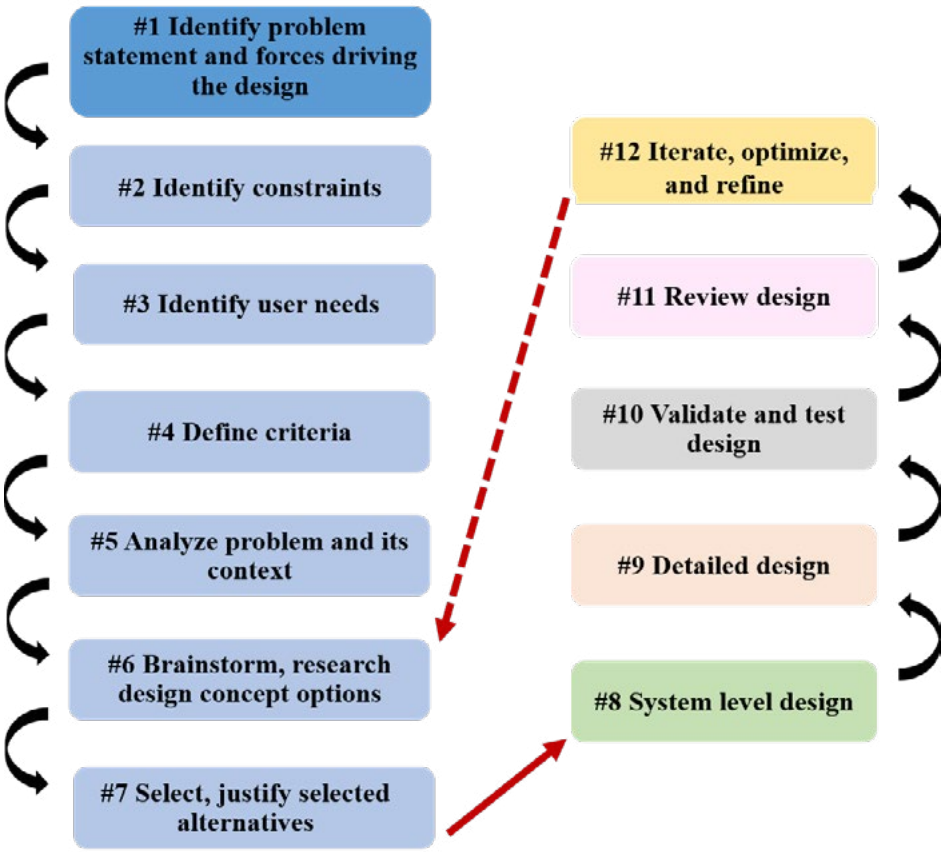


Fig. 2: Engineering design method

Crossroads: sustainable infrastructure + entrepreneurship + online engineering education in 21st century Africa

Murray Metcalfe | Nadine Ibrahim | Rahim Rezaie | Chibulu Luo
University of Toronto | Canada

This presentation reflects on rapid urbanization in Africa. We discuss the unexplored intersection of sustainable infrastructure and entrepreneurship, leveraging online engineering education at scale to develop great African cities of the future – showcasing unique African solutions.

Rapid urbanization

Rapid and large-scale urbanization, together with a drive towards environmental and financial sustainability, creates considerable challenges and opportunities for engineers and engineering education in Africa. The number of African cities with over 5 million in population will grow from 10 today to over 60 in 2100, when African cities will make up 5 of the top 10 largest cities, or 13 of the top 20 worldwide (Fig. 1). This trend will place significant demands on the continent, which must be met in light of resource constraints and environmental considerations. Interestingly none of the world's largest cities in North America, Europe, Latin America or China will be in the top 20 by 2050. The largest African cities will be enormous – projections of over 70 million residents in Lagos, Kinshasa and Dar es Salaam. The central challenge is to ensure that sustainable infrastructure enables African cities to grow by multiples in population and economic strength while growing disproportionately slower in terms of costs, greenhouse gas emissions and other pertinent factors [1]. To achieve these goals in Africa requires efforts to develop new approaches to building sustainable infrastructure at low cost, identify the extent and nature of engineering knowledge and talent needed to build sustainable cities, and devise new approaches to scale up engineering education and talent production efforts to meet the required cadre of engineers. Meeting these objectives could require substantially reimagining and reinventing engineering education.

World Ranking	City	Population (millions)
1	Lagos, Nigeria	88
2	Kinshasa, DRC	83
3	Dar es Salaam, Tanzania	74
6	Khartoum, Sudan	57
7	Niamey, Niger	56
12	Nairobi, Kenya	47
13	Lilongwe, Malawi	41
14	Blantyre City, Malawi	41
15	Cairo, Egypt	41
16	Kampala, Uganda	40
18	Lusaka, Zambia	38
19	Mogadishu, Somalia	36
20	Addis Ababa, Ethiopia	36

Fig. 1: World Cities by Population projected to 2100

Urban sustainability

Appropriate infrastructure in African cities will be required to support their rapid growth and to avoid potentially disastrous consequences for the cities, their enormous future populations, and more broadly the global economy and ecosystems. Those building these mega-cities will need to find new ways to build appropriate infrastructure (such as buildings, basic services, and transportation systems) to ensure that future growth of those cities is economically viable in resource-constrained settings, maximizes efficiencies, and minimizes adverse environmental impacts. It is imperative that the emerging megacities be both economically and environmentally sustainable, challenges with deep implications for engineering practice. Such engineering challenges are further exacerbated by many of these mega-cities being coastal and thus particularly vulnerable as sea levels rise and storm intensity increases as a result of global warming. Current trajectories and business-as-usual approaches to city building, characterized by expensive, large-scale and centralized infrastructure, are not only costly to build and maintain, but risk creating "nightmare scenarios" for emerging African mega-cities, their inhabitants and the global community. Greenhouse gas (GHG) emissions in Africa today are at sustainable levels on a per capita basis, but GDP/capita needs to substantially increase. African urbanization will be a hallmark of human development in this century and will transform the planet. While the Africans will "own" this development, the west (and China) will have a role, but it will be reduced over time. Sustainable urban solutions will look different in Africa, and a defining question emerges as to what is the great African city of the 21st century? In response, Africa is faced with two options: (1) following the path of "great" western cities, and rise to comparable levels of GHG/capita emissions, creating an unsustainable continent and world, or (2) leapfrogging technologically and through urban design to grow economically without proportional growth in GHGs. The options created and decisions made by future African cities engineers will determine what happens, and those future cities engineers are being education in African institutions today, and will hold positions of leadership and decision-making well into the future.

Infrastructure entrepreneurship

The carbon-intensive model of "great" Western and Asian cities cannot be sustained, particularly in Africa. Many questions unfold, through the lens of entrepreneurial activity and sustainability including: What types of organizations are required? What are the future roles of traditional universities and of emerging alternative higher education and technical training providers? The role of those of us in the west? Africans will decide the approach to and form of cities infrastructure - how can we in the west best help in African efforts to educate engineers? Is there a more sustainable model of African cities vs. the traditional model of "great" western cities? What city of today will be the great African City of the Future? How to educate future African engineers who not only build infrastructure but who are global, sustainable, urban engineering leaders and entrepreneurs? In the words of John Gardner, "We are all faced with a series of great opportunities brilliantly disguised as unsolvable problems." Entrepreneurship will be key in Africa, and there will be less dependence on government provided infrastructure. The words infrastructure and entrepreneurship are rarely used together – but can be [3].

Engineering education at scale

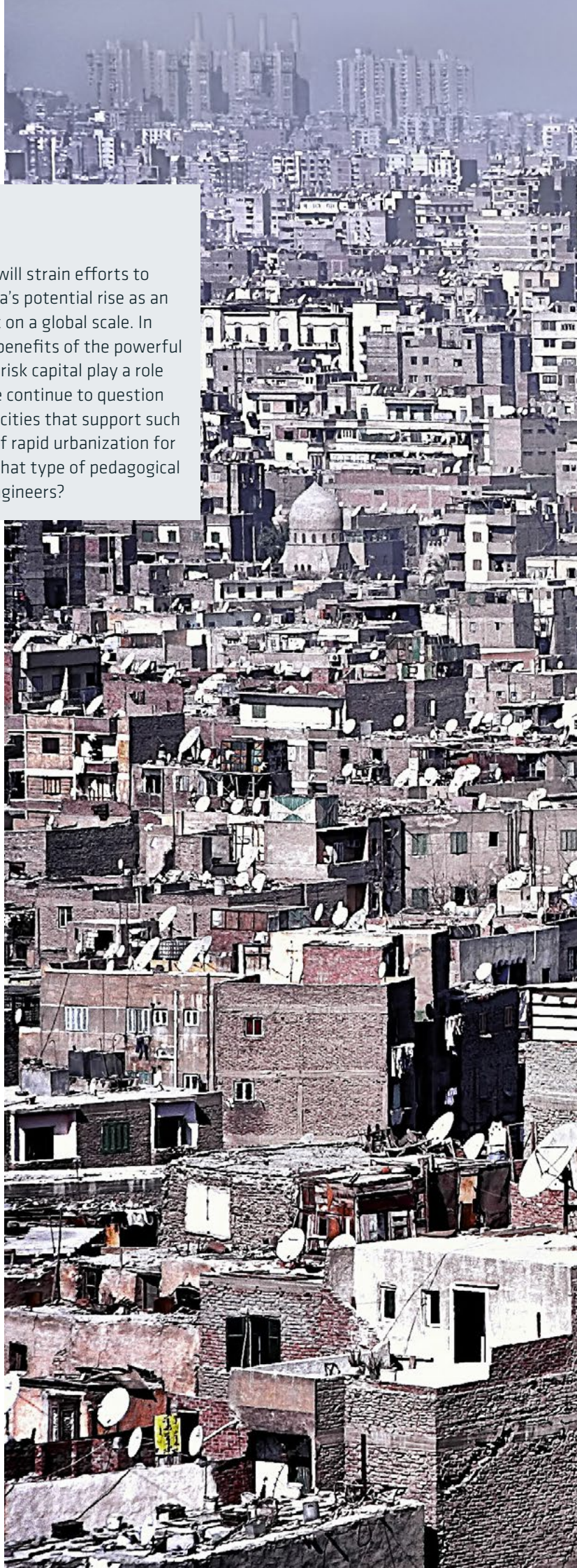
Given the above realizations, it is necessary to identify progressive education strategies based on innovative teaching and learning methods that can be used to educate the required cadres of what we at UofT Engineering term "global city engineers" in Africa (and elsewhere) in a manner that links rapidly evolving approaches with on-the-ground infrastructure development needs. Recent analyses, such as by UNESCO [2], suggest that Africa's development is hindered considerably due to shortfall of quality engineering talent, a problem that is expected to worsen. This understanding has led us to new and important

questions regarding how to train the new cadre of African engineers to build thriving cities and communities with resilient and sustainable infrastructure; both in sufficient numbers and with appropriate training. The conventional model of engineering education is inadequate. The recommendation that breaking down disciplinary boundaries and creating more cross-disciplinary programs is very timely, as engineers are challenged to support growing urban populations. The premise lies in recognizing that complex challenges are multi-dimensional and require diverse expertise to come together, where students who do not learn and practice this in their academic training become ill-equipped for the "real world" and leading to employability challenges. There are exciting new institutions emerging in Africa, though inertia and constraints on resources hinder these educational modernization efforts. Pedagogical innovations have a key role to play and must be scalable in the African context to effect change. The need to better prepare students for work in the industry by focusing on "power skills": entrepreneurship, management, leadership, sustainability can take better advantage of modern information and communication technologies (ICT), where there is great potential for the use of engineering software and virtual labs in engineering education. Leveraging online education holds considerable promise for addressing some of these challenges.

Online courseware

EESC-A's long-term goal is to build a network of academics from the University of Toronto (UofT) and engineering schools in Africa. Its specific objectives are to: (1) work with and facilitate African educators to define the key elements of future sustainable cities from an African perspective, (2) develop relevant content for an online course while recognizing contributions appropriately, (3) collaborate with African universities more broadly, primarily through electronic approaches, to assist with educating future engineers, and (4) actively involve UofT scholars and students in engaging with counterparts in Africa, by pointing to specific issues and topics for research efforts.
The first online course "Sustainable Cities: Adding an African Perspective" (Fig. 2) is modeled after an in-class course at UofT for Civil Engineering students, but with an African perspective. This is a 4-module course offered at no cost to participants through our Educational Technology Office, and aims to introduce students to the theories and tools to reimagine cities from an urban sustainability perspective. The course modules are beginner level building blocks for a course on Sustainable Cities that cater to the new inter-disciplinary trend around Cities Engineering.
The modules provide an introduction to concepts of sustainability, urbanization, and climate change; tools and methodologies for environmental assessments, material flows, and urban metabolism; and examples from global cities and from African cities to showcase best practices and different approaches to sustainable city design and engineering.

Fig. 2: Small Private Online Course (SPOC) on Sustainable Cities: Adding an African Perspective



Summary and outlook

The projected explosive future growth of African cities will strain efforts to develop supporting infrastructure Simultaneously Africa's potential rise as an entrepreneurial powerhouse will be increasingly evident on a global scale. In continuing to explore how these two worlds meet, the benefits of the powerful model of technology innovation, entrepreneurship, and risk capital play a role in solving Africa's looming urban infrastructure gap. We continue to question how can future African city engineers build sustainable cities that support such large populations in Africa? What are the implications of rapid urbanization for engineering education on the African Continent? And what type of pedagogical innovations are needed to train the required cadre of engineers?

References

[1] Hoornweg, D., and Pope, K., 2017. "Population predictions for the world's largest cities in the 21st century." Environment & Urbanization, 29(1): 195-216.

[2] UNESCO, 2010. Engineering: Issues, Challenges, and Opportunities for Development. Paris, France. http://unesdoc.unesco.org/images/0018/001897/189753e.pdf

[3] Metcalfe, M., 2014. New models for financing innovative technologies and entrepreneurial organizations. In Soman, Stein and Wong: Innovating for the Global South: Towards an Inclusive Innovation Agenda, University of Toronto Press, 2014.

Laid back mentality

Busisiwe Legodi | Former CIMERWA Ltd CEO | South Africa

The paper discusses the impact of the socially laid-back mentality in most parts of the African continent.

Globalization

Through technology disruption, globalisation has gained tremendous momentum over years. Communication evolution is not an exception, considering the speed of communication have become viral through media, but that has not taken over the power of face-to-face human interaction.
In most African countries, the common denominator of what is called UBUNTU in South Africa principle still reigns. In fact, the word ubuntu is just part of the Zulu phrase "Umuntu ngumuntu ngabantu", which literally means that a person is a person through other people. It relates to how one interacts with other human beings, nature, or The Creator. Ubuntu was and still is the guiding principle. Conscious and constant application of UBUNTU principle has been a key trait to my survival and successful engagements with people of different calibers.
Globalization and urbanization have since influenced and suppressed the UBUNTU Principle to some extent and overshadowed by the pressures, burnout, and stresses of urban life. The common phrase that is "Hurry Up, Time is Money".

The laid-back mentality at a glance

As an expat in Rwanda, I lived further away from city life in the Western Region of RUSIZI district, in a village of Bugarama, Muganza. This is where I witnessed and experienced the meaning of laid-back mentality. It came to my realization that I had to quickly adjust and fit my lifestyle. If not, I would have been bored and frustrated. My personality trait from those who interacted closer to me would describe me as a no-nonsense, spontaneous, hardworking, outgoing, passionate, go-getter, family orientated, caring, humorous, and a perfectionist.
There are some laid back mentality traits that can be beneficial and can make you be liked by everyone irrespective of color, race, or gender. Laid back mentality means having a state of inner comfort, easy going, and calmness, relaxation around what others relate to as hectic circumstances. None of the stated really suggest a failure to accomplish anything, just a more thoughtful and wizened way. I have found that the best way to get comfortable with something that makes me uncomfortable is to expose myself to it. I had to strategically place myself in the position I fear the most. I learned to be competent in that position. This experience and exposure to the Eastern African region taught me that my success is dependent on my attraction to people around me.
Laid back mentality should not be confused with uptight, this is bad because instead of doing something about the challenge you stress about it with no confidence to face it.

Social interaction

The way in which most Africans reacts to social challenges especially when engaging with foreigners in their space is seen by most as laid back mentality, but for Africans that is a way of life "Ubuntu'. Laid back mentality person may show some of the following traits, is relaxed, easygoing, free and easy, casual,

cool, equable, even-tempered, nonconfrontational, low-maintenance, calm, unflustered, unflappable, unworried, unconcerned, unbothered. For some people, the laid-back mentality is engraved in their genes, while for some it is a skill that can be learned.

Workplace interaction

In the current era, be it as an employee or entrepreneur whereby success is measured by the productivity level, it is critically important to understand and consciously draw a line of an extent to which you should be laid back. Be concerned if your laid-back personality result in the following at your workplace: getting up in the morning is a struggle; no self-motivation to start on any beneficial initiatives; you are surprised by turnout because it is not what you anticipated; high energy people freak you out; no matter the effort, your point of view is not understood by all; just give little with no effort; have careless or

whatever attitude; believed to be pushover; always stoned; shy away from confrontation; people think you are lazy.

Qualities that can elevate you on the radar

Exposure and practice is the best way to learn about your personal traits and how they impact on others.

Assertiveness

From the moment you enter the room, how you walk, how you talk, how you effortlessly get the response. Learn about cultural do's and don'ts. At least greet people in their own language. For example, in some regions, you need to kneel down and bow your head down as a married woman when greeting men, as a gesture, regardless of your status in the community or business.

Subtlety

People will be excited to engage with you because you leave people's imaginations to run wild. People like progress, share ideas that can change their lives for the better. Example, share real-life stories so that they realize that you are just human, you were born and bred just like them.

A Positive demeanor

Maintain calmness under pressure (grace).

Kindness

Be nice and kind to people, people they will read through your eyes if you are pretending. Avoid discrimination, treat all people with the same respect. Kindness can be offered, can be offered in different forms like Finance, advice, coaching, mentoring, training, listening, etc. Take note, this must be towed way stream relationship, both parties must show interest to participate.

Calmness

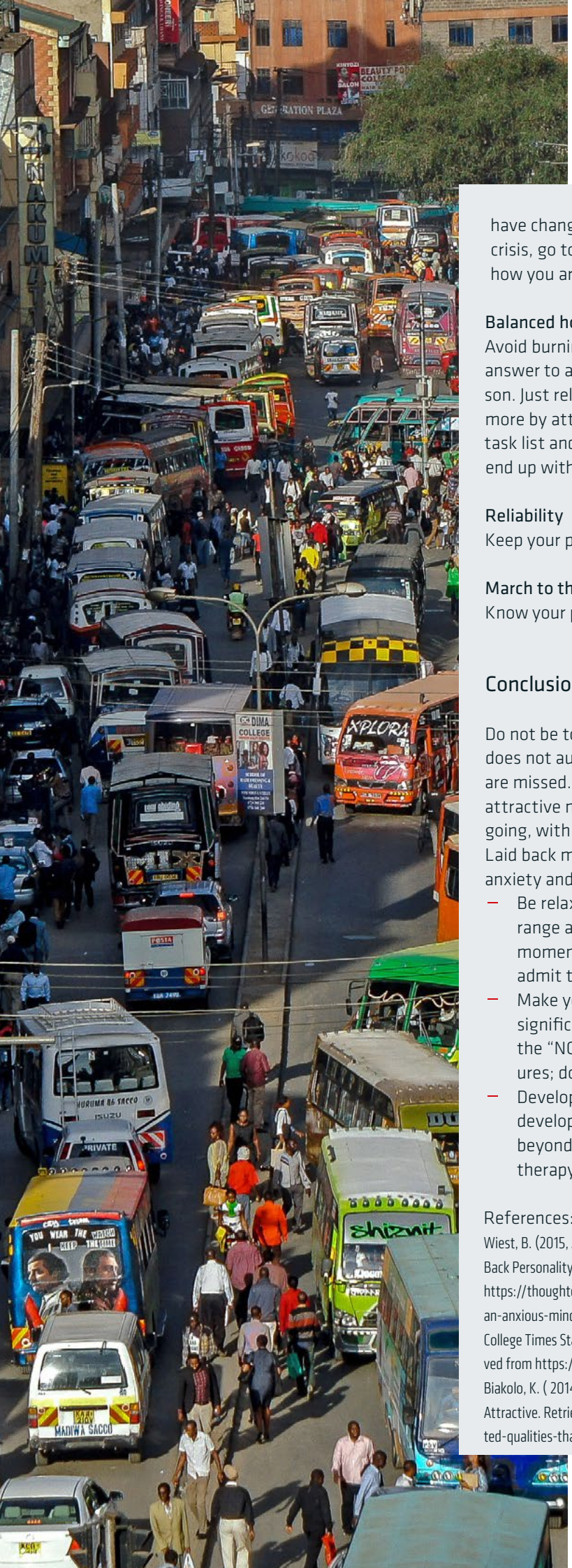
In today's pressures and stressful lifestyle, this is easier said than done. If you are a busy bee or the "NOW" person, be careful not to frustrate your most valuable calm employees by pushing them too hard. Know and understand each employee personality traits and capacity and treat each other as individuals.

Thoughtfulness

If you want to grow and be recognized in life, avoid doing the mere minimal, sometimes just do something little without being asked.

Patience

The capacity to accept or tolerate delay, problems, or suffering without becoming annoyed or anxious. Not applicable to a disaster. Globalization and media



have changed the speed of information transfer, in case of a crisis, go to the ground and meet your stakeholders and indicate how you are in control of the condition.

Balanced honesty

Avoid burning your figures through pretense. Give an honest answer to all the questions, even NO is an answer, give it the reason. Just relax and think before attempting a task, you will achieve more by attempting one item at a time from your daily planned task list and perfect it, instead of committing too many tasks and end up with nothing achieved.

Reliability

Keep your promises, if you said you will do something, do it.

March to the beat of your own drum

Know your purpose in life, believe in it, and do what pleases you.

Conclusions

Do not be too laid back in a workplace. Being a laid back person does not automatically mean nothing gets done, and deadlines are missed. Learnings from earlier in my life taught me that being attractive makes you happier, confident, passionate, relaxed, outgoing, with a sense of humor as an individual.

Laid back mentality can assist us with the tools needed to manage anxiety and stress in the following way:

- Be relaxed at the moment by taking deep breaths; rearrange anxious thoughts; bring yourself to concentrate on the moment; practice calming meditation, avoid overthinking and admit that your point of view is not authentic
- Make your life simpler by prioritizing tasks according to their significance; Avoid monkeys jumping on you back by acquiring the "NO" skill and avoid multitasking; appreciate small pleasures; do not fear missing out
- Develop your viewpoint by stopping to be a perfectionist, develop your thinking before responding; admit to what is beyond your control; embrace your time; if necessary pursue therapy.

References:

Wiest, B. (2015, August 11). 17 Things That Happen When You Have An Anxious Mind But A Laid Back Personality. Retrieved from https://thoughtcatalog.com/brianna-wiest/2015/08/17-things-that-happen-when-you-have-an-anxious-mind-but-a-laid-back-personality/

College Times Staff. (2014, August 27). 13 Struggles-every-laid-back-person-deal with. Retrieved from https://www.collegetimes.com/life101/struggles-every-laid-back-person-deal-94119

Biakolo, K. (2014, September 23). 10 Underrated Qualities That Make Anyone Instantly More Attractive. Retrieved from https://thoughtcatalog.com/kovie-biakolo/2014/09/10-underrated-qualities-that-make-anyone-instantly-more-attractive/

Fostering innovation through research and education for infrastructure development: a call for synergy between Town and Gown

Kolawole Adisa Olonade | University of Lagos | Nigeria

In the knowledge age, innovative research is a bedrock for development, which requires synergy between the town and gown. The gown generates knowledge while the town develops and utilizes the knowledge for economic growth and sustainable infrastructure development. The strategies to foster collaboration between the town and gown are presented.

Background

Education driven with innovative research is an impetus for human development and societal transformation. Universities are expected to provide the required education to drive the economic growth of the society because they are pivotal components of underlying infrastructure for innovation on which the system of knowledge is based. When there is disconnect between the universities and the larger society, retrogression will definitely set in. The challenge of disjoint between the universities and the society is an age long one.

From historical point of view, the belief then was that place of learning needs to be secluded from the community to prevent unnecessary interference. Therefore, most universities were sited in remote areas far from the community and became unconcerned with the economic and social problems of the larger society. Consequently, universities promoted themselves as elite strongholds of information and knowledge, while Professors and students adorned themselves with their academic gowns, which were distinct from townsfolks, who were outside the universities. This separation is generally referred to as town and gown. Thus, gown literarily refers to the university, while the community outside the university is referred to as town.

Due to urbanization of most cities, the initial separation between the universities got shrunk and became a challenge to many universities. The universities thereafter started raising their fences so high to avoid unnecessary encroachment. These acts gave the universities another nomenclature of Ivory Tower. Not until 1980s, when the paradigm changed, and academic efforts were directed primarily towards research and publication [1]

This scenario is better put by Harkavy [2], in the case of American universities, he said, "in the decades after World Wars I and II, American higher education increasingly competed, ferociously, egocentrically, narcissistically, for institutional prestige and material resources. Almost single-mindedly, pursuing their self-centered goals, they increasingly concentrated on essentially scholastic, inside-the-academy problems and conflicts rather than on the very hard, very complex problems involved in helping American society realize the democratic promise of American life for all Americans". This is exactly what characterized most African universities today because their university systems were fashioned to follow that of Americas.

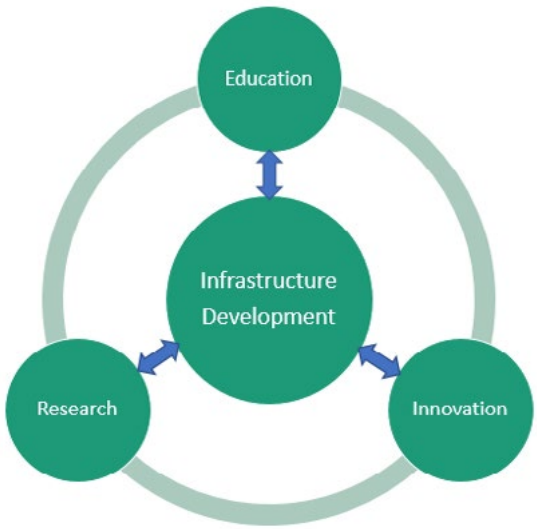


Fig. 1: Education, research and innovation for sustainable infrastructure

Need to fall the wall between Town and Gown for inclusive development

The reality of modern challenges dictates that status quo of bifurcation between the academia and the society cannot be maintained. Increase in population with larger proportion being youths has tremendously increased the proportion of potential seekers of higher education, which is overwhelming on the available facilities in the colleges and universities. Students have to live within the society because the dormitory in the universities are not sufficient to accommodate them. This phenomenon called studentification has compelled unplanned interaction between the town and the gown. As earlier mentioned, the challenge of urbanization makes the town move very close to the university, creating, also, an interaction between the town and gown. Consequently, the town and gown are now jointly faced by societal challenges which require collaboration in addressing them.

Looking at the present global challenges of environmental crises orchestrated by earlier generations of energy use, greenhouse gas emissions and their consequential effect on climate change, as well as lack/ insufficient infrastructure to support healthy livelihood, ingenuity of the academia in collaboration with relevant stakeholders in the society becomes a great need. Thus, the earlier the wall between the town and the gown is broken, the better. Just like at Stanford, the university and business forge a borderless community in which making money is virtuous and where participant profess sometimes inflated belief that their work is changing the world for the better [3].

Education, research and innovation: tripartite for sustainable infrastructure

Sustainability is a major concern of all and it is the only way to go, to save our world from imminent extinction. There is urgent need to provide adequate infrastructure with minimal depletion of the ecosystem. The danger of urbanization is a reality as the planet is over stretched to the point at which more people live in cities and towns than in rural areas, more so within the less developed countries whose urban infrastructure is often either fragile or non-existent. The demand for effective infrastructure services are therefore immense. Equally, there is need to conserve energy, and the need to devise a means to adapt to the impact of climatic change. To address these myriad of challenges, there is need to change behavior, change technology and change the fuel [4]. What is certain is that the bedrock to fast-track the required changes and ensure sustainable infrastructure is right education and purposeful research that provides basis for sustainable innovation. While at the same time availability of appropriate infrastructure will boost the quality of research and education (Figure 1). To achieve this, our universities must, as a matter of urgency, rise to the occasion and find their ways into seeing the town (industries) as partners in progress, while the town should be ready to accommodate the gown (university communities).

Synergy between Town and Gown: the ways to go

It is certain that there would not be a meaningful progress in provision of the needed infrastructure unless we bridge the gap between the town and gown. Stakeholders in the academia and the industries have attributed low productivity and poor economic growth to disconnect between the town and the gown. But the question has always been what does each benefit from the synergy? Is there any common goal? Should the town see itself as a benefactor of the gown or vice versa? Surely, the two should see themselves as partners in progress and see their cooperation as a win-win relationship for mutual benefit. A cursory look at the processes involved in the two industries (academia and industries??), one finds that they are similar. In the industry raw materials are processed to finished goods which are required to create conducive environment for learning and training in the university community for profit in return. The university, on the other hand, takes in students as raw materials, which it processes through education and training, to produce the manpower required by the industries for academic esteem. Figure 2 shows

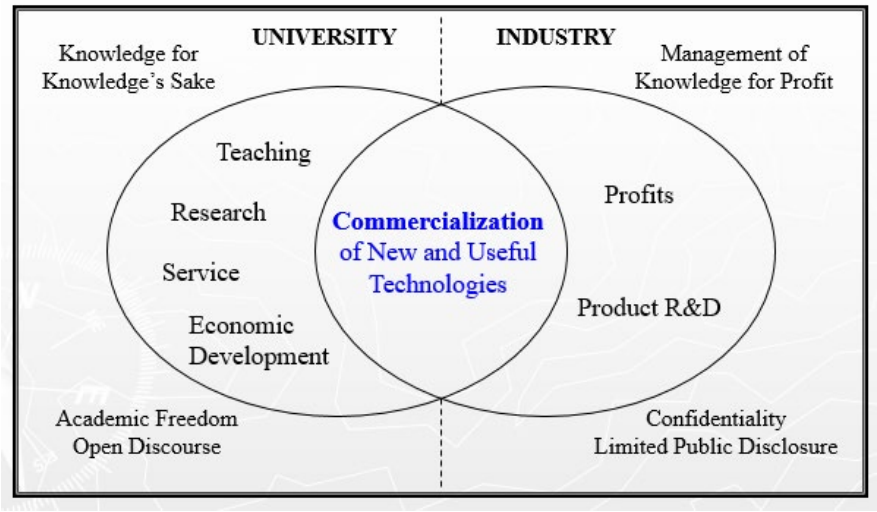


Fig. 2: Synergy between the university and the industry [5]

the core values of each of the industries and where the common interest lies. The common interest of commercialization of new and useful technologies should be focused and developed; but how?

The way to go includes but not limited to:

i. Academia needs to adjust their system and give credence to innovative research so as to attract investment from the industries.

ii. The industries could establish their R & D department in the university where the facilities will be used for them and for training of the students.

iii. Academia should promote multi-disciplinary approach to research and learning within its communities.

iv. Employment policy could be agreed to, between the academia and the industries. By so doing, the university incorporates into its curricula, that which meets the requirement of the industries for ease of employability of its students.

v. There is need to establish confidence level that guarantee the business of the industries without jeopardizing the university system. This can be achieved by developing a long-term and short-term strategic partnership with built-in flexibility that work best for both parties.

vi. The issue of ownership can mar or make the relationship, so this must agree to from the onset to ensure sustainability.

Conclusion

Our modern world needs both the town and gown to address the challenges facing it. Therefore, the town and gown should see themselves as partners and establish a strong collaboration that will generate innovative idea for the needed infrastructure.

References

[1] Maurana, C., Wolff, M., Beck, B., & Simpson, D. (2000). Working with Our Communities: Moving from Service to Scholarship in the Health Professions. Paper prepared for discussion at community-campus Partnerships for Health's 4th Annual Conference. April 29th-May 2nd, 2000, Washington, DC.

[2] Harkavy, I. (1998). School-Community-University Partnerships: Effectively Integrating Community Building and Education Reform. Presentation at the Joint Forum Between the U. S. Department of Education and the U. S. Department of Housing & Urban Development, Washington, DC, January 8, 1998. Retrieved from http://www.upenn.edu/ccp/Bibliogrfaphy/Ed_HUD_paper.html on 1/16/05.

[3] Faborode M. O. (2018). Cracking the code of industry-academia partnership in Nigeria: challenge to knowledge academies, 2018 Academy Technology Dinner Lecture, June 20, 2018 Lagos, Nigeria, 1 – 52.

[4] Paul Jowitt (2010), Engineering, innovation, social and economic development in: UNSECO REPORT: Engineering: Issues Challenges and Opportunities for Development, pp. 39 – 42.

[5] Dr. Guriqbal Singh Jaiya (2018). University-Industry Partnerships: Role of Intellectual Property, available: http://www.wipo.int/freepublications/en/intproperty /928/wipo_pub_928.pdf. Accessed: 25th November, 2018.

Reflections on the civil engineering curriculum for engaged social development in the 21st century

Yunus Ballim | University of the Witwatersrand | South Africa

The paper makes an argument for a civil engineering curriculum that better educates our students in the local and global context of social development needs and that better prepares them for the critical questions of the human condition that they will face as professionals.

Understanding curriculum

The curriculum of an academic programme is often confused with the content that is taught in the programme. But "curriculum" is much more than the content or subject material that of the programme because it includes consideration of aspects like the skills and competence to be developed in students, the coherence of this development across the modules that make up a qualification, the pedagogical approach to be used and assessment instruments that will allow not only development but also judgement of student learning. Content provides a context for these considerations and content on its own is not sufficient to induct the student into the fundamental principles and ways of reasoning in a particular discipline.

Like teaching, curriculum is a subject for application of specialist mind - or at least a mind that is sensitive to the important factors that influence a successful curriculum and one that knows when to seek the advice of specialists on the subject. To cast content as being the same as curriculum is to misunderstand - and so trivialise - a complex academic process that, when done properly, is focused on development of the way in which students and graduates engage in the world of ideas within their chosen disciplines. Importantly, curriculum is part of a continuum of academic planning aspects that includes the admission policy of the programme, the pedagogical approaches that are used to deliver the programme and the exit "standards" that the institution expects their students to satisfy.

Curriculum therefore has to be more focused on developing the reasoning skills, abilities and competencies of our students. In the applied sciences, such as engineering (broadly), where our graduates will intervene directly in the critical questions of the human condition, the curriculum must try to give them exposure to different ways of knowing, including developing their sensitivity to reasoning approaches in the equally difficult areas of the social sciences – sociology, history, philosophy, etc. On this matter, I am with Isaiah Berlin [1] – I have yet to be convinced that the great traditions of human intellectual endeavour can so neatly be divided into the 'sciences' and the 'humanities'. All have been hurt in this hard separation. The physical sciences have focused on development of specialists and 'technocrats' with little sense of the impacts of their models and algorithms on human development. On the other hand, one of the more significant threats to democracy in the modern world is the generally low level of scientific literacy of our human sciences graduates and the ease with which they hand their future over to technocrats on important questions of the relationships between science and society.

Curriculum must also be sensitive to political context. Allow me a personal reflection: I was taught civil engineering in South Africa in the late 1970's, at a time when the national design code had lower water pressure requirements for Black residential areas, compared with White areas – as one example of the depth of reach of apartheid. When I returned to my university a few years later as an emerging academic, I recognised that it would be wrong to hold my lecturers accountable for the approach of the design codes since they did not write the regulations. However, I did hold them accountable for not telling their students that the Standard Building Regulations at the time did not represent proper civil Engineering. In this

sense, their students were under-educated as civil engineers. It was this argument that led to the first introduction of a compulsory course in Development Engineering in our Civil Engineering programme in 1992. We considered it as a necessary part of the education of our students as civil engineers who are sensitive to the development context of their studies.

Towards the competency-based curriculum

In consultation with engineering academics and education specialists, the Engineering Council of South Africa (ECSA), the legislated professional body that regulates practice in the engineering profession and accredits higher education academic programmes in South Africa, has developed a competency-based approach to engineering curriculum [2]. While there are still prescribed minimum credits for the content components like mathematical sciences, natural sciences, engineering sciences and design and synthesis, it is expected that these content areas will be used to develop the following 11 competency areas in students:

1. Problem solving;
2. Application of scientific and engineering knowledge;
3. Engineering design;
4. Investigations, experiments and data analysis;
5. Engineering methods, skills and tools, including information technology;
6. Professional and technical communication;
7. Sustainability and impact of engineering activity;
8. Individual, team and multidisciplinary working;
9. Independent learning ability;
10. Engineering professionalism;
11. Engineering management.

Two further aspects of the ECSA approach are worthy of note. Firstly, the accreditation requires that at least 10% of the curriculum is made up of "complimentary studies" in areas like sociology, philosophy, anthropology, etc. Secondly, ECSA recognises that the university academic programme is part of a continuum of graduate education that starts in the schooling system and continues into the world of professional work. The features of this continuum are illustrated in Figure 1.

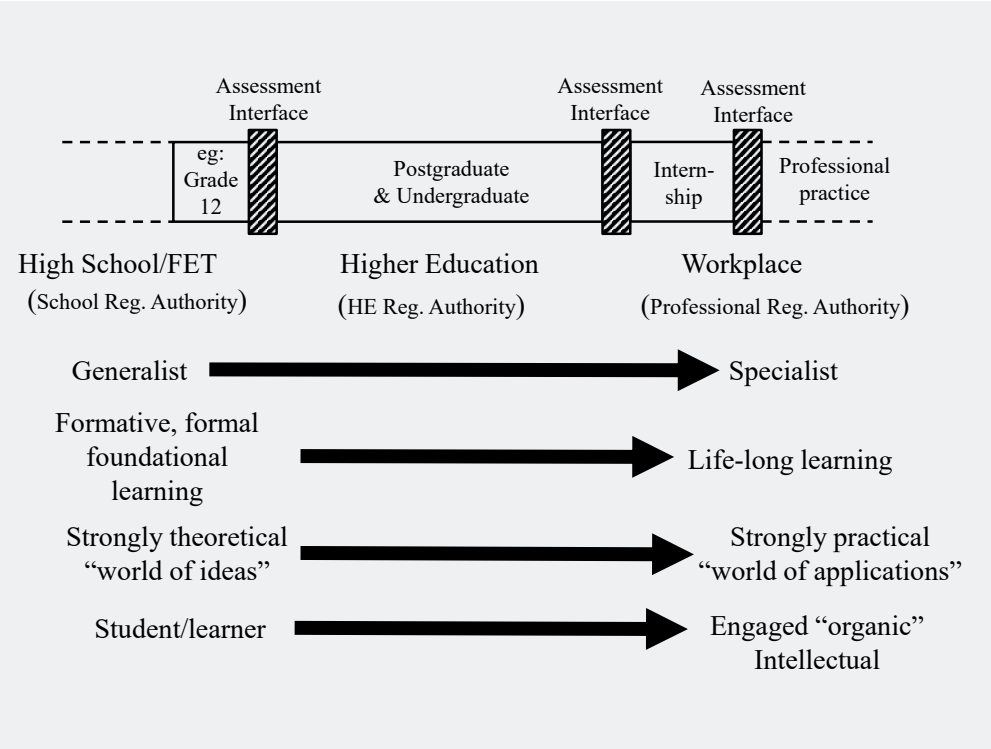


Fig. 1: The learning "continuum" of our graduates

Following the ECSA approach, it is expected that the institution offering the qualification will be able to demonstrate – in word and in deed – that students have been introduced to each of the competencies, that they have had an opportunity to develop and practice their approach to each of the competencies and that they have been assessed to measure their abilities in the competency areas. Figure 2 shows an example of a three-dimensional approach to curriculum development (note that Figure 2 is a part of a larger matrix and is used here only for illustration). Each of the content components or modules that make up the qualification (in this case, a BSc in civil engineering) is mapped against the competencies that are to be developed in the ECSA accreditation scheme. A third dimension is introduced by breaking each competence into three levels of developement: Basic, Intermediate and Exit. Within each competence area (eg: Problem Solving), the markers are expected to progressively move from Basic to Exit level as the student advances through the different levels of study in the programme.

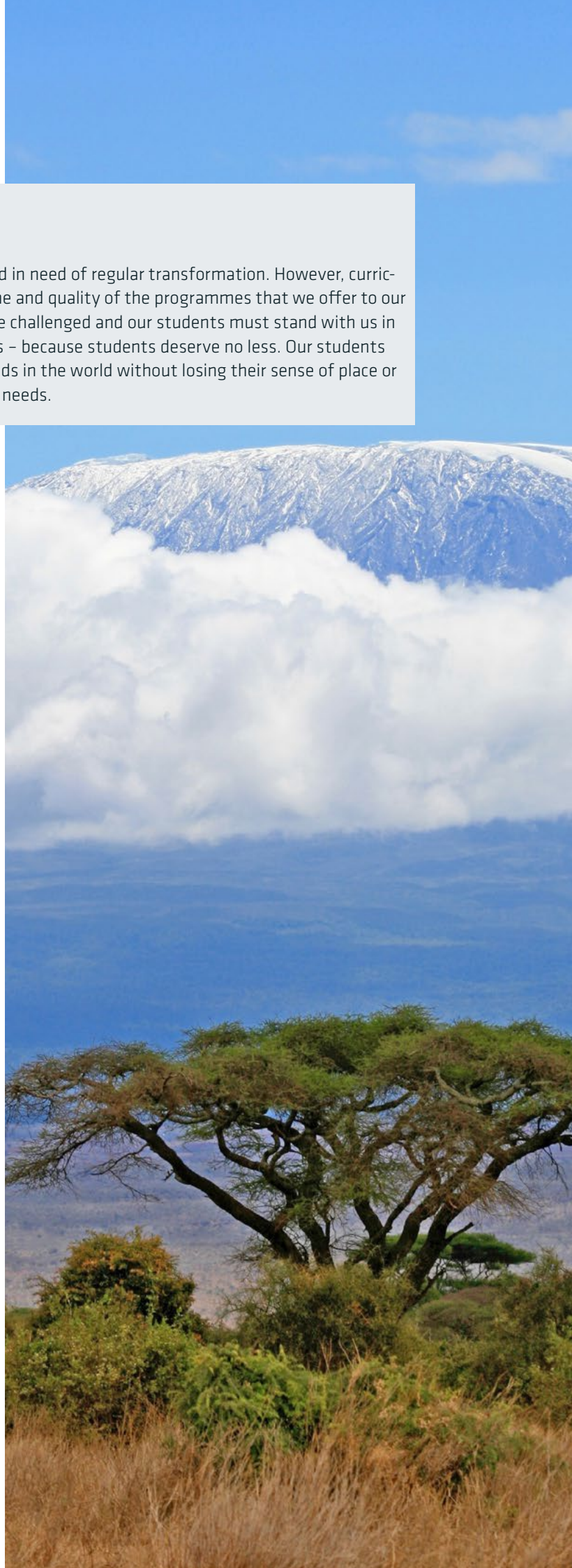
The advantages of this approach are that student competency development can be visually mapped across the programme, individual academic course coordinators can structure the delivery of their courses in a manner that develops the identified competencies and, most importantly, each academic that teaches on a course becomes accountable to the collective of academics who are involved in delivering the full programme.

Course Code	Course Name	Problem Solving			Fundamental & Specialist Knowledge			Design and Synthesis			Investigations, Experiments & Data Analysis		
		B	I	E	B	I	E	B	I	E	B	I	E
CHEM180	Chemistry I	✓			✓						✓		
CIVN101	Civil Eng & Development	✓											
CIVN102	Engineering Computing												
CIVN104	Engineering Skills	✓						✓					
MATH180	Mathematics I	✓			✓								
CIVN219	Materials & Structures		✓			✓		✓			✓		
CIVN222	Eng. Planning & Design		✓					✓			✓		
CIVN223	Numrcal Methods & Stats	✓				✓		✓			✓		
MATH280	Mathematics II		✓				✓						
MINN250	Surveying for Engineers		✓				✓					✓	
CIVN303	Structural Design		✓				✓			✓	✓		
CIVN304	Construction Materials I		✓			✓						✓	
CIVN327	Infrastructure Mngmnt		✓										
CIVN328	Infrastructure Planning		✓						✓				
CIVN408	Construction Materials II			✓			✓			✓			✓
CIVN409	Hydraulic Engineering II			✓			✓			✓		✓	
CIVN420	Investigational Project			✓			✓			✓			✓
CIVN421	Integrtd Resource Mngmnt			✓			✓			✓		✓	

Fig. 2: An example of the matrix

Closure

It is important to recognise that curriculum is "alive" and in need of regular transformation. However, curriculum transformation must also be about raising the tone and quality of the programmes that we offer to our students. Pedestrian and boring curricula deserves to be challenged and our students must stand with us in ensuring international comparability of our programmes – because students deserve no less. Our students must be able to ply their crafts alongside the finest minds in the world without losing their sense of place or grounded-ness in the realities of the local development needs.



References

[1] Isaiah Berlin. The divorce between the sciences and the humanities. The Second Tykociner Memorial Lecture, University of Illinois, 1974.
[2] Engineering Council of South Africa. Qualification Standard for Bachelor of Science in Engineering (BSc(Eng))/ Bachelors of Engineering (BEng): NQF Level 8. Document: E-02-PE. 2014. Available at: https://www.ecsa.co.za/education/EducationDocs/E-02-PE.pdf

Knowledge transfer from universities to students and to practice – with a focus on civil engineering materials

Ole Mejlhede Jensen | Technical University of Denmark | Denmark

The paper describes the challenges in knowledge transfer within the discipline of civil engineering materials, and how the situation may be improved.

Civil engineering materials are special

A mechanical wristwatch can be made with bearings in rubies processing unique properties of long life and low friction, the watch glass can be made of sapphire crystal for optimal shatter and scratch resistance, the strap can be made of leather for comfort and beauty, and the watch case can be made of solid gold for anti-corrosiveness or more likely: simply to boast. The materials for a wristwatch can be selected with a great liberty of choice, it is machined and assembled in well-controlled factory conditions by trained workers, and during its final use the physical and chemical environment is to a high extent predictable. A similar situation applies to many other groups of materials – for dental use, electrical components, machine parts, etc.

In the material world, however, a special position is taken by civil engineering materials. Huge amounts of materials and labor force are needed for construction of buildings and bridges. During construction and use, such materials have to withstand exposure to mother nature and rough treatment by humans. Availability and price are central to civil engineering materials, and for this reason non-perfect and inhomogenous materials have to be used. The construction field is strictly controlled by norms and standards and, generally, local conditions are highly important; geology, climate and construction practices. Civil engineering materials are ill-defined materials subjected to ill-defined exposure conditions and handled by ill-defined workers.

Massive research efforts have been made in civil engineering materials and a very large foundation of scientific knowledge has thus been established, but a relatively small fraction of it is applied in practice. This is because the route to the construction site is long and stony, because civil engineering materials are complex, and because many other factors than the pure material scientific ones are important to this area, see Fig. 1.

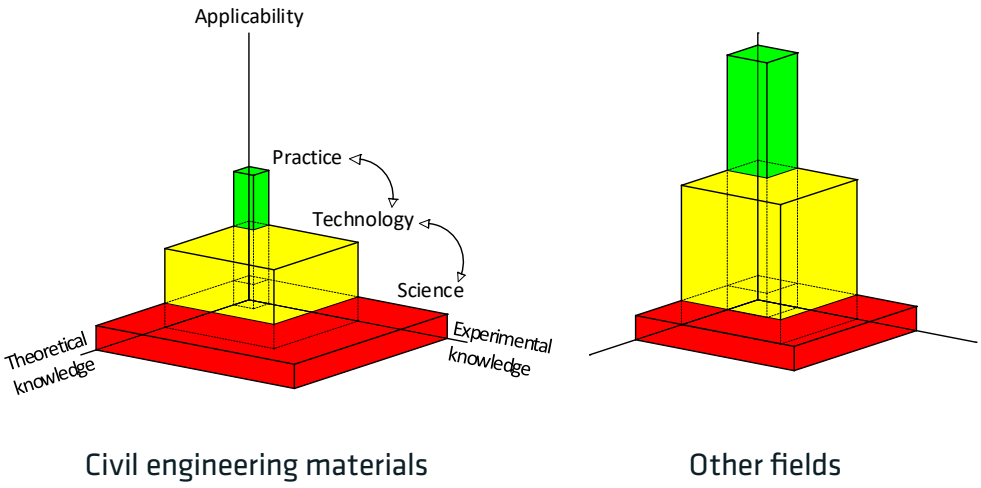


Fig. 1: Compared to other fields the knowledge transfer from science to practice is low within the civil engineering materials field. Here, science is defined as the production of knowledge, technology as the adaption of science and practice as the utilization of technology. From [1].

Development of materials understanding

In universities materials teaching have traditionally been a descriptive, empirical discipline with a starting point in the specific class of material: ceramics, metals, polymers and their subtypes. This has been the case for centuries and works well, as long as the material types are few and the requirements for them are not complex.

By the end of the 19th century a marked development took place in the materials field. The American professor J. W. Gibbs developed the scientific, calculative instrument, "Physical Chemistry", by which physical material properties can be derived from basic chemical data of pure substances. To a great extent, chemistry is the foundation for material understanding, and in this way, chemical engineering became the forerunner in establishing a scientific basis for understanding and development of materials. From a starting point, the physico-chemical methods only apply to pure substances, and for this reason its success did not easily spread to other engineering fields.

Through the first half of the 20th century major advances in instrumental and analytical methods took place. This gave sufficient insight to allow a basic scientific description of materials relevant to include the areas of mechanical and electrical engineering. The success precipitated around 1960 with the discipline "Materials Science". After all, most materials within mechanical and electrical engineering are sufficiently well-defined that material properties on a macroscopic level are dominated by properties on a molecular and microstructural level.

Attempts to include the civil engineering materials field, however, were not successful, because of the complexity related to these materials. Instead, the teaching and scientific treatment of civil engineering materials took a detour on the way from empiricism to fundamental science. Focus was turned to an understanding of various properties as a common denominator rather than the individual materials. Table 1 summarizes some of the above points.

Engineering discipline	"Noise level"	Examples
Chemical	Molecular	Amorphicity, mixtures
Mechanical & electrical	Microscopic	Grain boundaries, micro-cracks
Civil	Macroscopic	Honeycombed concrete, knots in wood

Tab. 1:
Contrary to other engineering disciplines many materials used in civil engineering, also have property relevant inhomogeneities at a macroscopic level. Within civil engineering even the inter-action between the materials may be more important than the exact properties of the individual materials. For this reason a basic scientific treatment of such materials has been challenging.

Status and way forward for teaching of civil engineering materials

In the half a century which have passed since materials science was coined considerable further advances have taken place within experimental methods for material analysis, and not the least calculative methods have improved dramatically through progress in computers. Today we have much more and much better data relevant for civil engineering materials. Also, we have a better understanding about microstructural phenomena. Our scientific foundation for civil engineering materials has become coherent, and to a relevantly high extent we are able to perform calculations on this basis. In parallel with this development increasingly more new civil engineering materials appear, and it has simply become impossible to "follow" the development by other means than to learn the "basics": Time has matured sufficiently

to do with teaching of civil engineering materials what was done within mechanical and electrical engineering 50 years ago, and what was done within chemical engineering 100 years ago, see Fig. 2.

At the Technical University of Denmark we have for 15 years taught civil engineering materials in this way, starting with basic science [2]. The disadvantage of this method is a slower start, but it is compensated by the advantages: For example students realize that properties of civil engineering materials can and should be understood scientifically, students become able to understand more complex material interactions, students get a more complete understanding, and their knowledge becomes more durable – after finalizing education students can keep themselves up to date by generating understanding of new materials and phenomena themselves. In principle we do not teach civil engineering materials – we catalyze.

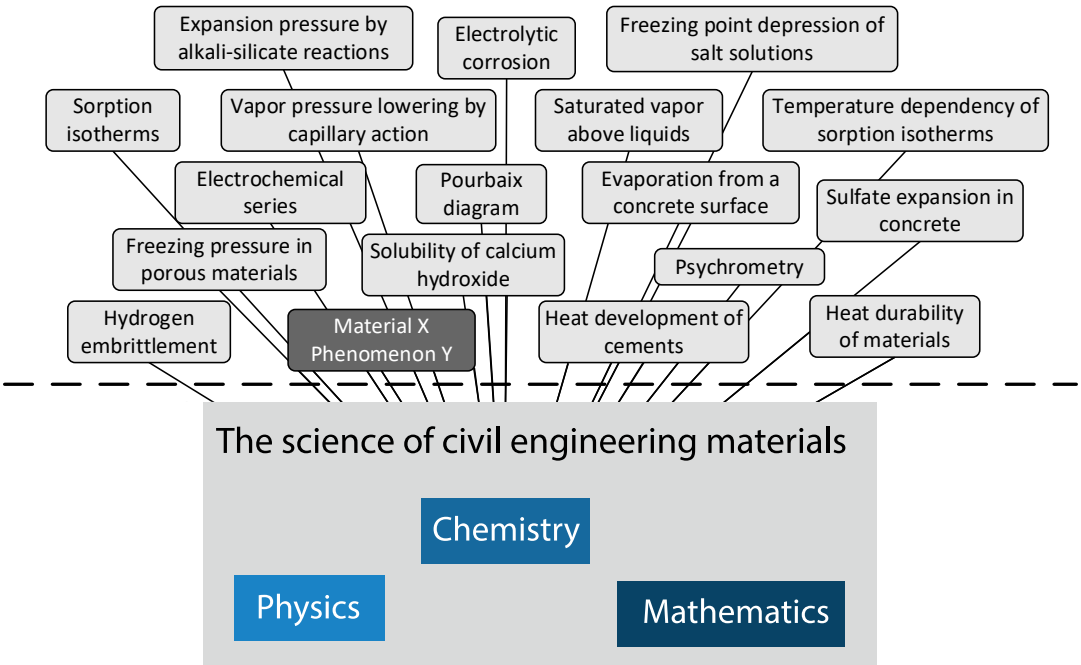


Fig. 2: If teaching of civil engineering materials takes a starting point in basic science, many apparently different materials and phenomena can be straightforwardly understood, including those, which are not present at the time of teaching. Learning outcomes become timeless and durable.

References

[1] Workshop on Cement & Concrete: Trends & Challenges, November 7 – 9, 2001 (Anna Maria, Florida), O. Mejlhede Jensen, P. Freiesleben Hansen & G. Idorn, "Nucleation and Growth in Concrete Research" in Materials Science of Concrete – Special Volume, 2002, pp. 21 – 31 (Eds: A. Boyd, S. Mindess & J. Skalny), American Ceramic Society.

[2] P. Freiesleben Hansen, "The Science of Construction Materials" (Edited by O. Mejlhede Jensen), Springer, 2009.

Educational tools and curriculum development for the advancement of engineering education in Africa

Funso Falade | University of Lagos | Nigeria

The paper invites physicists to take their subjects out of amphitheaters and to contribute to solving daily life problems of their communities in cooperation with other scientists and engineers.

Summary

Educational tools are those instruments that are used for the pedagogical purposes to facilitate learning by students. These tools are either for teaching or learning. Teaching tools are used by teachers to deliver instruction materials to the learners while learning tools are something that a student uses to work through ideas or concepts or processes while demonstrating his/her thinking planning and/or decision making on ways to creating or responding to an art.

In tertiary institutions there are two basic approaches to teaching and learning namely, traditional and Innovative methods. The traditional method of teaching consists of teachers reading out while students sit submissively taking notes. The method is passive and does not focus on practical industry application.

The innovative teaching methods are active and more impactful. Some of the active pedagogical methods are:

i. Team-Based learning
ii. Problem-Based Learning
iii. Project-Based Learning
iv. Outcome-Based Learning
v. Co-operative Learning
vi. Flipped Classroom
vii. Technological Enhanced Learning

A teacher must identify the peculiarity of his class and select an educational tool that takes into cognizance the learning style of the majority of students in his/her class.

Active learning

Active learning is about students doing meaningful learning activities and thinking about what they are doing during class session. It involves engaging students in the lecture rooms, in the laboratory, during design or project work. In active learning, teachers bring excitements into the classrooms and create a lively atmosphere to keep students on without necessarily allowing distraction into the classrooms.

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The need to use appropriate teaching method cannot be overemphasized. This need is succinctly captured in the study by Singhal et al. (1). Figure 1 shows that the most effective way to teach engineering courses is to practice by doing and teaching others.

Students' learning styles have been categorized into (i) deep learning and (ii) surface learning. Deep learning refers to the in-depth understanding of information and theories taught (Atherton, 2). Deep learners take full notes in class, and afterwards go through them to check on uncertain information. They regularly work through given problem sheets to test if they could apply theories covered during lectures. Surface learners are mainly concerned with the ability to remember important facts and theories given during lectures. They only memorize to pass examinations and do not care about its application.

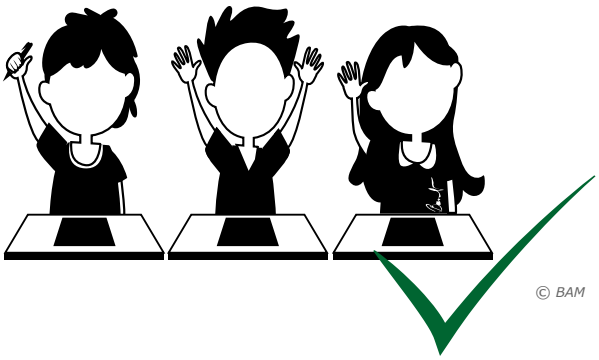

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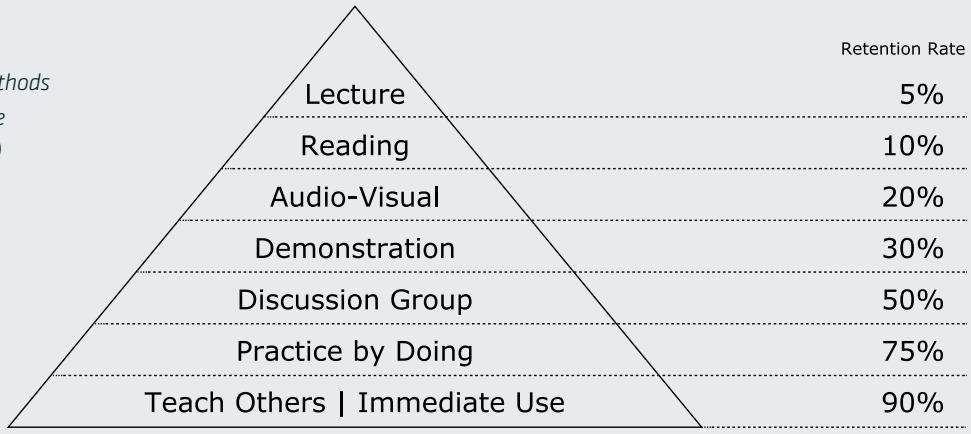
Fig. 1: Teaching Methods and Retention Rate (Singhal et al; 1997)



Curriculum development fot the advancement of engineering

Education

Generally engineering curricula are developed to solved societal problems in a sustainable way using engineering concepts and principles learnt in the university. The main features of the existing curricula are: (i) Common foundation years at 100 and 200 levels for all engineering disciplines (ii) workshop practice, laboratory work and tutorials (iii) design project with bias towards local applications (iv) broad-based engineering and interaction between students and professionals (v) final year project in which the students work alone under supervision (vi) special skills and in-depth study in a particular area of the programme through optional courses or electives and (vii) knowledge in the area of engineering management, economics and law.

In the curriculum the maximum stipulated duration of Industrial attachment is 40 weeks (National Universities Commission, 3) comprising the following modules: (i) students' work experience programme scheme I- 8 weeks (long vacation at the end of 200 level), (ii) students' industrial work experience - 8 weeks (long vacation after 300 level) and (iii) students' industrial work experience scheme II – 24 weeks (2nd semester of 400 level plus long vacation). The curriculum of a subject with practical content is generally organized into an average of 67% for the theoretical classes and 33% for laboratory. Students also use the laboratory to develop case examples on their own time.

The problems associated with the current curricula are: i) they are based on a foreign model which has evolved under ideal conditions (staff, equipment, infrastructure, training opportunities, etc) that are not easily duplicated in developing countries; ii) there is usually a shortage of highly competent indigenous teaching and support staff with sufficiently wide practical experience of engineering; iii) most of the available textbooks are often illustrated with examples from outside the local environment and which are irrelevant to the particular country; iv) the curricula are adjoined to be too academic and overloaded with intellectual content in pure science and mathematics at the expense of basic engineering and technology and v) inadequate provision for humanities, social sciences, business management concepts and entrepreneurship skills development.

New curriculum for engineering programmes

The current curricula do not teach graduates to be self-employed. Because the infrastructures are run down, the informal sector is also down-trodden thus making the environment difficult for any start-up small businesses by graduates who, though were not trained in the trade, are naturally gifted. Therefore, there is need to develop new curriculum for engineering education programme.

The new engineering curricula should be outcome-based and have innovation and entrepreneurship skills acquisition embedded in them. The new breed engineer or engineer entrepreneur will possess an adequate knowledge of core engineering and demonstrable technical competence. The engineer-entrepreneur would have acquired appropriate intellectual foundation resulting from the development of personal attributes or skills. The engineer-entrepreneur would be motivated to apply engineering knowledge and technical skills in the context of local environment, leading to the creation of culture relevant and people oriented technologies.

The fulcrum of the strategy is the collaboration between academia, industry (seasoned practitioner entrepreneurship and financial institution) and government and Non-governmental organisations (NGOs). The students will be given orientation to generate venture ideas with ability to write good proposals to enable them benefit from small and medium industries equity investment schemes (SMIEIS) as a source of venture capital to start small scale projects. The small and medium scale businesses are reputed for tackling unemployment situations in advanced countries.

The development of new engineering curricula may not necessarily translate to the production of ready-made graduates for the industry which will result in rapid industrialisation or growth in the economy of the continent except solutions are proffered to some constraints that may militate against good delivery of engineering curricula by the facilitator and promote quality learning by the students.

Constraints to quality engineering education

Some of the constraints that could affect the implementation of quality engineering curricula are:

- Poor Funding
- Inadequate Facilities
- Lack of Capacity Building Programme
- Weak University-Industry Partnership
- Lack of political will by the government

Prospects

Despite all the constraints listed above, there are indications that the low human capacity development will be improves considering the following positive steps being taken by the stakeholders:

- Pedagogy – Innovation
- Funding – Identification of other sources of funding
- Facilities – Qualitative and quantitative improvement
- Establishment of Technological Entrepreneurship and Innovation Centres
- Promotion of Linkage between Universities, Research Institutes and Technology Incubation Centres.
- Reform in the Industrial Sector
- Reform in Government Policy
- University/Industry Government Roundtable
- Information and Communication Technology

Conclusions

From the foregoing the following conclusions are made:

i. The current educational tool (traditional pedagogy) in the universities is passive and ineffective way of imparting knowledge.

ii. There is need to change from the passive to active mode of pedagogy.

iii. The development of engineering curricula should be in consultation with the stakeholders, namely, Members of academic community, industry leaders (Users), Professional bodies (Regulators) Employers' Association, Major Employers associated with specific programme to make the effort a worthwhile exercise.

iv. The restructuring of curriculum cannot be considered in isolation without considering those factors that will ensure positive outcomes.

v. Both university and industry have problems that hinder their abilities to meet up with challenges posed by the requirements for development.

vi. Reform is required in both sectors (university and industry) to make them work together with a view to formulating appropriate strategies for national development. Effective collaboration between the duo will translate to quality training of engineering graduate and they will be better prepared for the future challenges.

vii. The relationship between university and industry could only be sustained if government creates an enabling environment.

References

1. Singhal A. C, Bellamy L., McNeil, B. (1997), 'A New Approach to Engineering Education,' Arizona State University, Arison, pp 88.

2. Atherton J. S. (2013), 'Learning and Teaching; Deep and Surface Learning (On-line: UK) http://www.learning and teaching.info/learning/deepsurf.htm.

3. National Universities Commission (2007), 'Minimum Academic Standards for Undergraduates Programmes in Nigerian Universities', Abuja.

Appropriate high level physics solutions in developing countries – a cooperative approach to bridge scientific education and engineering

Robert Tchitnga | University of Ulm | Germany
C. V. Fohagui Fodoup and A. E. Tchahou Tchendjeu | University of Dschang | Cameroon

The paper invites physicists to take their subjects out of amphitheaters and to contribute to solving daily life problems of their communities in cooperation with other scientists and engineers.

Two major obstacles to physics education in Africa

Physics is undoubtedly one of the most admired school and academic subject. At the same time, it is one of the most feared topics for many non-physicists. It accommodates all other scientific disciplines and intersects with many interdisciplinary areas of research. This makes it both specific and very interdisciplinary as it can be encountered in Biophysics, Geophysics, Physical Chemistry, Medical physics and elsewhere.

Respect for physics is due to both its complexity and its utility. It becomes more complex to non-initiated people, particularly under its purely theoretical aspect. In this case, its usefulness may be misunderstood or may appear hidden behind mathematic formulas. Physics explains natural phenomena. However it is when a natural phenomenon is understood, that it can be used to create technological solutions at the needs of human beings. It becomes obvious that physics is a key subject that can largely contribute to and sustain the resolution of developmental problems in a society.

It is at this point that, generally, on the African continent, two of the major problems of physics education arise, namely:

- The lack or obsolescence of laboratory equipment, both for teaching and research, which render the teaching more theoretical, and
- The delay in adapting educational programs to the real or immediate needs of the population.

Binding realities for physicists in Africa

There can be an unanimous consent on one fact, as far as most of our countries are concerned. The majority of physicists on the African continent carry out research activities that are generally far from the developmental goals of their respective countries. The few of them tackling problems related to some local development objectives usually encounter serious difficulties in trying to publish their results in good scientific journals. As their academic career and international visibility are largely dependent on publications in good international peer-reviewed journals, many of them turn yet to put stress rather on more theoretical work with sometimes experimental parts generally carried out in developed countries' laboratories, thanks to various funding institutions and individual contacts abroad.

Decision-makers in this context either do not have sufficient funds, or they do not find the necessity to fund expensive equipment for research topics that have no direct and immediate links to problems suffered by their population.
According to the first president of the Cameroon Physical Society, Professor Paul Woafo from the University of Yaoundé I, "This constitutes a big threat to the development of physics activities and is certainly the most important cause of lack of public and decision-makers awareness on the benefits that come from research in physics" [1]. As a consequence, a large number of physicists who want to maintain their scientific standard generally move abroad to work in a more stimulating environment, resulting in the so-called brain-drain.

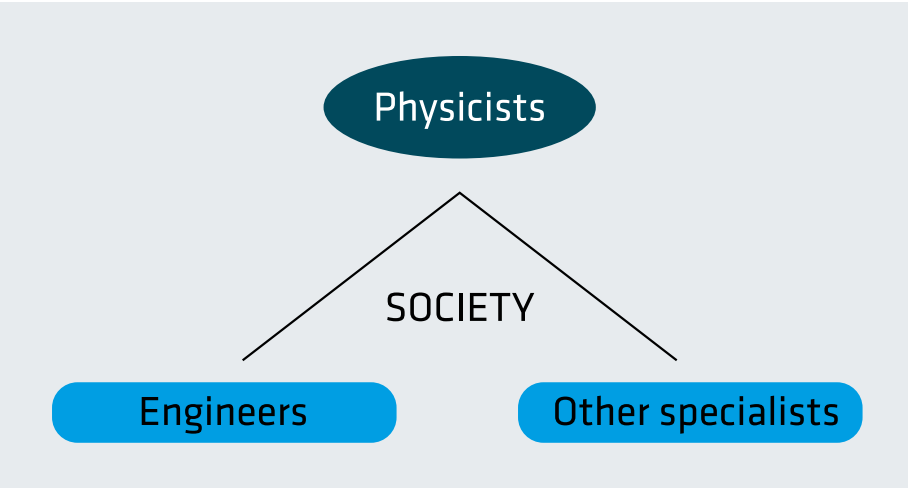


Fig. 1: Cooperative work between physicists, engineers and other specialists for sustainable solutions to problems with direct and immediate impact on the society

New perception of physics for sustainable development in Africa

In the present context, the African lecturer and researcher must take physics out of lecture halls and laboratories to popularize it, in order to show the population and the decision-makers, the usefulness and the nobility of physics for the society. They must develop low-cost poignant solutions to concrete technology related problems faced by their people [2-5].

The learners must learn to open what I would call "the third eye". It is a pictorial representation that consists in cultivating a high sense of observation based on problem oriented teaching. This "third eye" constantly seeks to identify problems in its environment that could be solved thanks to physics. With the help of teachers, lecturers and instructors, the learners search for solutions. They work interdisciplinary with all necessary skills and competences, then implement solutions with the help of engineers when and where it is necessary (Technology).

At the level of Cameroon, being aware of the facts mentioned above, since 2009 the Cameroon Physical Society launched a series of biannual conferences on the general topic: "Low Cost High Physics and Appropriate Solutions to Real Life Problems in Developing Countries". Its aim is to take Physics out of Amphitheaters, to make it a friendly subject to everyone. It has become a great moment of popularization of physics in Cameroon. The 6th edition is scheduled for November 25 to 30, 2019 in Dschang, Cameroon.

Some results already obtained confirm the usefulness of that approach [1-3, 5].

Some effective examples of physics for development

Technological solutions to pressing problems of the population with appropriate contributions of physicists appear in various domains:

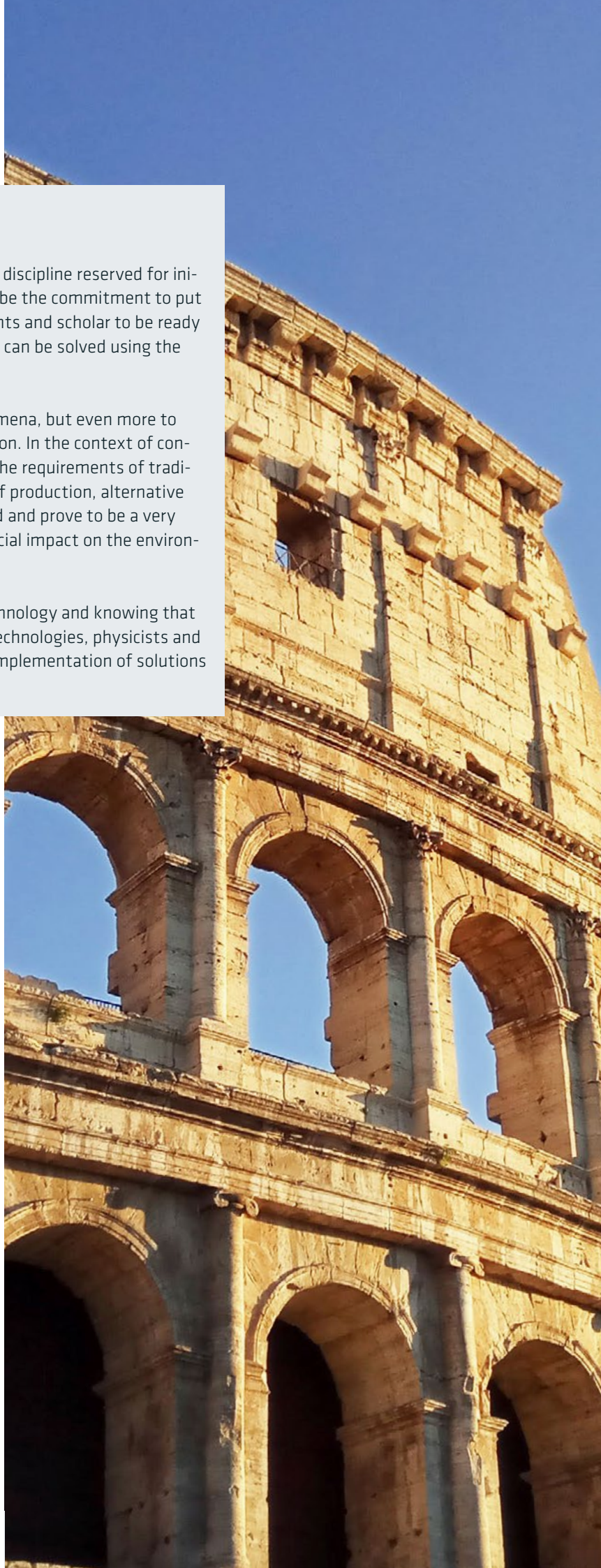
- **In civil engineering:** solutions to problems related to comfort in buildings can be found in the literature [4,7]
- **In arts and culture:** to save arts and culture, physicists, linguists and electronic engineers proposed an electronic calendar that can integrate African languages [8]
- **In didactics:** many teaching aids can be produced by physicists at very low cost by using every day modern technologies or recycling tools to overcome the lack of funding for expensive laboratory equipment for physics [3,5,6]
- **In telemedicine:** using the Internet of Things (IoT), physicists contribute to help remote area with no specialized medical personal to consult cardiac patients [2].
- etc.

Summary and outlook

Physics should no longer appear as an amphitheater discipline reserved for initiates only. Taking physic out of lecture halls should be the commitment to put more endeavor and emphasis on encouraging students and scholar to be ready for identified challenges in their environment, which can be solved using the knowledge and skill acquired in physics.

It must serve not only to understand natural phenomena, but even more to solve the technological problems of a given population. In the context of concrete technology, examples are known: Faced with the requirements of traditional cement production such as high energy cost of production, alternative solutions using agricultural waste have been studied and prove to be a very effective and sustainable solution with large beneficial impact on the environment [4].

Most problems in that category being related to technology and knowing that advances in physics often enable advances in new technologies, physicists and engineers are called upon to work together for the implementation of solutions (Fig.1).



References

[1] Woafo, P. (2017) . Conference announcement. http://www.scp-web.org/documents/Conference%20CPS%202017-%20General%20announcement.pdf (accessed: 2018/11/10; 00:46)

[2] Tchamda, A. R., Tchitnga, R., Pelap, F. B., & Kom, M. Low-Cost Phonocardiogram Board with Graphic LCD, Solar Panel and Embedded Heart Sound Analyser.

[3] Fokapu, O., Hennequin, D., Lollman, D., Piuzzi, F., Suzor-Weiner, A., & Woafo, P. (2018). Le concours «Challenge Physique Expérimentale en Afrique». Reflets de la physique, (58), 38-41.

[4] Schmidt, W., Msinjili, N. S., & Kühne, H. C. (2018). Materials and technology solutions to tackle the challenges in daily concrete construction for housing and infrastructure in sub-Saharan Africa. African Journal of Science, Technology, Innovation and Development, 1-15.

[5] Tchitnga, R., Fotsin, H. B., Nana, B., Fotso, P. H. L., & Woafo, P. (2012). Hartley's oscillator: The simplest chaotic two-component circuit. Chaos, Solitons & Fractals, 45(3), 306-313.

[6] da Rocha, F. S., Fajardo, F., Grisolía, M., Benegas, J., Tchitnga, R., & Laws, P. (2011). Using "Student Technology" in Introductory Physics: A Comparison of Three Tools to Study Falling Objects. The Physics Teacher, 49(3), 165-167.

[7] Vincelas, F. F. C., Ghislain, T., and Robert, T. (2017). Influence of the types of fuel and building material on energy savings into building in tropical region of Cameroon. Applied Thermal Engineering, 122, 806-819.

[8] A. E. Tchahou Tchendjeu, R. Tchitnga, H. B. Fotsin "FPGA based seven-language electronic calendar for the revival of the cameroon culture" Poster presented at 4th International Conference of Cameroonian Society of Physics 2015, held from 24 to 28 November 2015 at Yaoundé, Cameroon.

Transformative and social innovation system for creative, smart, green and African integrated development in the 4th Industrial Revolution

Mammo Muchie | Tshwane University of Technology | South Africa

The paper reports that it is time for a networked, unified, transformative and social innovation system that triggers creative, innovative, smart, green and African integrated development in the fourth Industrial Revolution.

The time has come for Africa to stop being betrayed and to move beyond aid, poverty, war, conflict, unemployment and corruption in this digital age time of the 4th Industrial Revolution. How can Africa come out of the raw material resource trap?

We are now in the 4th Industrial Revolution known as the period of the knowledge economy where exponential technology, digital age and quantum computing, soft computing, machine intelligence, internet of things, artificial intelligence, nano technology, emerging technologies, biotechnology and advanced materials have impacted on the global value chain. A new challenge and opportunity has arrived for those like Africa that are at the lower end of the global value chain. Will the technology revolution enable them to go beyond catch-up and leap frogging to create a new economic development landscape or not? Can they move away from the lower end of the global value chain through digital age to the higher end of the global value chain?

How to re-think innovation for development in this time of the fourth industrial revolution is urgent. We have to discover to find co-evolutionary dynamics to move out of the linear path of social-economic development. It is now the time to move out of the lower end of the global value chain remaining in the agricultural, mineral and raw material phase by entering directly to the higher end of the global value chain with innovative transformation from the digital time. A system that integrates the science, technology and innovation system by adding mathematics and engineering incubation is highly needed now more than at any time before. System theories and mathematical modelling and STEM design and incubation by employing innovation and entrepreneurship will be done in finding ways to manage the global value chain from the lower end of agriculture to the higher end of the knowledge economy to transform structurally the African social-economic landscape. There will be an exploration of rigorously formalised digital developments that connect all the emerging exponential technologies to address the transformation challenges from agriculture to the knowledge economy. Some cases that can assist to develop models from the existing development patterns will be explored. The digital development has to be designed to manage the global value chain either by breaking it through the application of the STEM and all the new technologies or utilise and apply the technological applications to go for beyond catching up or leapfrogging to bring about the African integrated, innovative, inclusive and smart knowledge economy and society. The Intelligent system will have to make a difference and the real challenge is to bring together systematically how to integrate new knowledge discovery and acquisition, new data mining, bring about learning through digital machine technologies including optimisation, planning, and evolutionary computation to do the transformation effectively and timely. This is a very timely and relevant challenge that Africa is facing today: either it scales-up to the global value chain through digitalisation or it continues to suffer. Time to scale-up and reach the knowledge based international division of labour and global value chain now.

Africa has to become the next digital, mobile miracle, soft computing and machine intelligence manufacturing hub, it has to undertake green led industrialization and fully integrated advanced economy. The work we have started since we produced the book: Putting Africa First: the Making of African Innovation Systems (2003) highlights the need to find a critical application of innovation systems and the inclusion of an integrated or pan-African transformation.

There is a need for a more unified and integrated system of innovation conception that relates specific research issues with the broader systemic features that remain largely to be studied researched and developed. The second is the specific link of innovation system with the peculiarities of the development challenges Africa has faced since the early 60s, not yet being to achieve fully building integrated infrastructure, food security, clean water, housing, health and education by eradicating poverty, inequality, unemployment, insecurity and realizing a fully peaceful and prosperous Africa. There is a need to generate an alternative model that can clearly demonstrate how the system of innovation can be re-designed to apply it in the Africa context.

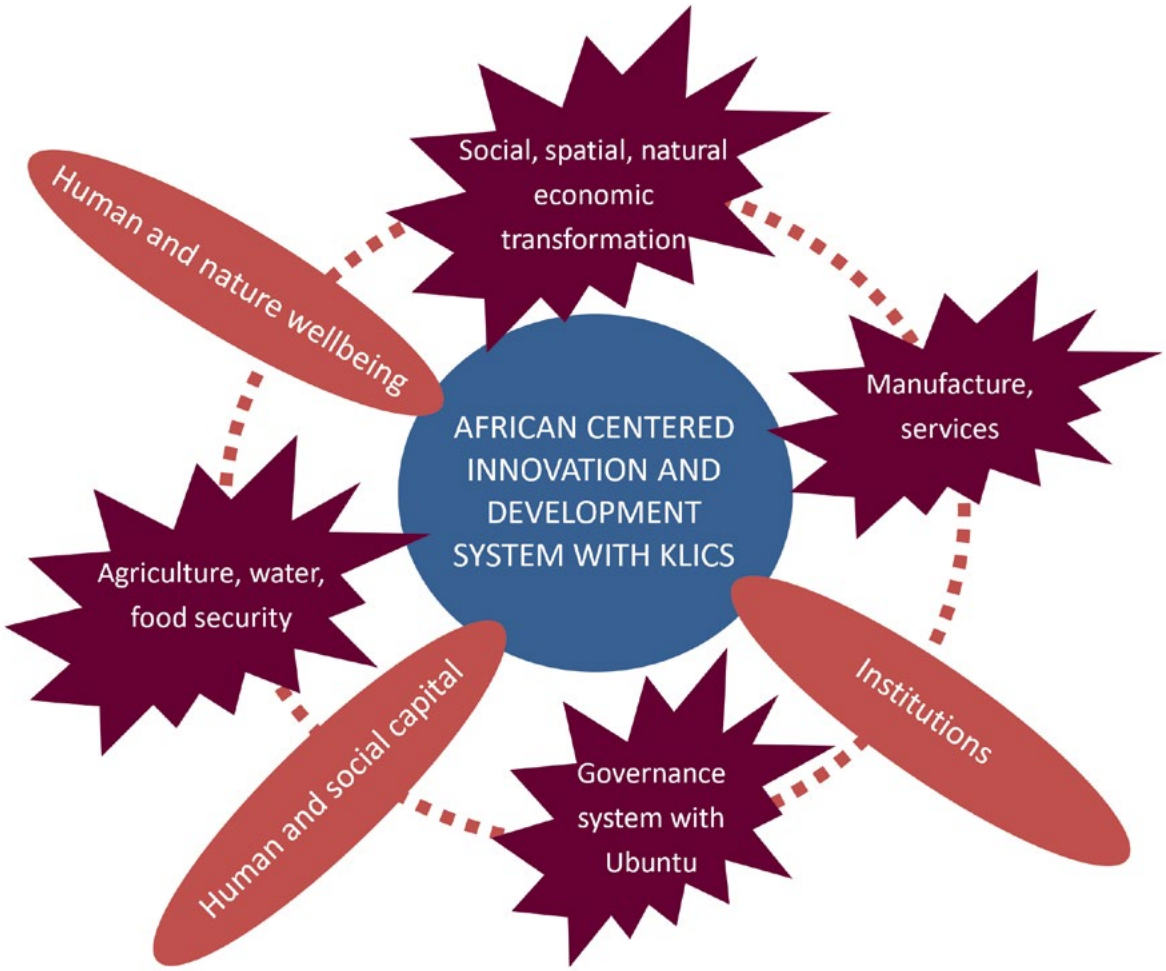


Fig. 1: A new African-centered transformative social innovation and sustainable development system for integrated, smart, green and entrepreneurial digital Africa with Klics (Knowledge, learning, innovation and competence building)

Andreas Rogge

Bundesanstalt für Materialforschung
und –prüfung (BAM)
Department "Safety of Structures"
12200 Berlin
Germany

Andreas Rogge received a diploma in structural engineering at the Technical University of Braunschweig (Germany). After four years of working experience as a design engineer in an internationally operating engineering company in Frankfurt, he worked for six years as a research assistant at the Technical University in Munich. He received a PhD degree in civil engineering for a thesis on the triaxial behavior of high strength concrete. After another six years working in an engineering company in Berlin as leader of the buildings department, he has now been working at the Bundesanstalt für Materialforschung und -prüfung (BAM) in Berlin for eleven years as head of the department "Safety of Structures". He is member of the board of directors of ENBRI (European Network of Building Research Institutes) and member of the advisory council for civil engineering standards in the German standardization organization DIN.

Where do you see the technological challenges of the next decades related to the global environment?

Construction industry will without doubt keep a decisive function and therefore a leading responsibility for our environment on a local, regional and global level. This is valid for developing regions due to the increasing demand for adequate housing, infrastructure, energy supply etc. as well as for further developed countries due to changing demands f. e. regarding ageing societies. However, these demands can only be dealt with by a rapid increase of the productivity of the construction sector in all areas. Innovative technologies requiring less workforce per building unit in production, transport and construction are the key for the next decades. Relevant factors will be advanced production processes, a sustainable use of resources, a higher percentage of standardized and prefabricated (and preferably removable) elements and digital tools for optimized working processes on site.

Which changes are necessary to create a sustainable global future?

The construction sector is still dominated by a huge and extremely fragmented number of participants in each single project. Besides the inevitable productivity losses due to coordination problems, the willingness of the participants – most likely not working in the same constellation again – to develop or only accept comprehensive changes of their actual technical environment, which require some effort and understanding up front, is very limited. Therefore, the most necessary change in future will be an almost total turnaround in the world of civil construction, fostering a better cooperation and understanding among all participants and leading to a shared knowledge base and a common awareness of technologies and resources.

What is the role of architects and/or engineers in this?

Engineers and architects are and will always be the link between science and practice on one hand as well as between client and contractor on the other hand. Since materials and technologies are rapidly improving, this function requires knowledge in an increasing number of areas, f. e. in the use of bio-based materials, robotics in additive manufacturing or in the use of digital tools and platforms.

How will architecture and construction technology change in the future, and what will be the implications?

Sustainability and productivity requirements will dominate the construction sector for the next decades. A responsible use of resources will be one key element to cope with the increasing demand for building materials. This comprises the construction material itself, but also a necessary reduction of waste materials (for packaging etc.) or materials for auxiliary constructions (formwork, scaffolding etc.). Since the width of technological areas cannot be fully covered during university education, the development of tools that allow a further knowledge gain in a practicable way is essential for the engineering profile of the future. Furthermore, the increasing speed in the development and implementation of new techniques leads to the effect, that the understanding and application of these new techniques cannot be left to the next generation of university absolvents only but each single participant has to adapt new techniques during his or her whole working life irrespective of age or experience. However, the educational tools to allow this lifetime learning on a highly qualified level are still to be developed and made accessible to everyone.

How will the digital transformation change our future, and how can we get prepared? Where are the challenges, where are the potentials?

The first and most obvious outcome of the digital possibilities is the change of numerous technical processes by supporting digital assistance. This will range from the computer and/or robot assisted placement of building elements on site (bricks, façade elements, prefabricated beams etc.) along with improved digitally run logistic paths or simple mobile apps providing material or application information to site workers in a direct way. A second ground breaking transformation will be the fact, that

almost all relevant data about a building, starting from design along construction up to the entire life cycle are digitally available and can be easily stored. This will require a lot of digital skills and efforts to create common data platforms for the huge variety of data formats, as well as lots of additional problems concerning integrity and ownership of data, but in a near future all relevant information will be available and accessible to all parties at any time. In a first step, these information bases will be related to a single project. For the design and construction process, this concept is already in use by different BIM systems (Building Information Modelling), the integration of monitoring data during life-time will be the next step. However, on the long run it will be possible to combine data of lots of projects and to create additional knowledge by combining and by further exploring these data by artificial intelligence (AI) systems. The immediate and very direct economical benefit will f. e. be the reduction of fault repetitions by making use of others' experiences, but more than that AI technologies will allow to detect dependencies or long-term developments that are not obvious to normal eyesight investigations. And since the currency in which the participation in these systems will be paid is the provision of one's own data, no one will be able to act in an economical way outside this digital world. The development of skills or at least understanding of these digital processes will become a key factor in education and practice in the future.

In terms of higher education, where are the deficits? What is still good, what is already good? Where do you think we will have to go?

Modern times and modern societal problems require a wide variety of knowledge and skills. F. e. transport of the future with its evident need for efficiency enhancement and energy reduction will be dramatically transformed by new usage concepts (car sharing), innovative cars (autonomous driving) and sustainable and durable infrastructures and especially by the intelligent interaction of these three. The overall problem can neither be solved by a civil engineering solution nor by a mechanical or electrical engineering invention nor by traffic planning concept alone. The same applies to the building site of the future with new, sustainable and bio-based materials, new construction techniques (f. e. additive manufacturing) or novel technical requirements like life cycle monitoring systems. The diversity of very ambitious competences leads to the necessity of deeper and therefore more specialized education curricula (which are already on a good path at modern universities) as well as for the personal ability of these specialists to communicate and interact with other experts of other disciplines (which has to be improved intensely). This requires on vocabulary, a common way of thinking and a common knowledge base for their cooperation. Interdisciplinary work will more and more become a fundamental skill in higher education and the establishment of respective education systems reflecting and enabling the personal development of team-minded specialists will be a demanding challenge of the future.

Namata Serumaga-Musisi

The Griot Introspect
Ghana

Namata Serumaga-Musisi is a 'decolonial space maker' trained in architecture (University of the Witwatersrand, Johannesburg, SA). Her experience ranges from commercial and residential architecture to artistic/creative engagement and advocacy, all of which have seen her take on a number of roles in the development narrative. Her work is intended to serve as a facilitator of the movement towards decoloniality, in which the built form is merely a physical embodiment of decolonial explorations.

Since 2016, Namata has been based in Accra, Ghana, where her work shifted to incorporate art as [facilitator of] dialogue. She volunteered as an artist for Chale Wote Street Art Festival; and worked with ANO for whom she coordinated a series of workshops and the preparation of ANO's Kiosk Museum exhibiting Ghanaian festival traditions during Chale Wote 2016.

The Griot Introspect was first published in the ECAS 2017 magazine. Other written work can be found in Nubuke Foundation's New Dawn, as well as in an upcoming project by DOM Publishers' to which Namata contributed 'The Liberation [of the] Threshold', an essay on the reclamation of form in the postcolonial city. Maps from the Griot Introspect's Mapping the Living were exhibited in curator Olabisi Silva's Gallery of Small Things at ACDF 2017 in Lagos, Nigeria, as well as the 2018 Dakar Biennale.

Namata has also been lead designer on Mmofra Foundation projects intended to facilitate the creation of playable cities for children. In a project completed in October 2018, Namata designed and implemented play spaces for children in markets.

How does globalism change our world? Where are the challenges, where are the potentials?

With globalisation comes an inevitable standardisation of practice, culture, being. This becomes problematic when participating societies have not yet been able to reclaim their own identities, or been able to reclaim the right to self-determination. Without a full appreciation of self, we are then at risk of responding to imported influence without a critical analysis or awareness of what it is that we need or desire. This results in inappropriate, a-contextual responses to pressing questions, and in urban spaces causes violence in the lived experience of the resident (the Living City) as they navigate the imposed Physical City.

What changes are necessary to create a sustainable global future?

Development must be centred on humanity, instead of capital; the infrastructure of the Physical City must be moulded/altered to house [and not exploit] the Living. That is to say, instead of building cities as absorbers of surplus capital, we must build them to respond to the needs of the majority, of society. For example – instead of investing vast amounts of capital in shopping centres that rarely reach capacity,

energy and investment could be directed towards site/context-specific, community informed solutions for our overpopulated and neglected markets, which serve the greater majority and in many cases are the backbone of economy.

A Physical City – an infrastructure – that adequately accommodates the Living is one that takes into consideration not just the wellbeing of the people, but their impact on their surroundings. By merging these multiplicities, we begin to address the majority of concerns outlined in the Sustainable Development Goals; something as 'simple' as waste disposal becomes more manageable in an infrastructure that accommodates its people.

What is the role of architects in this?

Architects should be facilitators of dialogue, critically analysing the spaces we currently create and inhabit on both the micro and macro scale; exploring locally informed, context appropriate solutions to the urban question. Architecture is one of the mediums through which the state of societies are articulated; as such the architect should almost disappear in their work, becoming a tool with which the [currently] neglected majority can amplify their needs, presenting one's spaces as a platform on which people become form.

What will next generations of social architects need?

Next generations will need to lay [much more] emphasis on the period of brief design and development, working with artists and other social commentators to engage those for whom they design. Through my project The Griot Introspect I explore ways in which one can engage clients, working with them to fully understand and articulate space. My sequence is Recorded Spaces as Installation as Intervention as Designed Space – a process in which the built form is an inevitable product, but not the main focus, that will hopefully not only engage the communities with whom I work, but also bridge understanding with people outside of them.

What will be more important, global solutions or local solutions? What will be more important, interdisciplinarity or specialisation? Why?

Global solutions can only be truly appropriate in application once the local context is properly understood. A continent still working towards a state of decoloniality cannot fully immerse itself in globalised solutions as it has not yet completed the revaluation of self and need. This is not to say that we must remove ourselves from the global development discourse – self-determination is a process that must take place before – not instead of – globalised discourse. It is important to look beyond borders, in every sense of the phrase. I find myself working more and more with artists and communities than with built environment professionals – it is serving to keep me grounded in reality in a form of practice that often tends towards the experimental/explorative.

In terms of higher education, where are the deficits? What is still good, what is already good? Where do you think we will have to go?

Not enough emphasis or time is given to local context. 'African' architecture is too often taught in disjointed retrospect. This unfairly implies that African architecture 'ended' with the disruption of colonialism, which in turn implies that our architecture – in all its diversity – was purely an aesthetic, and that it was rigid, static. If we can allow ourselves to observe the sequence from the precolonial to present, even begin to explore the dynamic ways in which African architecture responded to the arrival of the West, and how it exists today, I believe there would be less rigidity in design – we would have a better understanding and resolution of our own needs within the global context. 'African' architecture is more than an aesthetic or historical trivia – the fundamental role it bears on our present inhabitancy of space must be acknowledged, explored, engaged.

Karen Scrivener

Laboratory for Constrution Materials
EPFL (Ecole Polytechnique Federale de Lausanne)
Lausanne
Switzerland

Karen Scrivener obtained her PhD at Imperial College in 1984. She worked for Lafarge in France for 6 years, before being appointed Professor and Head of the Laboratory of Construction Materials, at EPFL, Switzerland in 2001. Her research focusses on the understanding the chemistry and microstructure of cement based materials and improving their sustainability. She is editor in Chief of the leading academic journal "Cement and Concrete Research" and was made a fellow of the Royal Academy of Engineering in 2014.

Where do you see the technological challenges of the next decades related to the global environment?

The most important challenge facing the world today is global warming. If this is not tackled we will see living conditions in many parts of the planet becoming increasingly difficult with more and more natural disasters and threats to food and water supplies. Of course, energy production is the major contributor to CO_2 emissions, but we must not forget the important role of materials. Cementitious materials (such as concrete) alone contribute close to 10% of man-made CO_2 emissions. It is important to focus on technological solution which can be applied in practice. However, we should also consider our consumption patterns and particularly in western countries reduce our consumption of meat and living space.

Which changes are necessary to create a sustainable global future?

As stated we need to look at our patterns of consumption. However, on the technical front and in relation to cementitious materials it is also important to make connections through the usage chain – to better educate engineers and find ways for low carbon technologies to be better accepted and applied in the field.

Which role do materials play in this?

Materials production accounts for a very significant amount of CO_2 emissions so it is absolutely critical we find ways of lowering the impact. At the same time construction materials are crucial to provide decent living standards for the world's growing population. Cementitious materials are by far the most important making up over half or all materials used. They can be produced everywhere and have a low environmental impact.

How will cement and concrete technology change in the future, and what will we have to establish to cope with these changes?

We have to recognize that changes in cement and concrete will be evolutive rather than disruptive. The composition of "Portland" cement is a direct consequence of the composition and geology of the earth and there is no possibility of changing this completely. Nevertheless, if we look at each step of the process: cement, concrete, structures, use; we can still make very substantial improvements. This requires connecting the dots between researchers, engineers, architects, users, etc.

How will the digital transformation change our future, and how can we get prepared? Where are the challenges, where are the potentials?

Of course digitalization will have a huge impact on our lives in the future. However, people cannot live in nano or virtual houses. So we must not forget these material needs.

In terms of higher education, where are the deficits? What is still good, what is already good. Where do you think we will have to go?

The first point of higher education is we need to improve access at all levels particularly for women. This depends on good access to primary education. At the level of higher education, I think it needs to be better connected to real life problems, but also we need to use globalization and digital technologies to make knowledge more accessible at all levels.

John L. Provis

Department of Materials Science and Engineering
University of Sheffield
Sheffield S1 3J
United Kingdom

John Provis is Professor of Cement Materials Science and Engineering, and Head of the Engineering Graduate School, at the University of Sheffield, UK. He holds degrees in mathematics and chemical engineering, and a PhD in chemical engineering, from the University of Melbourne, Australia. He was awarded the RILEM Robert L'Hermite Medal in 2013 for his work on geopolymer and alkali-activated cements, an honorary doctorate (Dr.h.c.) from Hasselt University, Belgium, and a European Research Council Starting Grant (2013-8). He is a Fellow of IoM3 and of the Institute of Concrete Technology, Chair of RILEM Technical Committee 247-DTA, and a member of the RILEM Technical Activities Committee, and committees of ASTM, BSI, ACI, and IoM3. He has published more than 200 journal articles, and holds editorial roles for the journals Cement and Concrete Research, Materials and Structures, Frontiers in Materials, and Advances in Cement Research.

Where do you see the technological challenges of the next decades related to the global environment?

I think that the key technological challenges of the next decades are likely to lie at the interface between technology and society; no longer can we develop technologies in isolation from their social context, nor can we assume that technology in and of itself is enough to solve the most pressing problems we face as a global society. We face a global crisis in climate change mitigation and adaptation, but we must also balance our response to this against the needs of all global citizens. Thinking particularly about construction materials, it is impossible to meet the development needs of areas which are not well served by infrastructure, if the "international community" just decrees that we must reduce or eliminate our usage of materials that are perceived to be polluting, without considering the essential role that these materials are playing in bringing an improved standard of living in many parts of the planet. Rather, we must focus our efforts on developing, deploying and embracing the technologies which can improve global quality of life in a sustainable way, driving our behavior from needs rather than "technology push".

Which changes are necessary to create a sustainable global future?

Only to connect to a sustainable global future, we will need to educate both technologists, social scientists and policy-makers, so that they can all mutually interact and gain benefit from each other's expertise. We need to break down the disciplinary barriers which lead technologists to seek solely technical solutions to problems, and rather to engage in a broader discussion where direct, societally appropriate answers to the most pressing problems in sustainability can be developed. This will lead to the opportunity to truly build a sustainable future, using technological development in service of sustainability rather than as a parallel (or worse, competing) end goal.

Which role do materials play in this?

Materials science and engineering must play a critical and central role if we are to achieve a sustainable future – both in terms of the development of new materials which can meet society's performance needs with a reduced environmental footprint, and also in enabling more efficient usage of existing materials. The core basis of sustainable materials development is that no resource can or should be wasted – and every material is a potential resource.

What will next generations of scientists, engineers and decision makers need? How can they be prepared for it?

The next generation of scientists, engineers and decision makers need to be more than just these things, and more than any one of these things. Policy-making must balance engineering, science and societal considerations, engineering and science must be placed into appropriate context, and the social sciences must be underpinned by an appreciation for engineering principles and the opportunity to leverage the opportunities opened by new technology.

What will be more important, global solutions or local solutions?

The future of technology must be founded on local solutions. The word is the sum of its parts, not the average – so it is impossible to develop and deliver appropriate, efficient, applicable technological solutions in isolation from the societal and social context in which they are to operate. Localism lies at the heart of this future; global technology must be locally adaptable if it is to be resilient, robust and efficient in service to humanity. This is not to deny any role for a global overview or commonalities between localities – quite the opposite, as it is the ability to connect localities which will enable the appropriate technologies to be identified and disseminated between locations. However, a global solution is by necessity externally-imposed upon the societies operating in each part of the world, and will never be embraced in the same way, nor used as efficiently, as a solution that is specific to the location in which it is to be used.

In terms of higher education, where are the deficits? What is still good, what is already good? Where do you think we will have to go?

Higher education worldwide has many strengths, but tends to move forward only at the speed at which its textbooks can be revised. Students bring energy, innovation and new perspectives that can, and must, be harnessed for societal benefit. Simply memorizing and rote-learning facts cannot, and must not, be the basis for a degree-level education; many of these 'facts' will change through decades in practice as technology and engineering move forward. Education must be about a way of thinking, enquiring, questioning and innovating – about philosophies and heuristics, ways to interrogate data sources to identify a way forward, rather than just obtaining information. There is of course a core position in this for the acquisition and transfer of core information – an engineer ignorant of basic facts is a danger to themselves and their clients – but the ability to use these facts with wisdom and discretion lies at the heart of a truly effective professional education.

Wolfram Schmidt

Bundesanstalt für Materialforschung
und –prüfung (BAM)
Department "Safety of Structures"
12200 Berlin
Germany

Wolfram Schmidt received a diploma in structural engineering at the RWTH Aachen in Germany and holds a PhD in civil engineering from the Eindhoven University of Technology in the Netherlands.

He has been working at the Bundesanstalt für Materialforschung und -prüfung (BAM) in the department "Safety of Structures" since 2005. His research focus is on admixtures, rheology, and high performance concrete as well as bio-based raw materials as chemical admixtures or supplementary cementitious materials for high-performance concrete applications. Since 2018 he is also secretary of the German Rheological Society DRG.

He is co-founder of the Pan-African Cement Proficiency Testing Scheme (PACE-PTS) and co-initiator of the conference series "Advances in Cement and Concrete Technology in Africa" (ACCTA). In 2017 he received the German-African Innovation Incentive Award. He is member of RILEM and fib technical committees and member of the RILEM Educational Activities and Development Advisory Committees.

Where do you see the technological challenges of the next decades related to the global environment?

In order to identify the technological challenges, it is necessary to look at pressing social and environmental challenges. If humanity does not find ways to allocate the global wealth to the populace and if our ending resources will not be used in a sustainable way, life of earth will be coined by social unrest and an increasing number of natural hazards. Therefore, the challenges technology needs to solve are linked to habitat, infrastructure, urbanisation, environment and resources.

At a closer look, we will find that no other technology field is more involved in all these problems than construction technology. But it seems, we are treading water here. Instead of innovating, re-thinking, and modernising, the dominating opinion is that what we've been always doing is also the best for the future. This totally ignores the changed global boundary framework of today which will continue to change dramatically.

Today, we increasingly gain knowledge about fundamental mechanisms behind our established technological processes. Improved analytical tools, digitisation, and global communication support and accelerate this, but all these advancements do not really change our habits. The challenges of the future, thus, will be to really utilise all the knowledge and tools that we do have today to get rid of backwards oriented technologies, to enhance promising technologies, and to develop best practice future technologies. This requires a new generation of conscious engineers, architects, and materials scientists, but there is no other way.

Which changes are necessary to create a sustainable global future?

Only because many of us cannot identify effects of global warming in their direct environment, it does not mean it is not real. Many people are already directly affected, particularly in the global South. Therefore, global awareness is the first step, and much has already been changed today. The next step is taking the responsibility. This will include getting rid of traditional ways of thinking. It does not mean that former ways of thinking were not right at their time and state of knowledge, but only because it was right in a past framework does not automatically mean that it is right in another environment.

Today, construction and materials technologies are totally overregulated. I do not mean that standards are bad. It is good to have standards, where it helps to democratise technologies and open markets. For example, certainly it helps the entire market if the dimensions and technical specifications of electric plugs are identical for all devices, from hair-dryer to television. But everybody will agree that there is no reason to standardise the colour, weight or the particular shape.

In the same way as standards can be reasonable limits, they should facilitate novelties where it is possible or required. Yes, probably our current construction standards are kind of idiot-proof, but is idiot-proof what we need to mitigate our climate challenges? No! New ways are required. We need a regulative framework that encourages people again to think, to develop and to improve. And certainly, we need the individuals who are brave enough to do.

Which professional groups play a major role in creating sustainability on Earth, and what is the role of architects and/or engineers in this?

I think, it cannot be denied that economic and legal considerations have permeated into every angle of our life. This also applies for construction technologies: economisation and regulations determine their acceptance, feasibility, and applicability. In this way, today, economists, legal profession and policy makers play one most important role by either facilitating or hindering sustainable innovation. Today, it seems that policies, regulations and purely monetary cost assessments rather block innovation, but when governments and people start to understand that sustainable technologies can be as safe and as cheap as traditional technologies, the situation will hopefully change. The price to pay is more permeable and adaptable regulations and more responsibility to technology drivers.

How many breakthrough technologies may not have been invented or not have made the market because of conservative cost-risk assessments? Therefore, more mediators between the disciplines might be required. This again demands for good educators, inspiring teachers that train students to automatically think out of the box and who can trigger curiosity for other disciplines and new ideas. Unfortunately, there are too few of these individuals. It seems, it is so much easier to teach students standards instead of ways of thinking.

In civil engineering, this may be the most dramatic necessity. Civil engineers exploit the largest part of the global resources, and along with architects, they define the structures of our cities and the efficiency of our infrastructures. Therefore, they are a crucial group of people for our global climate. This is why professors in this area should not focus on teaching textbooks from the past. The people, who can really make a change are professors who aim at being inspiration to the students, people who do not only want to teach but also learn from the creativity of the students. In an ideal case a professor should be manager of this creativity in a way that she or he channels the ideas to help lifting them to a higher level. It will mean lifetime learning for the teacher, but it will pay back to the societies tremendously.

How will architecture and construction technology change in the future, and what will be the implications? What will next generations of scientists, engineers and decision makers need? How can they be prepared for it?

Today, "sustainability" is not much more than a marketing buzzword. Every product or technology, all research and development claim to be sustainable, may it be ground-breaking or rubbish. In those parts of the world, where most research and innovation take place, the finiteness of the global resources is neither yet really visible nor tangible. Maybe it is a bit more than a vague idea. However, in other parts of the world resource scarcity and climate change have a tremendous impact on the quality of living.

A marvel solution or an unexpected overabundance of new yet totally unknown resources is rather unrealistic, and thus in the future both architecture and construction technology will have to adapt to the fact that finite resources and climate change are real. The next generations of scientists, engineers, and architects will have to take this into account, whether they like it or not. It is therefore advisable to prepare the next generations of decision makers in due time for this global challenge.

What will be more important in the future, interdisciplinarity or specialisation? Why?

Technology in general should always serve the society. Best technologies require specialist knowledge. Thus, specialisation is inevitable to develop technologies that help master the challenges in our world. However, specialist knowledge alone without transmission into society is exclusive and thus a root cause for inequality rather than a solution for societal challenges. More and more specialisation alone is a one-way direction if it cannot be transferred into tangible use. A permanent optimisation of a motor does not make a better car, if not the entire system is optimised.

A balance between specialist knowledge and its application in technologies can thus be considered as the silver bullet for the solution of the challenges addressed before. Today, there seems to be certain imbalance, and more technology transfer is required. Interdisciplinary communication, thus, is one major skill every decision maker should be equipped with to successfully master this transfer.

In terms of higher education, where are the deficits? What is still good, what is already good? Where do you think we will have to go?

One major engineering skill is the capacity to find the best possible technological solution for a given framework and set of tools. It seems to me that this skill is getting less and less taught to the students. Instead, engineering students are mostly trained to be appliers rather than developers. Although developers would be required so urgently for the mitigation of our climate challenges. I think, this used to be better in the past, and from all I overhear from colleagues, this seems to turn out to be a global issue.

The reason might be found in strict and school-like curricula, that put too much focus on hammering information into the students. However, learning by rote does not allow for mental and intellectual growth. I understand that the market demands for young spirits, but sometimes time is a good educator as well to make people understand a problem in its entire complexity.

I know that longer studying times are impossible in a world where in most places universities are hardly affordable for a broader population, and every semester is a real investment. Still I think maturity is important as well. I hate to say it, but to me it seems, particularly male students often lack a certain level of maturity when they are finishing their studies, but often they directly start in management positions, where maturity and social skill would be so important. Therefore, nothing seems to be really good in most educational systems. Certainly, there are always excellent people, male and female, but the higher education institutions have to create so many more of them.

So, if we do not have more time for education, how can we achieve accelerated maturity? Education has to be contemporary, which includes using contemporary media and contemporary tools. More student focused teaching is often confused with less content, lower complexity and easier exams, but this is not true. I believe that even hard education can be fun, when it is done by the right teacher in the right language using the right tools. In a time, where information is often outdated within just a couple of years, I believe, we do not have to teach students too much information of the past and today, but rather should we teach them how the yet unknown information of tomorrow can be managed and utilised in the right way. This requires more research capacity build-up, more project-based learning, more interdisciplinarity, more contemporary media and tools.

Ghada Bassioni

Faculty of Engineering,
Ain Shams University,
Cairo, Egypt

Ghada Bassioni, Dr. rer. nat. 2004, Technische Universität München TUM, Munich, Germany, is currently a Guest Professor at the Technische Universität München and is on leave from her permanent position as Professor and the Head of the Chemistry Division at the Faculty of Engineering, Ain Shams University, Cairo, Egypt. She is a member of the Egyptian National Committee for Pure and Applied Chemistry, Egyptian Academy of Scientific Research and Technology. She is also appointed as the Egypt-Germany coordinator, Science and Technology Development Fund (STDF), Egyptian Ministry of Higher Education and Scientific Research and has been a member of the Global Young Academy from 2013 – 2018.

She has been recognized with several national, regional and international awards. She is a Fulbright, Next Einstein Forum, African Science Leadership Program and "Lindau.Alpbach.Berlin." fellow since 2016.

She has organized a significant number of scientific and gender-related workshops and conferences and co-lead the Women in Science working group of the Global Young Academy for several years.

How does globalism change our world? Where are the potentials, where are the challenges?

In an ideal, globalized world, no visible borders exist. The borders in our minds remain a challenge though... Color, gender and physical ability should no longer play a role. How we cooperate, tolerate and accept each other with our many differences are key factors for a sustainable, fairly resource managed globe.

Which changes are necessary to create a sustainable global future?

Education needs to be granted for everyone as a first step to achieve a harmonized mother earth. An inter-cultural and inter-generational dialogue is necessary to try to minimize any social challenge and maximize the degree of acceptance and collaboration. A political will on all fronts needs to be there to raise awareness in a globalized context.

Which professional groups play a major role in this?

Key players for a sustainable future are young scientists who are dynamic and motivated enough to create the technologies necessary for that. Decision makers should pave the way for new ideas and innovation strategies in order to encourage these young scientists to gradually change the world.

How will architecture and construction technology change in the future, and what will be the implications?

As far as buildings are concerned, I believe materials of the future will be more environmental friendly, will be smart and can adapt to different environments. Green technologies in construction and the use of natural renewable resources in every aspect should be a main focus in buildings and architectural design of the future.

What will be more important in the future, interdisciplinarity or specialisation? Why?

Real innovation and translational research are only possible as a result of combining different brains with different ideas. Nowadays scientific knowledge is so gigantic that no single human brain can have it all. I truly believe in interdisciplinarity and the power of the change. Many useful inventions can be designed as an effort of different perspectives coming from different scientific fields.

In terms of higher education, where are the deficits? What is still good, what is already good? Where do you think we will have to go?

Higher Education implements the ability of critical thinking and finding solutions for daily, short-term and long-term challenges. Therefore, in my point of view, in Universities curricula have to adapt and be accommodated to the state of the art knowledge in the many different fields. The internet and its content needs to be checked for credibility as well. I believe that academic institutions in a cumulative effort worldwide have to play a more visible role as intellectual drive to a better world.

Mark Alexander

Department of Civil Engineering
University of Cape Town
Rondebosch 7701
South Africa

Mark Alexander is Emeritus Professor of Civil Engineering and Senior Research Scholar in the University of Cape Town, and a member of the CoMSIRU. He is a Fellow of several professional and academic institutions, including the University of Cape Town. He is a registered Professional Engineer in South Africa. He teaches and researches in cement and concrete materials relating to design and construction, with interests in concrete durability, service life prediction, concrete sustainability, and repair and rehabilitation of deteriorated concrete structures. From 2012-2015, he was President of RILEM, an international organisation concerned with construction materials and structures. He co-authored "Aggregates in Concrete" (2005), "Alkali-Aggregate Reaction and Structural Damage to Concrete" (2011), and "Durability of concrete – design and construction" (2017), and was Editor of "Marine concrete structures. Design, durability and performance", (2016).

Where do you see the social (and political) challenges of the next decades related to the global environment?

'Sustainability' remains on the periphery of much of society at present, despite lip service to its importance. This is due to many factors: a) political intransigence b) global business environment and entrenched interests, and c) dominance of the international agenda by powerful lobbies and governments. To alter this will take courageous actions by key nations, corporations, and individuals. But many 'ordinary' people will gladly adopt needed strategies if they are convinced of the need to do so.

Which changes are necessary to create a sustainable global future?

Much greater political will from the leading and richest nations, including key emerging nations; legislation and regulation to bring in a new paradigm; communication and education (repeatedly and continuously!) of populations to help them understand the implications.

Which professional groups play a major role in this?

There is no one group or profession that can 'solve' this problem. It will take a joint and coordinated effort. But human society has large inertia, and often change only when faced with major calamities or undesirable outcomes (e.g. the 'Day Zero' scenario in Cape Town in 2018). But there is still lacking a coordinated agenda and set of agencies who will 'drive' the needed changes in society, including in education, using an evidence-based approach and reasoned arguments.

How will cement and concrete technology change in the future, and what will we have to establish to cope with these changes?

I cannot see how our construction methods and materials will vastly change in the future – in the main. More and more people will need the basic necessitates of life, and this includes many construction-related aspects. There will be niche applications of novel technologies, but most of these are still very preliminary or may not hold the key to major sustainability shifts. So, we need thorough education of the next generation of builders, engineers, architects, etc. in the challenges and available solutions, but we also need massive efforts to reduce and even reverse the main causes such as emissions. This will have to go way beyond our current state of the art.

What will be more important in the future, interdisciplinarity or specialisation? Global solutions or local solutions?

The answers to the questions posed above are not simplistic, and cannot be framed in terms of absolutes or one option over another. What is needed is networks and linked agencies, governmental, industrial, etc., that embrace a common agenda and work for the common good, in view of the challenges. There will be space for specialists as well as those with interdisciplinary skills, with the latter being possibly more important as time passes to drive change across several boundaries. This will have to be a team effort of all the skills, knowledge, and resources available to us as human-kind.

In terms of higher education, where are the deficits? What is still good, what is already good? Where do you think we will have to go?

Even in our own institution, we have not managed yet to develop a consistent and coherent set of protocols around major societal challenges (or at least that is my perception). Long-established curricula are very hard to change! Reputational and professional risk always attaches to major changes. My view is that, in general, too many silos remain and it is very difficult to break these down. Pressure on research and teaching budgets is not helping. Courageous and visionary leadership is needed, but then there must be matching support from senior management.

Daman K. Panesar

Department of Civil and Mineral Engineering
The University of Toronto
35 St. George Street
Toronto, Ontario, Canada

Daman K. Panesar, Ph.D., P.Eng. is a Professor with the Department of Civil and Mineral Engineering, University of Toronto, Canada. She received her BEng. (McMaster University), MASc. (Western University), and PhD. (McMaster University) in Canada. Panesar's research activities are focused on the sustainability and durability of cement-based materials and structures. One broad objective of her research program is to advance concrete technologies and concrete composites aimed to extend service life of structures and infrastructure while reducing the environmental impacts, and improving the economic feasibility. Her research outcomes are applied to underground, nuclear, transportation and building structures. She is Chair of Canadian Standard CSA-N287.5 (since 2010); Co-Chair Division 1-Structural Mechanics and Reactor Technology (since 2011); Member of the Research Management Committee of the India-Canada Centre for Innovative Multidisciplinary Partnerships (since 2013); Secretary of the International Association of Computational Mechanics- Female Researchers Chapter (since 2016); and on the RILEM Technical Activities Committee (since 2018). She also serves on the editorial board for Cement and Concrete Composites (since 2013), and the Canadian Journal of Civil Engineering (since 2018). Panesar has received honors including: an Early Researcher Award by the Ministry of Economic Development and Innovation (2013-2018), and an Early Career Award, Erwin Edward Hart Professorship (2016-2019) for her scholarship and exemplary graduate student mentorship.

Where do you see the challenges of education for the next decades? Which changes are necessary to create a sustainable global future?

In a digital world moving fast and forward, it is necessary not only to orient students towards a transient future but equally important is to impart engineering education of the concepts/design/standards/policies, which form the basis of our existing structures and infrastructure. In the upcoming decades, one challenge will be not only to educate for the future, but also to educate about the engineering design basis of the past. This will be increasingly important as structures are designed and constructed with longer service lives than ever before. Education and critical assessment of the original design basis in comparison with current design basis and future design projections is a key pillar to effectively manage, assess, and maintain currently existing structures/infrastructure and to responsibly design and construct new structures and systems. For example, some necessary questions to discern are: how have the design criteria, constraints, codes specifications, societal need, available technologies changed between the time of the original design, to today? How are codes, criteria and societal need projected to change in the future? Incorporation of this information is necessary for responsible design decisions that will affect future generations.

Which professional groups play a major role in creating sustainability on Earth?

Government institutions have a powerful role in being able to create progress towards sustainability on Earth, as well as the ability hamper progress towards sustainability. This response addresses the context of the environment and ecology. Progress towards global sustainability of our ecology is hindered by nations having opposing views on climate change. Within one nation, to achieve compliance of federal climate change commitments requires that each province/state enact climate change policies at the local level. However, in reality, there can and does exist disparity between federal policies and provincial/state regulations which has direct implications on strategic projects, availability of resources for research/development and implementation of schemes which are incentives to achieve sustainability (i.e. carbon pricing, cap and trade system). In particular, newly elected governments who repeal their commitment to international agreements and demise cap and trade, and carbon pricing systems is absolutely catastrophic for countries to successfully achieve targets for greenhouse gas emissions reductions. A local, national and global unilateral perspective is essential for success in creating sustainability on Earth.

What will be more important in the future, interdisciplinarity or specialisation?

Specialization vs. interdisciplinary. Fundamental science vs. applied science. Research vs. practice.
It is not a question of which is more important, but rather, it is about the progress and evolution of the engineering solutions and technologies. Research should drive practice. Fundamental knowledge should translate to the application of science. Specialization is a necessary seed to enable inter- or multidisciplinary branches. The engineering aspects of a multidisciplinary design serve as the basis for a safe/reliable/secure structure or system. Therefore, it is imperative that the fundamental engineering principals in an inter- or multidisciplinary project do not get lost or become diluted by practical considerations, cross-fertilization of concepts, and other influencing integrative parameters which could compromise the ultimate safety of the engineering system.

Tina Nyamache

Village Capital
Nairobi
Kenya

Tina Nyamache serves as the Africa Operations and Partnerships Associate at Village Capital. Prior to that, she was the National Project Manager for FK Norway and AIESEC Kenya for, a project that worked with recent graduates who wanted to realise their ideas around social innovation. She served as an executive assistant in various departments including Education, Social Services, ICT, Trade, Industrialisation, and Cooperative Development at the Nairobi County Government of Kenya. She sits on the board of advisors for the Kenya Economic Youth Network. Tina holds a B.S. in International Business Administration and a double minor in Finance and Marketing from the United States International University. She is a fellow at the Amani Institute with a Postgraduate Certificate in Social Innovation Management.

Where do you see the challenges of education for the next decades?

Human beings are naturally different and diverse; however, our education system is based on conformity and not diversity. Students thrive when they have a broad curriculum that cerebrates their different talents and educators need to explore them. The biggest challenge for education is how educators have structured their curriculum. We should be asking how we should educate the students of the future to be more mindful of the existing real-world problems. Educators need to spark curiosity, creativity, mentor, stimulate and engage the students in coming up with innovative ways to address our future challenges.

An example of current challenges is; increase in population which is creating more pollution in our environment and we are running out of resources. This will prepare the students to face current and future challenges.

In the next decades we will have more transformation at all levels of education because of the innovations that are happening, digital natives and the generational forces at play. Educators need to help students navigate the challenges and discover their place in our world, which is rapidly changing.

Which changes are necessary to create a sustainable global future?

To create a sustainable global future, we first need to break down sustainability by sector. How does it look like for each sector? Then work out action plans for each sector (details matter greatly). In order for the solutions that we come up with to become successful, we need collaboration from all stakeholders in each sector.

The most important thing is shifting peoples' mindset about sustainability. Most people want to be part of a sustainable world but don't know how that looks like, we need to be more specific and paint a clear picture of how sustainability looks like in practice. How is a sustainable world different from our world today? How is it better? It's hard to predict the future, we need to have an honest conversation about what

sustainability means to each person in our day to day lives. To have a sustainable global future, individuals in the real world need to be convinced to join this movement or made to act in the common interest.

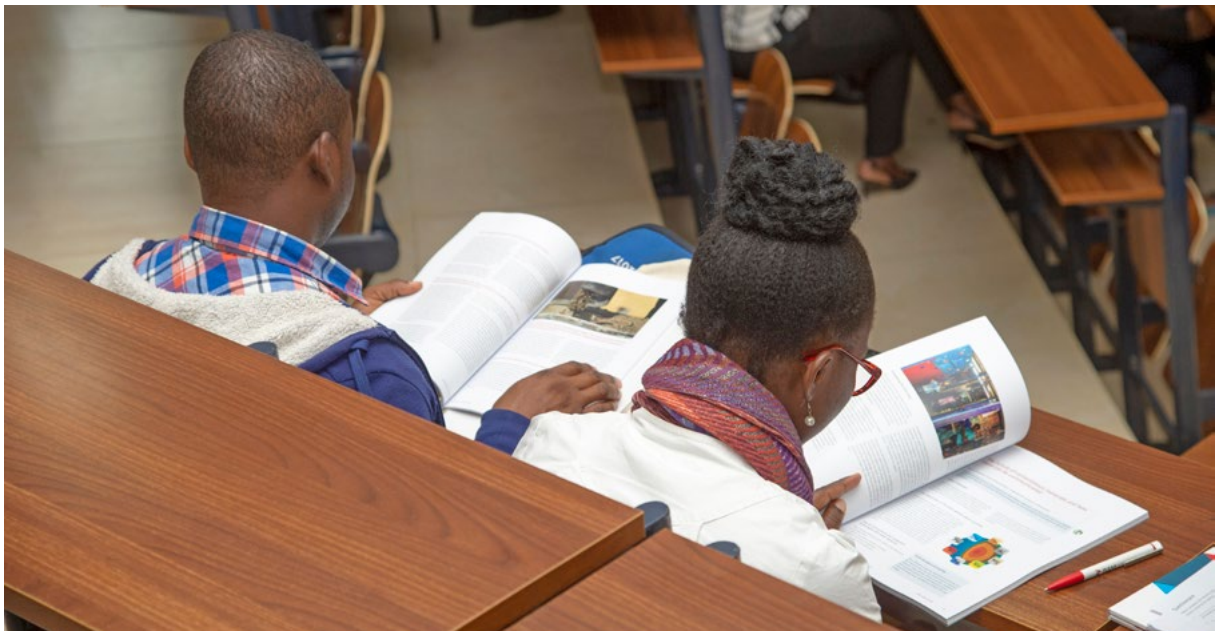
This needs to be a collaborative initiative that can be pushed by our governments, educators, institutions developments and community leaders.

Which professional groups play a major role in creating sustainability on Earth?

Teachers, nurses, urban planners, economists, agro-forester, environmental engineers, medical doctors, farmers and urban agriculturalists, elementary school teachers, nutritionists, occupational therapists, youth development coordinators, philanthropists, international NGOs, policy makers and social workers.

How will architecture and construction technology change in the future, and what will be the implications?

According to Arch Daily, technology is helping us to make the impossible possible in areas like architecture and design. We need to combine bio-empathy, bio-mimicry, design, engineering, and innovation to create environmental friendly products that will produce value for the economy in the long run.



What will be more important in the future, interdisciplinarity or specialisation? Why?

We are witnessing that using skills and knowledge from different disciplines is practice for solving problems outside school walls and can spark curiosity for students.

As the world keeps changing, interdisciplinary becomes an asset when challenges arise that are more complex like affordable housing, financial health, poverty – this require multi-disciplinarity.

If used correctly, in combining knowledge and best practices we can create innovative solutions. Different disciplines can be partly used to create new disciplines and to extend the knowledge frames of previous disciplines. However, working in an interdisciplinary setting may not be for everyone and that is ok because some field specific challenges are solvable under one discipline.

Our education system is organised on the basis of disciplines, yet our world today and the future is not. Educators need to design more courses that are interdisciplinary, where one discipline learns from the perspective of another, or disciplines are integrated.

This will allow more context-specific programmes that prepare students for future jobs or they might potentially create hybrid solutions that cut across multiple industries.

In terms of higher education, where are the deficits? What is still good, what is already good? Where do you think we will have to go?

The cost of higher education keeps rising, a lot of graduates come out into the job market that is not providing high-paying jobs. As a result, most people spend most of their lives paying their collage/university debts. Employers have raised concerns of a skills gap, most graduates do not have the hard or soft skills required to perform these new technologically demanding jobs.

Due to the high cost of education, there is an increase in the number of higher education institutions and online causes, this will force a shift in how higher education is structured. The non-traditional institutions will reduce their costs and rely on online tutorial videos and online courses and offer short professional courses at reasonable prices. This will give the employers more options for qualified talent pool to hire, students will get more financially viable choices to specialise in, and the university will have multiple revenue streams. Most importantly, this gives students the freedom to explore different professions and find what they are great at.

Murray Metcalfe and Nadine Ibrahim

Murray Metcalfe is Professor, Globalization in the Faculty of Applied Science and Engineering at the University of Toronto (UofT). At UofT he is currently also an Adjunct Professor of Mechanical & Industrial Engineering and of Civil Engineering, and a Senior Fellow at the Global Cities Institute.

He holds a B.A.Sc. in Industrial Engineering from the University of Toronto and a M.S. and Ph.D. in Engineering-Economic Systems (now MS&E) from Stanford University. Before returning to UofT he had a 30-year professional career, first at McKinsey & Company and then in multiple positions in the venture capital industry in the U.S.

Nadine Ibrahim holds a BASc (2000), MASc (2003), and PhD (2015) in Civil Engineering, and a Certificate of Preventive Engineering and Social Development, from the University of Toronto (UofT).

She has been active in futures research on engineering education for the future and chairs a special interest group on the Engineer of 2050 at the Canadian Engineering Education Association (CEEA), and co-authored a book chapter "Educating Engineers for the Anthropocene" which appeared in the State of the World 2017: EarthED: Rethinking Education on a Changing Planet, published by the Worldwatch Institute.

University of Toronto
Department of Civil Engineering
35 St George St., Toronto, ON M5S 1A4
Canada

Where do you see the technological challenges of the next decades related to the global environment?

The immense urban growth and renewal that is anticipated requires infrastructure, technology and supporting social, economic and environmental networks to sustain growing populations. The engineering disciplines participating in rehabilitating and building this infrastructure will also require resources and financing to ensure sustainable growth and development. The impact of this challenge is pivotal in meeting sustainable development goals in developing cities, and transforming to smart cities in more developed ones, with significant implications for urban prosperity and low-carbon growth. Climate mitigation is getting more costly the longer we delay action. Climate action planning in cities has been evolving

as a result of improvements in energy data, progressive climate governance, ambitious greenhouse gas (GHG) reduction targets, and the necessity for timely mitigation efforts. With climate targets and commitments in place, city governments are looking to prioritize their budgets, to achieve targets in 2050 and beyond, in concert with other city priorities.

Which changes are necessary to create a sustainable global future?

These are exciting times for work in the domains of sustainable cities and engineering education, during what is characterized by the OECD (2015) as the "Metropolitan Century" coinciding with the emerging thought by the Canadian Engineering Education Association (2017) in defining the "Engineer of 2050." From global visions to local priorities in cities, the message for teaching and research in these areas is clear: How can cities sustain their growing populations and achieve urban prosperity? And, how are the engineers of the future prepared to take on the challenges resulting from rapid urbanization? The changes that are necessary include fostering not only a sustainability skill set, but also a sustainability mind set, in academia and in industry. Changes to create a sustainable global future in light of the technological challenges as identified in 2014 in a report of the Royal Academy of Engineering on implications for the education system include:

1) Quantification of the future infrastructure requirements will determine residential space needs, transportation network capacity, energy supply and demand, and water availability and capacity makes a compelling case in the sheer magnitude of the infrastructure and technology that needs to be built and installed. More affluent cities seek modernization and efficiencies, and developing cities seek ways to leapfrog to sustainable solutions.

2) Climate action discourse cannot be devoid of the economic implications of mitigation alternatives, in addition to climate policies and carbon pricing strategies to reduce GHG emissions. Marginal abatement cost curves are powerful visuals that make technical and economic analysis of climate action possible, and empowers cities to effect positive change for more resilient and sustainable energy futures.

What is the role of architects and/or engineers this?

Engineering students who choose to study engineering are passionate about designing, creating, and innovating. The ways in which engineers are trained, they are motivated to contribute to the betterment of society. Despite being a disciplined profession, and is born from very conventional ways of learning, engineers are hands-on, problem solvers, critical thinkers, system designers, and translators of technical jargon, in addition to being the liaison among other specializations.

What will next generations of scientists, engineers and decision makers need? How can they be prepared for it?

The engineering of sustainable cities in developing and developed world contexts, will necessitate redefining engineering as the professional enters the next stage of modern transformational change. This transformation will aim at decoupling natural resource consumption from environmental impacts yet still see an increase in economic growth. The next generation of engineers need competencies in sustainability and preventive engineering.

1) Sustainability is now considered an expected engineering competency, where it needs to be characterized, integrated and streamlined into engineering education to give students the economic and social literacy required for their technical specializations. Teaching tools that disseminate sustainability across engineering disciplines will have a profound influence on engineering education, and the graduates who will influence the identify of the profession.

2) Preventive approaches for the engineering, management and regulation of technology are similar to the ways we interact with our contexts in our everyday activities. We need to map the relationships between technology and its contexts to transcend professional specialization by making use of other bodies of knowledge, which is important to guide decision-making when comparing new technologies to conventional counterparts. The applications of preventive engineering is a rich topic where engineers have a role to play in bringing to political decision-makers and public policy the implications of the desired and undesired effects of technology and economic growth. Research is only beginning to explore the preventive approaches in healthy and sustainable cities, energy, materials and production, and work design, development strategies and computer technology.

What will be more important in the future, interdisciplinarity or specialisation? Why?

We believe universities produce people that are equipped to effect change in society. Interdisciplinary teaching inspires engineering students through an environmental-consciousness, and an economic and social literacy that empowers their technical specializations to create liveable futures. An enriched learning experience is created when the learning takes place in and out of the classroom, contextualized to our socio-economic settings and environments. The value given to contextualized learning leverages the power of local knowledge, and online learning in particular stimulates collaboration among academic peers in different domains and geographies. From the perspective of teaching about sustainable cities, which is inherently multidisciplinary because it encompasses components of the built environment like buildings, transportation, energy, water, wastewater, and waste networks, cities are the leading drivers towards sustainable solutions, and teaching about them uses a systems thinking approach for urban engineering. Interdisciplinary knowledge lends itself to transdisciplinary competencies that are essential for global challenges. Global challenges are interconnected, and the world's problems are not compartmentalized – neither should their solutions. The solutions to the world's problems are not discipline-specific, and neither should the way we learn to comprehend our world. One way to overcome the shortcomings of specialization is to strengthen students' interdisciplinary skills. The expectation of working in teams in the workplace makes engineers the most suitable candidates to act as the bridge among disciplines. Engineers of the future will be managing the impacts of climate change and urbanization, in the face of new climate realities, rapid urbanization and globalization, where they will need

to adapt their skills to respond to and resolve global challenges, and contribute consciously in the economies that will absorb them. Research on the characteristics of "Engineers of 2050," which I have started to lead, and others like "Global Engineering Leader," and "Whole New Engineer" is necessary to identify and develop transdiscplinary skills. Innovations in pedagogy will reimagine undergraduate engineering education and how it brings in other domain competencies into engineering education and practice.

In terms of higher education, where are the deficits? What is still good, what is already good? Where do you think we will have to go?

The benefits of a hands-on, practical and technical training in engineering is what makes it exciting, relevant to the real world and solve real problems. Higher education should transition into enrolment into "global missions" rather than just being enrolled in an engineering discipline. For example, rather than choosing to study civil engineering, or mechanical engineering, or electrical engineering, students in the future can choose to enrol in a mission to address urbanization, or global poverty, or child hunger, and as such higher education institutions would provide tailored programs to teach the necessary competencies to enable these students to address global challenges while being motivated to learn, and ensuring relevance of their education to the needs of society, and therefore employability.

The learning model can use a makeover. If we compare the ways people commute today and a hundred years ago we'll realize that in the past we used horse (or donkey or mule) drawn carriages, and now we use cars, and more innovation in the future as it relates to electric vehicles, hyperloops and other transportation fantasies. If we compare the ways people obtained food in the past and today, we'll realize that we have emerged from hunter gathers in the ancient times, to doing groceries online. But when it comes to the learning model in the past and in the present, we'll notice that we have not moved much from the scene of an instructor at the front oft he class delivering information to students. This model can utilize the innovations in online learning, information technology, virtual teams, global classrooms, and other educational dreams and aspirations.

In your role (as an educator, practitioner, technical expert, etc.), what actions can you start taking to drive global change, and lead engineers a step closer to the sustainability efforts?

In my role as an educator, I teach courses on sustainable cities that tie in research findings from my global experience to support context-based and project-based learning in my teaching strategies. My research and teaching interests are interconnected, where my research findings enrich my teaching, and my teaching is a product of my education and global experiences in research and industry. My current and previous research is a springboard to research in other cities and city networks.

Learning goes beyond the classroom, and it is what happens before and after the class time, and beyond the course, that is what students retain and carry with them in the long-term. Providing students with the ability to interact with real applications of the theory taught in class makes the content more relevant and more applicable to their knowledge base. Offering students the chance to observe real world applications and be able to recollect the theory behind them gives a new perspective to the material. The skills gained by this approach are transferable and it is an approach to lifelong learning that students can continue to apply with new material. Students bring their perceptions to the course content, and I would expect them to think of course material as it applies to the real world outside of the classroom. One of my teaching goals is to adopt the "Engineering Habits of Mind" as discussed in "Thinking Like an Engineer" in which students learn systems thinking, problem-finding and problem-solving, while visualizing, improving, and adapting.

City-to-city learning has become a knowledge industry, though more commonly seen from the perspective of policy, economics, and social sciences. The degree to which cities will reproduce best practices will depend on learning from one another, and the knowledge sharing among engineers. E.g. what the indigenous communities in Canada can learn from similarly low-resource African cities is a valuable outcome of "reverse" innovation. Knowledge sharing among cities as it relates to urbanization has not found its mark in literature in general, and engineering research in particular. Analysis of how and why urbanization trends differ among cities, by analyzing geophysical factors (e.g. access to resources, and gateway status) and technical factors (e.g. power generation, urban design) using infrastructure metrics and data analytics will define the potential for city-to-city learning. The importance of creating knowledge by cities for cities and their engineers represent a big step towards contextualizing sustainability, and advancing the adoption of innovations in infrastructure and green technology solutions.

Busisiwe Maria Legodi

Former CIMERWA Ltd CEO

Busisiwe Legodi is an Entrepreneur, innovative executive with extensive experience in cement manufacturing. She has extensive experience in navigating the entire set-up and administration of business with focus on achieving business growth objectives within turnaround & rapid changing environment; targeting top level assignments, preferably in International locations. She has over 20 years of experience gained through working at various levels within the cement industry. She was the former CEO of CIMERWA Ltd, PPC's Rwanda manufacturing division since 2014 after being the General Manager at PPC since 2012.

Busisiwe holds an MBA from Monash SA, holds Bachelor of Technology in Chemistry, Total Quality Management from UNISA, and Quality Assurance from City and Guild of London Institute, London, UK.

Busisiwe is one of the founding members of the PPC Ltd Women's Forum, as well as a member of the International Women's Forum. She is an appointed member of Totally Concrete East Africa advisory board member. Was involved in the concept of starting the WIMA (Woman in Manufacturing) of which she is a member.

She was also one of the Standard Bank Top Women Awards finalists for 2014 and 2015. The Top Women Awards is a prestigious collaborative platform dedicated to recognising outstanding leadership, inspiration, vision, and innovation in organisations that have stepped up and shaped women's roles within the private and public sectors. In 2014, she won the PPC Best Women Leadership Award. She is also a winner of the Women in Concrete Excellence Award 2013, and the finalist in the CEO Regional Awards, 2016.

Where do you see the social challenges of the next decades related to the global environment?

Increased levels of unemployment: Self-development, agility, and stay abreast with the ever changing technology that will ensure relevance and sustainable development. Promote Innovation and entrepreneurship.

Natural resource depletion: Prevent environmental degradation by using alternative energy resources like solar power instead of coal in operations. Prevent environmental pollution, invest in research technologies that will ensure availability of clean drinking water. Family planning.

Emergent of decease: Invest in research and prevention.

Exposure to corruption: Ethical economic markets development by developing the technology that will minimize exposure to fraudulent transactions.

Which changes are necessary to create a sustainable global future?

Improve the literacy, expose children to technology in their early childhood. Globalize the schooling and qualifications by globalizing the currently clustered country specific education curriculum system, example e-learning). Governments to promote availability, accessibility and exposure to technological resources by all their citizens by creating easily accessible computer libraries resourced with internet access. Sensitivity and promotion of environmental friendly, healthy, and balance lifestyle. Entrench the loyal value system within the community from early in life.

Which professional groups play a major role in creating sustainability on Earth?

Early child foundation educators to high school. As human beings we are influenced by our surroundings that we are exposed to from the moment we start learning and understanding the world around us. Early childhood is the best moment to influence and expose children to technology because they are still at the exploratory mindset where their minds are not yet clustered by beliefs. Proceeding with the same until high school will foster a better foundation for the future generation as they will be aligned to the then technology.

How will cement and concrete technology change in the future, and what will we have to establish to cope with these changes?

It took more than a decade for the cement and concrete technology to evolve, but it has since caught up with the latest technology evolution emergent in the past 3 decades. This is evident with the recent speedily growth of green technology buildings and 3-D building which are speedily taking over which is more preferred because it is predictable, it eliminates exposure to construction fatalities, quicker installation, and real time off-site project management.

Though affordability is still a challenge, its application is still preferred and applied in repeatable form of building like low cost accommodation which will possibly use the same mold to build multiple for construction.

What will be more important in the future, interdisciplinarity or specialisation?

Specialization will give people comparative advantage in the future. Comparative advantage is more often the result of education, training, or experience. With specialization, people will be relatively more efficient in their field of expertise. For instance, a professional chef will spend less time to prepare a special delicate meal which is better presentable, tasty, and shorter in time.

At the individual levels, comparative advantage often appears to be the result of inborn talent. For instance, talent for fixing computers.

At the national level, comparative advantage may derive from differences in natural resources or from differences in society or culture.

Seemingly noneconomic factors also can give rise to comparative advantage. For instance, English-speaking countries have a comparative advantage over non–English-speaking nations in the production of books, movies, and popular music.

In terms of higher education, where are the deficits? What is still good, what is already good. Where do you think we will have to go?

Deficits: Curriculums not aligned to the work environment skills and knowledge requirements; different countries offering different curriculums; affordability.

Still good: The e-learning centres to continue providing online education and training.

What have to go: Remove old curriculums, remove lecturers with only theoretical knowledge with no relevant skills.

What can be done for the future: Align the curriculums to fit the market skills and knowledge needs. Recruit lecturers with relevant skills and experience.

Kolawole Adisa Olonade

University of Lagos, Nigeria

Kolawole Olonade is a structure and cement-based materials expert with focus on utilisation of various wastes (agricultural and industrial) for the production of high performance concrete. He had his undergraduate study in Civil Engineering from the Federal University of Technology, Nigeria; Masters in Civil Engineering from the University of Ibadan, Nigeria, while he obtained his PhD degree in Civil and Environmental Engineering with bias in structures and materials from the University of Lagos. He started his teaching and research career with the Federal Polytechnic Ilaro and then joined Obafemi Awolowo University, Ile-Ife in 2010. Currently, he is a Senior Lecturer in the Department of Civil and Environmental Engineering of the University of Lagos. He is a chartered engineer by the Council for the Regulation of Engineering in Nigeria (COREN). He is equally a member of the Nigerian Society of Engineers, Nigerian Institution of Civil Engineers as well as a senior member of RILEM. Dr. Olonade is an active member of the Technical Committee of RILEM: TC 251-Sulphate Testing Resistance, TC 281-Carbornation of Concrete with Suplementary.

Cementiitous Materials and TC AMC- Use of Agro-Based Materials as Cementitious Additions in Concrete and Cement-Based Materials. He is a recipient of a number of awards and grants, which include the distinguished German-African Innovation Incentive Award.

Where do you see the technological challenges of the next decades related to the global environment?

I seem to see the technological challenges of the next decades in the following areas:

Deployment of appropriate technology: the world is now a global village, but this does not preclude the fact that there are differences in regions of the world. People are not the same, cherished-values differ, and climatic conditions vary. These are major factors that should influence what technology to be deployed in a particular environment in the next decades. For the fact that a technology meets the yearnings of the people in Europe does not necessarily mean it will be cherished by Africans. Even the needs of people in the rural areas differ from those of people living in the city. Providing appropriate technology to people of diverse cultural backgrounds remain a challenge.

Take-it-all syndrome: the nature of challenges facing the modern world requires multi-faceted approach, and as such, requires diverse professions and people to address them. Nevertheless, self-aggrandisement has the potential to overwhelm the purpose of a technology. It could be a stumbling block to collaboration among professionals to address a research problem. For instance, who become the major partner in a research work, who should be the first author of a publication, who owns copyright, are grey areas in the scientific community. This remains a challenge to solving problems that require interdisciplinary approach.

Rigid policy and standards: Without undermining the relevance of standards in technological-based disciplines, standards seem to do more disservice to engineering training. This is because many students

of engineering, by virtue of their training, are limited by standards and do not think beyond the box. By this, students see engineering as an exact profession that requires exact solution to every problem. In the real sense of it, engineering is both exact and precise as well as dynamic.

Transparency: Transparency can be positive or negative, depending on the realm of discussion. In knowledge, however, transparency is positive because it brings the researcher to accountability, creates opportunity for replicability, as well as advance the course of knowledge for human development. For instance, a patent technology could be purchased by a company seeing the patented technology as a challenge to its business to prevent competition.

Which changes are necessary to create a sustainable global future?

Appropriate technology should be deployed to people. Social and cultural background of the people should be a strong factor, when deploying technology to people. I give an example of a village in Nigeria, where the women trek a long distance to rivers to fetch water. They enjoyed the situation as it gives them the rare opportunity to meet their friends and chat, giving them social relevance. In the wisdom of the government, a hand-pressed borehole was provided for the community to ameliorate the stress these women go through in fetching water. To the dismay of the provider of the technology, the women receive the gesture with disdain and never used the borehole. To them, the technology was a hindrance to their social existence. So, technology will only be beneficial when it meets the core-values of people.

In addressing the take-it-all syndrome, there is need to de-emphasise "first-authorship", "principal or major partner" and so on, in a collaborative research. It should be more of shared-value and this will help to win the confidence of co-researchers.

Adoption of open access to advance technology development is also required. In universities, principles upon which standards and codes were developed should be taught to the students so that they would develop innovative thinking and analytical minds to address the challenges of the modern world.

Which professional groups play a major role in creating sustainability on Earth?

Professionals in built environment such as civil engineers, architects and town planners are key to creating sustainability on earth because urbanisation, provision of infrastructure as well clean environment are the main challenges facing the modern world. The more these professionals are cautious of their roles and ready to play them, the more we are sure of sustainability.

What will next generations of scientists, engineers and decision makers need? How can they be prepared for it?

The new generation of scientists, engineers and decision makers need creative thinking, looking-forward approach, as well consideration for the environment while they explore nature. Thus, the natural ecosystem should be maintained as much as possible for a safe world. The journey to achieving this must start from the classroom. We need to prepare students for integrated knowledge as well as knowledge that create wealth. There is need to engage students in the classroom and create spaces that are interdisciplinary by nature. So, right from the university, students learn how to understand a system and create a knowledge economy. We instil in students a culture of interdisciplinary approach to solving problems.

What will be more important in the future, interdisciplinarity or specialisation? Why?

The future challenges are multi-faceted and could only be approached by interdisciplinarity. To combat global warming, urbanisation and depletion of natural resources as well as provision of infrastructure, require diverse knowledge. For provision of infrastructure, for instance, there is need to have social scientists on board to look at the social effect the infrastructure is likely to have on people and how will people be ready to accept it, economists to perform cost-benefit analysis, civil engineers and architects will be involved to design structures that take minimum materials and provide functionality, town planners are equally needed. Political scientists will be needed to interact with governments to promulgate policies and laws that will checkmate abuse of public infrastructure to ensure sustainability.

In terms of higher education, where are the deficits? What is still good, what is already good? Where do you think we will have to go?

Traditional teaching with focus on specialisation is still very rampant in most of our higher education. In the classroom, the teacher only comes with his/her old notes and pour the knowledge to the students with little or no response from the students. The facility to impact knowledge that creates wealth are lacking, while many of the subjects being taught are nowhere near addressing the current and future challenges. Nevertheless, enthusiasm and flair to learn are still inherent in many youths. There is need to formulate and teach new courses that address modern challenges. Sustainability as a subject would need to be taught from several academic disciplines. Since answers to major global problems cannot be found with single traditional discipline, problems based on interdisciplinarity should be treated with students, while making classroom more of student-teacher centred rather than teacher centred.

Yunus Ballim

Department of Civil & Environmental Engineering
University of the Witwatersrand, Johannesburg
Proivate Bag 3, WITS, 2050
South Africa

Yunus Ballim holds B.Sc., M.Sc. and PhD degrees in civil engineering from University of the Witwatersrand (Wits). After six years in the construction industry, he was awarded the Portland Cement Institute Research Fellowship based at Wits in 1989, was appointed as a lecturer in 1992 and he currently holds a personal professorship in Civil Engineering at Wits. He was the Head of the School of Civil & Environmental Engineering from 2001 to 2005. His research is mainly in cement and concrete materials science. He holds a South Africa National Research Foundation rating as a researcher and has done so since 1994.

He served as the founding President of the African Materials Research Society and held the Bram Fisher-Oxford Fellowship in 2000. Between 2006 and 2012, he served as the Deputy Vice Chancellor - Academic and the Vice-Principal at Wits. He served two terms as a member of the Commission for Higher Education in South Africa and was Chair of the Higher Education Quality Council.

In 2012 and 2013, he was the Chair of the Board of the National Institute for Higher Education in the Northern Cape and is presently the Vice-Chancellor of the Sol Plaatje University in Kimberley.

Where do you see the social challenges of the next decades related to the global environment?

My concern is that, globally, we have replaced the idea of "access to a dignified life" with the idea of "access to a wealthy life" and that the equilibrium position to be aimed for is a universally middle class human species. The problem is that there is not sufficient inputs (food, consumer goods, etc) nor sufficient capacity to absorb the waste output on one earth, if all humans live the lifestyle of the average middle class citizen in a "developed" country. This must necessarily result in unequal distribution of access to social justice and a system where the wealthy buy themselves out of inadequate or inefficient public services (private healthcare, security, education, etc) while the poor mostly contend with the bad services or sometimes fight each other for the little that is available.

Over the past 10 years or so, there has been a growing rage in the world as people lose their confidence in the social institutions that have failed in their post-World War 2 promise to deliver access to a dignified life for as many people as possible. The disrespect that the corporate sector has shown for even light regulatory frameworks, the tendency to corruption by governments, scandals in faith-based organisations and unemployed graduates are some of the factors contributing to this rage. The resulting brutish responses throughout the world must raise concern about the sustainability of the current social relations in the world.

Which changes are necessary to create a sustainable global future?

The challenge then is to ask how we extend the reach of social justice to the most marginal of our societies. I presently work in a province in South Africa where 1 in 10 of the children who died in 2017, died of starvation or malnutrition. This in a country that has a modest population size and is one of the wealthiest economies on the African continent and where around 30% of the food produced is discarded. While there certainly are technical questions that have to be addressed relating to service delivery – water, clinics, schools, roads, etc. – there is also the question of resource distribution, the effectiveness of the public sector and the bureaucracy, where many engineers will find employment, and the values that guide their approach to their work. (I use the word "values" here to mean the things that regulate behaviour in the absence of rules.)

Sustainability as a concept must therefore also include the sustainability of the social fabric and the ways in which we have constructed it. Increasing levels of inequality make the fabric unsustainable as the wealthy find that they have increase their spending on defence of their wealth and in "othering" groups who are perceived as more powerless, so that they can be excluded on the basis of their identity. Concepts like "over-population" must include a measure of the consumption patterns of the people in the area. Such a measure will then be related to the capacity for the area to sustainably tolerate the number of people with the given consumption patterns.

Which role does higher education play in creating a sustainable future?

Participation rates of young people in higher education has been increasing in many countries throughout the world. This is a positive development in two contexts: the more educated citizens are, the better they are able to hold the leaders of their social institutions to account, in the best interests of a properly functioning democracy. Secondly, the changing nature of work and value creation in the relations of production is increasingly demanding a better educated person who wishes to fully participate in the local and global economy. But this also creates the opportunity for higher education to become the primary seat where young people are educated (rather than merely trained) to become more positively contributing citizens. Rather than accepting itself as a microcosm of its society, with all the attendant social ills, the higher education institution has the opportunity to be a microcosm of what society could be like – more respectful in the inter-relations between academics, support staff, leadership and

students and a place where plurality of opinion is celebrated, not merely tolerated.

At the level of the academic discipline, higher education institutions have the opportunity to lead in the necessary task of bringing multi- and inter-disciplinary approaches to responding to the critical questions of the global human condition. Through the development of such an institutional academic culture, higher education institutions have the opportunity to educate their students in this acknowledgement of the inability for the critical human problems to be solved through single-discipline approaches.

How will cement and concrete technology change in the future, and what will we have to establish to cope with these changes?

The abundance of silica and calcium on the earth's surface means that Portland cement concrete is likely to stay with us for a long time. However, the demonstrated durability benefits of industrial waste materials like fly ash and granulated steel slag will have to be enhanced. The demand for very high strength concretes will have to decrease, as must the idea of plain Portland cement concretes, since the levels of CO2 emission are unsustainable. We will have to work hard to find alternative materials that provide similar or better long-term serviceability, without compromising structural performance requirements and the plain Portland cement concrete will have to be seen as the unusual exception. The current work on developing calcined clay as a cement replacement material, that is being undertaken in a number of countries around the world is particularly promising in this regard. I expect that we will continue to search for other such supplementary cementing materials since the argument against burning fossil fuels such as coal may well see a diminishing supply of materials like fly ash in the future.

This does mean that our students and future concrete technologists will have to be exposed to deeper levels of education in materials science and long-term materials behaviour. This is particularly necessary because the introduction of alternative cementitious materials generally makes for a material that is more demanding of the levels of sophistication in design and construction approaches. Stated differently, these new cementitious materials are much less forgiving of bad practice than in the case of Portland cement.

What will be more important in the future, interdisciplinarity or specialisation? Why?

I think it incorrect to frame the question as a conflict between interdiscisplinarity and specialisation. Our students will have to be more broadly educated without losing sight of the need for deep engagement in the narrow area of their chosen specialisations. As an example, we need civil engineers who are sensitive to the methods and approaches of (say) sociology or chemistry, without pretending to be sociologists or chemists. Our students must be better able to work with people in other areas of specialisation, recognising and being able to value their contribution to more respectful and more sustainable solutions. This also means that our students will have to learn to work in teams made of people from different disciplines and to provide useful information to people who are specialists but not in their own fields.

In terms of higher education, where are the deficits? What is still good, what is already good? Where do you think we will have to go?

My sense is that there should be far more cooperation, collaboration and cross-support between higher education "systems" across the globe. The current model is far too competitive and results in skewed distribution of intellectual talent across countries. I speak of systems, rather than institutions because it seems to me that the conversations have to first take place at national or systemic level and cannot simply rely on the well-meaning of individual institutions to address the problem.

We also have to work to strengthening the higher education systems in many countries. This includes the strength and competence of regulatory authorities to attend to matters like accreditation and quality, funding frameworks for undergraduate, postgraduate and research activities as well as broad defence of foundational principles like academic freedom and institutional autonomy.

At the discipline level, there is much work to be done to renew and modernise curriculum and pedagogical approaches in the development of our students. The international comparability of many of our academic programmes are seriously wanting in many countries and institutions and we would do well to respond positively to the challenge. Of course, this includes developing the teaching and learning competence of academics who have to deliver the programmes. This is not a small task and will require much time to properly address.

Ole Mejlhede Jensen

Technical University of Denmark
2800 Kgs. Lyngby
Denmark

Ole Mejlhede Jensen has BSc, MSc, PhD and DSc degrees in civil engineering. He is professor of construction materials in the Department of Civil Engineering at the Technical University of Denmark since 2003 and holds visiting and honorary professorships at several foreign institutions. He is member of the Danish as well as the Russian Academy of Technical Sciences, Fellow of RILEM and founder of its Educational Activities Committee. He has organized several international conferences, and organized and been involved in teaching at a large number of international doctoral courses. Ole Mejlhede Jensen's research interests are broadly construction materials, but mainly focuses on aspects of concrete and cement technology. This includes high-performance concrete, dimensional stability, hydration, curing and supplementary cementitious materials.

Where do you see the social challenges of the next decades related to the global environment?

The growth in the world's population equals the population in Iceland's greater capital area, every single day. It is a tremendous task to ensure food, housing and transport facilities for the present population and its continued growth. The burden this puts on the global environment is evident. The product of two factors govern the challenge: 1) The number of individuals and 2) the load from each individual.

Which changes are necessary to create a sustainable global future?

Obviously, there are many possibilities to reduce the load each individual puts on the global environment. For example, we can search for concretes with less energy requiring cements, we can eat grasshoppers and mealworms and we can go by bike. However, the load from each individual does has a lower limit, and for this reason population planning may be unavoidable. We should admire China as an active forerunner on this for almost 40 years.

Which professional groups play a major role in this?

This question has no simple answer; There is no profession to single out. If this were the case the challenge would be easier to tackle. Yes, more education should minimize the problem – no one dares to think otherwise – but paradoxically the societies and individuals with the highest education on the bottom line seem to be those with the least sustainable behavior. In the end the responsibility lies with the politicians, and behind them: all of us.

How will cement and concrete technology change in the future, and what will we have to establish to cope with these changes?

Concrete is an indispensable part of human life. It is an optimized, modern stone of which we build houses and infrastructure. Basically, no other material can substitute it. There will be a continued, massive need for it. The focus on sustainability will increase in the future, but notice that sustainability is a complex issue: On the bottom line it may be as valuable to reduce cracking of concrete as to decrease cement consumption. We need to improve every aspect.

How can we manage to get an ever increasing volume of information channeled?

We already have the information route: the world-wide-web, the modern version of the Gutenberg printing press, which in a surprising way has democratized knowledge. The challenge today and even more so in the future is not to get information, but to get rid of information – fake news, nonsense and voodoo science – noise drowning knowledge transfer. We strongly need to establish "noise filters".

In terms of higher education, where are the deficits? What is still good, what is already good? Where do you think we will have to go?

In general, higher education is constantly developing in a positive direction. On some issues, however, we can perhaps improve. The digital transformation wave is not free from its disadvantages – we seem to have lost some contact with each other and with our science, which is also important. I think it would be beneficial to have some "analogue transformation". In the learning process it is important to see, hear, taste, smell and touch.

Funso Falade

University of Lagos
and AEEA

Funso Falade is a Professor of Civil Engineering at University of Lagos. He joined the Department of Civil Engineering at the University of Ife in 1986 as an Assistant Lecturer. He commenced teaching as Lecturer 1 at the Department of Civil Engineering, University of Lagos in 1992 and was appointed Professor in 2001. He was Head of the Department of Civil and Environmental Engineering and is the current Dean of the Faculty of Engineering at the University of Lagos.

Among his numerous achievements are: best researcher award in Faculty of Engineering, 2005 and 2010. In 2010, he won the National Universities Commission (NUC) individual Award in Science and Technology (Research).

He is author of two books, and multiple research works and articles. He is a Fellow of the Nigerian Society of Engineers; Nigerian Institution of Structural Engineers; Nigerian Academy of Engineering, African Engineering Education Association and Nigerian Institute of Chartered Arbitrators.

Where do you see the social challenges of the next decades related to the global environment?

Technology includes physical equipment, infrastructure and installation including the knowledge, techniques and skills for their deployment and use.

The physical equipment has migrated from analog to digital and from massive size to microchips. Some of the challenges that we have e.g. climate change, deforestation etc. are a result of the use of technology by 'man' causing significant negative impact on the environment. In the developing and under-developed countries, this equipment is imported. The engineers in developing countries have not been able to use the available scientific ideas to develop appropriate technology for their environment. Therefore, they do not have control over the kind of technology they use. The major problem confronting both developing and under-developed countries is energy, that is in short supply. The importation and use of generators as energy source cause a lot of environmental pollution as a result of emission from the machines.

Potable water is also in short supply because of problem of purification. Citizenry drinks well water in an untreated state. If in the near future clean energy can be developed and made available to developing and under-developed nations, that will be a welcome development. Alternatively, it will be heartwarming if such research output can be a result of research collaboration between researchers from developed and developing nations. Such output will solve a lot of developmental challenges in developing and under-developed nations. Small-scale technologies for local water purification may be more effective as this will enable different households to domesticate the devices for ease of use. This will provide a low-cost source of drinking water.

Which changes are necessary to create a sustainable global future?

Sustainability is defined as meeting the needs of the present without compromising the ability of future generations to meet theirs. The three main factors of sustainability are: economic, environmental and social. The greatest threats to sustainable future are: population growth and urbanization, energy use and global warming, excessive waste generation and subsequent pollution of soil, air and water. These can affect the economic, environmental and social concerns of the citizenry.

What is the role of Architects and/or Engineers in this?

Engineers play an important role, in pursuit of a more sustainable future by providing an enabling environment. Engineers are charged with the responsibility of initiating, facilitating and implementing the technological development in the society. They work with other professionals, especially architects to plan and build projects that preserve natural resources, are cost efficient and support human and natural environment. For example, an architect may carry out a design relying majorly on the supply of illumination into the building from natural environment with a considerable reduction in the energy consumption. The design engineer on the other hand will design the building in a way that reduces energy consumption and water consumption. There will be less emphasis on the use of generators when there are power outages, thus, reducing the generation of an excessive use of fossil fuels that results in air pollution.

Generally, the activities of architect and engineers in providing housing, engineering infrastructure etc. required for the comfort of the citizenry affect the environment both positively and negatively as a result of deforestation. Global warming and climate change are direct result of deforestation. To have a sustainable future, it is very important that for any project to be designed and constructed, environmental impact assessment (EIA) of the project must be carried out by a qualified vendor. All impacts 'significant' must be given appropriate mitigation measures. This will ensure a sustainable future. This will include the analysis of impacts of how materials for projects are sourced and the processes used in getting the job done.

How will cement and concrete technology change in the future, and what will we have to establish to cope with these changes?

Concrete consists of cement, fine and coarse aggregate and mixing water. Cement is the binding medium in a concrete matrix. Among the components of concrete, cement is the most expensive material while coarse aggregate gives concrete volume and stability. Overtime, efforts have been made to replace partially or wholly each of these components with innovative construction materials that are cheaper with a view to producing affordable housing to the citizenry. The research on replacement of cement with additives e.g. sawdust ash, cassava peel ash, rice husk ash etc. has been on-going for some time now. Sharp sand has been partially replaced with laterite, granite dust etc. while granite chips have been replaced with materials like periwinkle shells, palm kernel shells etc. with a view to producing lightweight concrete to reduce the effect of dead load on the designed buildings. The use of admixtures as partial replacement of water content in concrete matrix has been adopted extensively in form of accelerating admixtures that fasten the setting and hardening process. The accelerating admixtures produce increased early strength concrete, while retarders slow down the strength gain over a longer period. Some admixtures are used to increase the workability of concrete at a given water/cement ratio. The use of admixture and additives reduces the heat emission during concrete production.

In future, the development of more innovative construction materials will continue to be invoked. These materials are cheaper and aim at converting waste to useful products, thus, protecting the environment.

What will be more important in the future, interdisciplinarity or specialisation? Why?

Interdisciplinarity can be in terms of established programs or research. Interdisciplinary program combines two or more academic disciplines. The combination can be intra faculty, for example, Electromechanical Engineering, Systems Engineering, Mechatronic Engineering etc. All these programs are within engineering family. The combination can be inter-faculty, for example, Biomedical Engineering, Agricultural Engineering, Food Engineering, Pharmaceutical Engineering, Computational Science and Engineering, Engineering and Technology Innovation Management etc. All these disciplines are a combination of courses from two or more faculties. Interdisciplinarity provides a platform for the formation of interdisciplinary academic programs that provides enabling environment for shared ideas and collaboration in solving societal or industry based problems. The concept provides multi-dimensional approaches to solving

problems. The research focus is also tailored towards this approach. The intra and inter faculty programs provide knowledge sharing within and outside the faculties across disciplines.

Specialization is discipline specific approach to knowledge acquisition. It is streamlined to the specific area of course of study. Disciplines provide the intellectual for scholars and researchers to inquire deep and have an in depth knowledge of the subject matter.

Examples of such specialization are, Chemical Engineering, Civil Engineering, Electrical Engineering, Mechanical Engineering etc. It is worth of note that within each field of study there are also specializations for example, Civil Engineering has four areas of specialization, Structures, Geotechnics, Water and Environmental Studies and Highway Engineering.

I believe that both interdisciplinarity and specialization will exist both now and in the future because of the critical issues both group will be looking at.

In terms of higher education, where are the deficits? What is still good, what is already good? Where do you think we will have to go?

In Africa, the deficits are: (I) Poor funding (II) Inadequate infrastructure (III) Inadequate teaching facilities both quantitatively and qualitatively at the training institutions (IV) Inadequate and obsolete equipment (V) Defective curriculum. (VI) Non-availability of adequate human capacity

(VII) Adoption of traditional pedagogy (VIII) Brain drain (IX) Poor staff training and retention profile (x) Weak university/industry partnership (xi) Poor industrial attachment program (xii) Non-availability of local codes and monitoring standards for the training of engineers (xiii) Inadequate ICT environment (xiv) Weak linkages with international institution,

What is still good is that we have some people who are determined to sustain the system not minding all the challenges. The curricula of engineering disciplines are being worked upon to make the graduates more relevant to industry needs.

We need to be steadfast and consistently sensitize the government to fund education. Many of the mentioned problems are direct manifestation of poor funding.

The institution of learning should have gainful engagement with the industry and partner with other institutions within and outside the country to promote internationalization of their curricula.

Robert Tchitnga

Université de Dschang, Cameroon
Institute of Surface Chemistry and Catalysis, Germany

Robert Tchitnga received a B.Sc. of Engineering in industrial maintenance at ENSIAAC of Ngaoundéré, and a Teacher Diploma in physics and chemistry at ENS Yaoundé both in Cameroon. He holds a Ph.D. from the University of Münster in didactics of technology and physics and he did his Habilitation in applied physics from the University of Dschang.

He joined the University of Dschang in 2000. Under the DAAD and DFG fellowships he was visiting lecturer at the FU-Berlin and guest scientist at the University of Ulm, where he is working at present. His main research interests include nonlinear dynamics, electronic circuits, control of complex systems, laser spectroscopy, and didactics of physics and of technology.

He is founding member and active president of the Cameroun Physical Society and Head of the Section Physics for Development, member of the African Network for Solar Energy, Regular Associate at ICTP in Trieste, member of the IOP, Head of the research group on Experimental and Applied Physics for Sustainable Development in Dschang and president of the NGO Africa Moringa Hub based in Ghana.

Where do you see the technological challenges of the next decades related to the global environment?

With the growing world population and the need for better living conditions for the humanity, the technological challenges related to the global environment will be seen in terms of finding answers to the general problems of housing and habitat, various suppliy chains (food, clean water, energy, etc...), environmental issues (Global warming, CO2 reduction, non-biodegradable waste management, etc...), mobility and transportation as well as information and telecommunication.

The other side of the challenge will be how to solve the above problems in the context of the digital revolution face to which the next decades stands, coping with the virtual reality, artificial intelligence etc.

Which changes are necessary to create a sustainable global future?

In my opinion, the necessary changes to create a sustainable global future will concern education. There is need to bring changes in curricula to adapt them to the context of new technologies influenced by artificial intelligence on the one hand, but on the other hand also to create more awareness of best practice to protect the resources:

- change in consumption habits
- respect and protection of the environment
- reduction of the wasting of energy
- production of less pollutants, etc.

Why is it so important that lecturers and professors focus on sustainability?

We are living on a planet with limited resources. Therefore, it is the duty of lecturers and professors among other educators to permanently recall it and implement any means that can reduce the wasting of these resources.

The present global warming problem or that of plastic waste reinforces the role of lecturers and professors who have to raise awareness that these are partly or completely manmade problems and can be controlled if the awareness is set.

How will architecture and construction technology change in the future, and what will be the implications?

With the world population growth and the development of balloon centrums, there is an increasing demand for housing. These requirements in higher number of habitats is going to invite architecture and construction technology to focus on new materials that are light, more resistant, based generally on regenerative materials, energy saving, etc. to cope with the resources' management mentioned before.

What will be more important, global solutions or local solutions?

In the future, global solution will be the predominant way or may be the only one. Nowadays, it is almost impossible to do anything without using the internet which is a good example for global communication. The block chain technology is another global solution that will soon be inevitable. Apart from those examples which are purely technological, subsequent effects of technology are also global; the global warming caused to a great extent by developed countries spares no part of the globe. Thus global solution will be the key solution in future.

In terms of higher education, where are the deficits? What is still good, what is already good? Where do you think we will have to go?

Higher education curricula are results of long time hard work from large teams. The merit of its authors and actors should first be commended. Nevertheless, curricula are or have to be submitted to revisions after laps of time thus to be adapted to generational, socio-historical and technological changes. In many cases, we hear claims that they are not adapted to the needs of the populations where they are implemented; this concerns most of the African countries because of their history.

Some of the deficits one can point out in higher education covers the following aspects: too theoretical content and therefore less practical. Not enough problem oriented and sometimes too many subjects that will never be used after the university time. The high education in term of number of semesters to cover is reasonable.

To answer the question on where we will have to go, we must sometimes scoop out from the historical sources to implement useful concepts. In Africa before the so-called modern school, education was based on the principle of "school of life" which was adapted to the need of the community. We will move in that direction while defining changes in curricula, so that the contents should regularly be readjusted prior to the needs of the society where this is implemented.

Points of view

Global and local challenges and potentials in construction

" In the developing countries, people need to resort themselves from the present situation of socio-economic stress and instability. There is also evidence that the problems have become greater, specially in the Arabic world in extent and severity in recent years of successive revolutions.
Chadlia Ounissi, Faculty of Sciences of Gabes, Tunisia, PhD student

Climate change is caused by mans' industrialization with construction industries having its own fair share of the blame. However, the solution lies in the adoption and continual patronage of traditional and unconventional building materials to foster the development of a green environment.
Banjo Ayobami Akinyemi, Landmark University Omuaran, Nigeria, PhD, lecturer

" Civil engineering is the mother of all engineering, but it is based mainly on experimentation and trial and error. Development of new techniques and materials in construction industry are very slow compared to computer science and electronics.
Said Kenai, University of Blida 1, Algeria, Professor

" African researchers in the field of construction have many challenges in disseminating their work acceptable to first world researchers. These challenges are made worse when they use locally available materials in an innovative way to improve African construction industry.
Rose Njeri Mbugua, Walter Sisulu University, South Africa, Lecturer

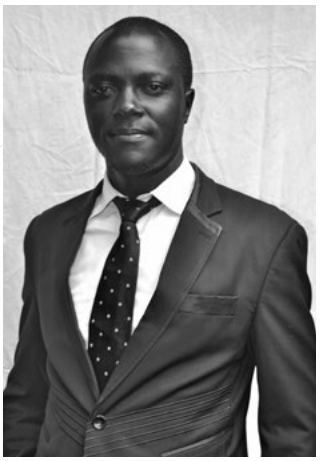
The construction industry must be able to develop home grown skills in countries where they work to be able to maintain the built infrastructure after completion of the projects. This will ensure the durability of these structures during their service life else the objectives the development of local skills will be defeated.
Akindehinde Ayotunde Akindahunsi, Obafemi Awolowo University, Nigeria, PhD lecturer

" Not everything has to last forever – Solid builidings are commonly planned to last for about 100 years, which is not always the necessity. The focus should be kept on the actual relation between input of resources, money, time and the real benefit. Possibly there is a more ecological solution for the matter.
Jule Anniser, Hochschule Düsseldorf, Germany, student

Paramount amongst a number of challenges the construction industry faces are safety issues, low productivity and the incapacity to adopt new technological settings.
Solomon Adomako, LAS-Roads Laboratory, Bologna, Italy

" There is the need to improve skill transfer from the multinational construction companies (through the enforcement and monitoring of local content legislation) to the indigenous companies to strength our construction sector viability.
Olukayode Alao, SusCrete Infrastructure Consulting/Impresa Pizzarotti SpA, Italy

" In many ways concrete can help achieving the UN sustainable development goals. The fast-growing population needs infrastructure and housing that concrete can easily provide. However, today we observe an increase of the production of bad quality concrete which is adversely affecting poor populations. I believe that concrete science has the capacity to reduce poverty if concrete researchers and policy makers would better integrate the local context and prevent mainstream concrete solutions.
Elise Berodier, EPFL, Switzerland, researcher and lecturer



New constructions in tropical climates of Africa should auto address the issues of thermal comfort and the environmental impact. In this respect, it should be built based on the local instead of the European standards for constructions (which are based on moderate climates).
Cyrille Vincelas Fohagui Fodoup, University of Dschang, Cameroon, PhD student

Potentials for sustainable construction based on education

" Sustainability is a topic which is not well understood and addressed in the construction industry worldwide. This is attributed to less emphasis by the construction entities on the environmental impact than on the economic and social impacts. The best way to address this is by educating the young generation who are emerging as future influential people by installing emotive ideas expressing the importance of utilizing resources while considering their future availability.
Alice Titus Bakera, University of Cape Town, South Africa and University of Dar es Salaam, Tanzania, PhD student

The construction and the development of a country call for sustainability in higher education and healthcare. So, the countries have to take the responsibility to enhance the quality of the learning process and to exploit hidden potentials. The most important is to invest in these two aims.
Chadlia Ounissi, Faculty of Sciences of Gabes, Tunisia, PhD student

" The weak economies of most developing countries and developmental challenges, issue of climate change aggravates the poverty level and amplifies problems these countries face. There is therefore the need to find local materials that can mitigate the problems of climate change and at the same time improve the economies of the developing countries. The need to source for local materials will be based on research, education and training in the dissemination of information on how these materials can be used to benefit the countries.
Akindehinde Ayotunde Akindahunsi, Obafemi Awolowo University, Nigeria, PhD lecturer

Education is the base for future development. It basically is sustainability itself. Concerning construction we should keep in mind: any building is worthless if it cannot be maintained and repaired by its users. This claims involvement and education of the users during construction. Sustainable building also demands for knowledge about alternative building materials, recycling and neglected techniques – by exchanging knowledge and implementing practical teaching, sustainable construction becomes achievable.
Jule Anniser, Hochschule Düsseldorf, Germany, student

" The decimation of forests contributes to destructive climate variability and global warming. There is need to foster research into the development of environmentally-friendly construction materials and building technologies in line with long-standing practices in the more developed Western economies.
Loudon Luka, Mzuzu University, Malawi, Head of Department

As the construction industry has a large share of the global environmental impacts, education on sustainable construction is crucial for the present and future generations' wellbeing. All the advancements in science and how to reduce environmental impacts are pointless if the job-site engineers have no knowledge of it and therefore end up not using the materials or methods that have been developed for better environment.
Yazmin Lisbeth Mack Vergara, Universidade de São Paulo, Brazil, PhD student

" Sustainable construction as highly prioritized by United Nations and EU established directives certainly needs a practical and theoretical outlook in educational setting. This concept, as of great importance must be pushed more into educational, research and training institutes across the globe to keep all abreast of the enormous benefits, facilitating a sense of eagerness to either on individual basis or collectively contribute to meeting the needs or regulations put on board.
Solomon Adomako, LAS-Roads Laboratory, Bologna, Italy

"The future of concrete is cement and reinforcement-free." This (too strong) statement stresses the too frequent use of excessive cement dosages and unnecessary reinforcement to compensate for poor design and bad formulation. A good understanding of the basic rules of strength in cohesive-frictional composites is the basis for sustainable construction with many geo-sourced construction materials.
Prof. Henri van Damme, ESPCI/IFSTTAR, France, professor emeritus and former scientific director

" The emerging trend in the establishment of field set-up research centers particularly dealing with development of construction materials will provide opportunities for appropriate technology transfer and it's up scaling. Inception and strengthened industrial linkages between academia and industry will promote multidisciplinary solutions to the challenges in construction industry.
Joseph Marangu Mwiti, Meru University, Kenya, researcher

Future skills in civil engineering, architecture and materials

" The requirements of civil engineers in the 21st century are continuously becoming more and more skewed viz-a-viz the skilling platforms. The expectation of practical civil engineering, architecture and construction materials is increasingly becoming more specialised and job or environment specific. The generalised 20th century mass skilling now calls for more specialised job demanding essentials in the 21st Century.
Muzafalu Kayondo, University of Stellenbosch, South Africa, PhD

The new generation of engineers and architects from African universities must be indoctrinated with the Next Production Revolution (NPR). We need to move past lip-service and begin to design the teaching models today through partnership with private and start-up companies.
Olukayode Alao, SusCrete Infrastructure Consulting/Impresa Pizzarotti SpA, Italy

" Soft matter science is essential knowledge for good hard materials engineering. "Soft" matter is the umbrella under which granular media (dry sand), colloids, surfactants, polymers, liquid crystals, biomaterials, porous and spongy materials are gathered. In short, all forms of matter which do not fit readily into our academic boxes. Yet, soft matter is at the heart of major developments in concrete technology including superplasticizers, self-placing concrete or 3D printing, not mentioning the basics of adhesion, rheology, and the proper use.
Prof. Henri van Damme, ESPCI/IFSTTAR, France, professor emeritus and former scientific director

While the engineering dimension of concrete draws plenty of academic and industrial interest, its social and cultural dimensions are not subject to the same level of research attention. Future key players in construction would need to be educated on local context with transdisciplinary approach to design appropriate sustainable solutions.
Elise Berodier, EPFL, Switzerland, researcher and lecturer

" Working as an expert witness in the many construction disputes regarding concrete, is alarming when the knowledge of the average engineer is tested in specifying constituent materials to suit the needs of a structure, in the environment in which it is to be built.
Bruce Raath, Johannesburg, South Africa, consultant

" The use of some local building materials for walls can improve the thermal performances of buildings. A suitable combination between the type of building material, insulation material and the energy source results in significant energy savings.
Cyrille Vincelas FOHAGUI FODOUP, University of Dschang, Cameroon, PhD student

It seems to me that interdisciplinarity is not implemented sufficiently at universities. A more direct approach might be required. For example, universities could have courses, where architects, civil engineers, and material scientists work together on projects and discuss across the disciplines about different materials, structures and uses as well as their particular pros and cons from various angles.
Sarah Leinitz, Bundesanstalt für Materialforschung und -prüfung (BAM), Germany, PhD student

" The need for infrastructure and housing is large in developing countries and there is a need to develop new materials and new skills for engineers and architects for sustainable construction. New materials that imitate natural materials and natural renewable materials should be developed. Architects and engineers should use advanced tools for testing and prediction of materials properties and as management tolls to cut cost and construction time.
Said Kenai, University of Blida 1, Algeria, professor

Currently, there is a very capitalistic drift towards "higher – faster – cheaper" in building projects, destroying our earth as well as our building history. However, the combination of civil engineering and architecture should result in the transfer of human being's different cultures and souls into our built environment. Engineering structures and building materials support the arts in architecture. Prospectively, we need to free ourselves from the current building competitions and requirements to work together aside the norms.
Mareike Thiedeitz, TU München, Germany, PhD student

" We need people who, besides getting the job done, are aware of the impact of their construction on people and overall environment. Therefore, in the future we will need more multidisciplinary partnerships and inter-industry collaborations. As individuals it is not advantageous for us to be a 'jack of all trades' but be a 'master of none'. In my humble opinion it is better to be a master in a team of different trade masters.
Nonkululeko Radebe, Karlsruhe Institute of Technology, Germany, PhD candidate

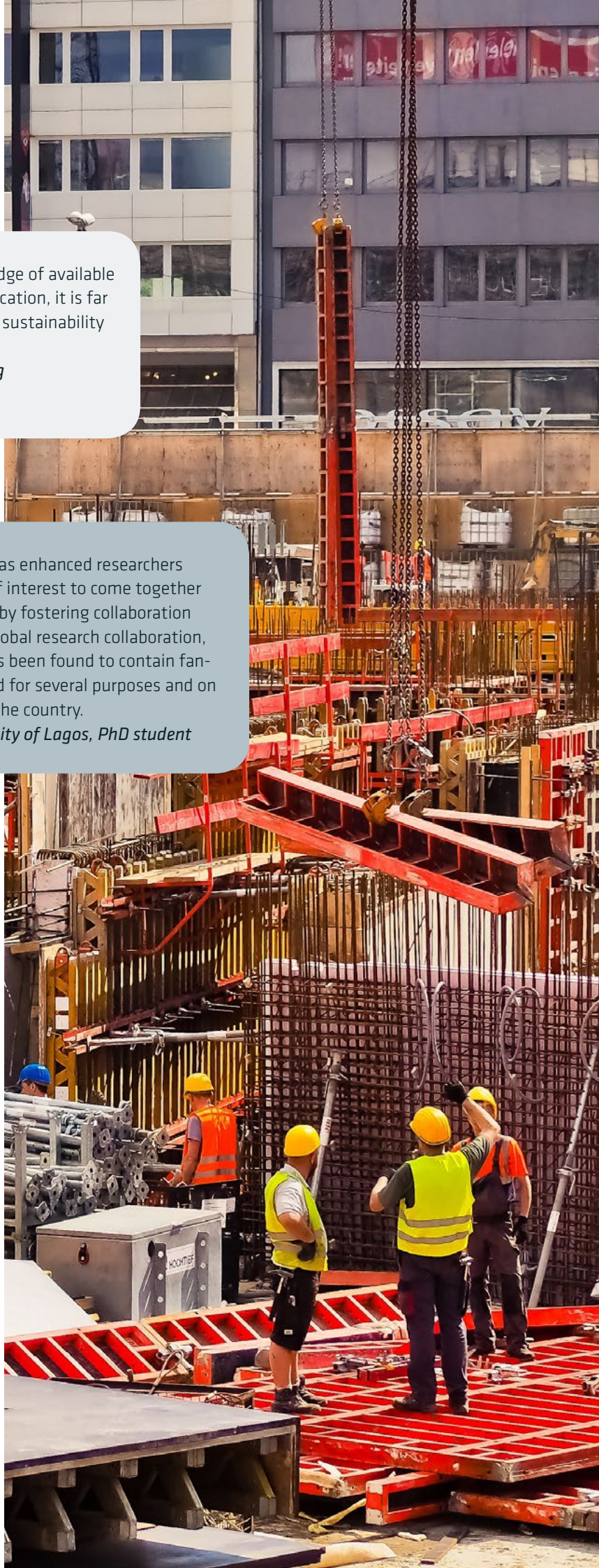
Global research and education requirements

Education plays a key role in fostering sustainability in the construction industry. In Africa, rapid urbanisation threatens environmental sustainability both directly and indirectly.
Loudon Luka, Mzuzu University, Malawi, Head of Department

The issue with global research is that to some degree it will start to neglect 'individual problems'. For example, studying cement hydration as a function of Swedish temperatures, will be of no use to researchers in Swaziland or Ghana. The problems are not the same therefore the solutions will not be same either. Gathering skills at a global level is vital but fundamentals are country, economy, climate and people specific. Therefore, global research cannot overshadow basic community research and education needed to answer specialized questions.
Nonkululeko Radebe, Karlsruhe Institute of Technology, Germany, PhD candidate

" Skills in the field of civil engineering and architecture are in very short supply. Skills in construction materials however, is almost non-existent. Very few university curricula have an adequate course in construction materials, in particular, concrete, which is a variable material with many properties that need to be exploited to the benefit of a structure.
Bruce Raath, Johannesburg, South Africa, consultant

Global research in recent times has enhanced researchers of different background and areas of interest to come together in solving global problems and thereby fostering collaboration amongst reputable scholars. With global research collaboration, some agricultural waste in Africa has been found to contain fantastic properties which could be used for several purposes and on the long run to increase the GDP of the country.
Balogun Ibrahim Oladipupo, University of Lagos, PhD student



" It is definitely important to have global knowledge of available raw materials, but regarding development and education, it is far more important to improve research related to the sustainability of the raw materials in one's own region.
Sarah Leinitz, Bundesanstalt für Materialforschung und -prüfung (BAM), Germany, PhD student

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Balogun Ibrahim Oladipupo, University of Lagos, PhD student

African research and education requirements

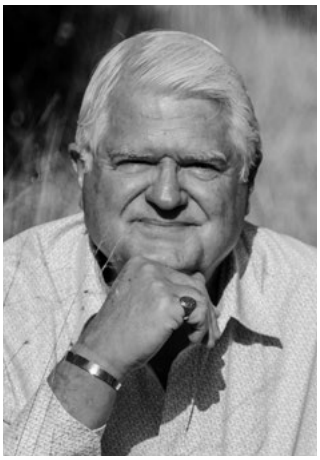
"Research and education sector in Africa requires support from their governments to invest in and recognizing the contribution of individuals to the research and education. Moreover, the sector is challenged with the lack of excellent communication skills and confidence of individuals to present their knowledge and ideas. This is influenced by two factors, language barrier and poor teaching curriculums from the academic institutes. Enhancing this area will assist African research and education development.
Alice Titus Bakera, University of Cape Town, South Africa and University of Dar es Salaam, Tanzania, PhD student

Perhaps more important than the rapid development of physical infrastructure in Africa is the need to invest in industrial research. It is imperative that Africa makes the connection between academic and industrial research, especially in science and engineering. To achieve this, the education style and requirements need to be paced forward to highlight the currently existing gaps – in academia and industry!
Muzafalu Kayondo, University of Stellenbosch, South Africa, PhD

"We need to Innovate, Enterprise, Commercialize or Evaporate.
Vusumuzi Malele, Tshwane University of Technology, South Africa, PhD candidate

Research in construction materials of African origin hardly attracts any funding from developed countries, unless there is collaboration between itself and a developed first world country. At the same time, funding entities in Africa are not interested in supporting research on these materials. Since most of these materials are not known and of little or no interest to the developed world, publication of such research work is hardly accepted by top notch journals. This ends up discouraging most researchers who could use their results as a tool to improve education/research standards.
Rose Njeri Mbugua, Walter Sisulu University, South Africa, lecturer

"Research institutions and construction industry regulators must work together in the dissemination of research findings and innovations into eco-friendly building technologies to all players in the construction sector. On the other hand, the development and implementation of curricula by tertiary education institutions on environmental and ecological sustainability in the construction and engineering sectors is an important step in the provision of appropriate training to students and industry players alike.
Loudon Luka, Mzuzu University, Malawi, Head of Department



One of the most difficult phases in the preparation of a training course is to decide what topics are necessary to teach engineers, to guide them through the huge diversity of the profession. The only source is the experience of the writer, and here involvement in legal disputes regarding materials is invaluable, as anecdotal background and illustration of points being made.
Bruce Raath, Johannesburg, South Africa, consultant

"I encourage African concrete research to create its own pathway towards sustainable construction. Making concrete in Africa involves different technical, social and cultural issues than in the Global North.
Elise Berodier, EPFL, Switzerland, researcher and lecturer

Despite the great efforts being made by each African country and well wishers to improve the quality of education and make it available to all, there is still lack of basic resources and services among many Africans. Young reserchers are faced with the challange of not having someone, willing to publish their work. Access to critical educational/scientific resources needs to be addressed, as well as mobilisation of resources for capacity building among staff in learning institutions.
Tabitha Maina, Hochschule Rhein-Waal, Germany, student

Contemporary teaching methods

" There needs to be a paradigm shift in the teaching methods: from traditional exam-oriented methods to one method that is focused on practical applications. Additionally, the school curricula need to be regularly revised to be in-line with the technological advancements.
Joyce Wanjeri Njoroge, University of Ulm, Germany, MSc. student

" Essentially when students leave an institution of learning at any level, be it high school or university as a bachelor or doctoral student, they should be able to be a valuable contributor in the space that they enter. They can only be a contributor if they have acquired a unique set of skills that makes them effectively communicate to everyone. This also means that they need innovative and creative ways to communicate. It's about team work. A more direct method is through more skill based (practical) schools that teach people how to weld, plumb, or build using new technologies all the while working on interpersonal skills mentioned above. Learning theory without exposure is like a bicycle with flat tires, in theory one could ride it, but the effort is futile because you won't get anywhere.
Nonkululeko Radebe, Karlsruhe Institute of Technology, Germany, PhD candidate

We need to teach what matters now in a practical format with the glance of the future implications.
Vusumuzi Malele, Tshwane University of Technology, South Africa, PhD candidate

" Education in Africa is hampered by the lack of one critical skill i.e. the ability of students to think through and solve a problem. The problem seems to originate in early education where learning by rote is still prevalent and prepares students for careers in law or medicine, where unfortunately, the best students are attracted. Examination questions, where facts are simply regurgitated, are answered better than questions where the answer is obscure and requires thinking around the problem.
Bruce Raath, Johannesburg, South Africa, consultant

" Implementation of contemporary teaching methods is challenged by the still older approaches. Teachers themselves need to be skilled in contemporary teaching methods in order to implement the necessary pivots to bring back the excitement in learning. Minus that, we are still on a tangent to low education motivation, low innovation, unemployment, and the associated challenges.
Muzafalu Kayondo, University of Stellenbosch, South Africa, PhD

Contemporary teaching methods allow students to effectively solve problems by optimising teaching/learning and encouraging behaviour management. It is built around strategies like: quality feedback, effective questioning, use of practical assessment tools (knowledge checks, peer and self-assessment, work-related scenarios and team challenges), reflective learning, discovery learning approaches, and technology enhanced learning (TEL) to mention but a few.
Chinedu Francis Ekechukwu, Wiltshire College & University Centre, UK, lecturer

Gender issues in STEM education

" Most policies in place have failed to support women after graduating in STEM so as to translate STEM education to STEM careers. Special mentorship programmes should be provided during training to prepare women in what is perceived as hostile working environment. To achieve this, synergy from the society, educators, families as well as governments is required to change any negative perceptions women may have about careers in STEM.
Rose Njeri Mbugua, Walter Sisulu University, South Africa, lecturer

With proper mentorship by women in STEM careers; more funding and follow-ups in their studies can be achieved. Perhaps it could be possible to see more girls take the STEM-career path to graduation. Furthermore, if Shuri (Marvel's Black Panther) is anything to go by, then a woman's place is definitely the Science Lab NOT the kitchen!
Joyce Wanjeri Njoroge, University of Ulm, Germany, MSc. Communications Technology student

My softness, emotions and caution does not stop me from being an effective engineer and leader, it enhances it. Hand me a pen and paper, I will show you how it is done, hormones and all!! I can handle body shocking, traumatizing deep stabbing menstrual pains on a monthly basis with a smile on my face in a professional environment, of course I can handle an engineering problem. Bring it! Let's work together, I have something to contribute as much as you do, gender aside, let's respectfully treat each other like fully functioning human beings.
Dikeledi Maboea, University of the Witwatersrand, South Africa, MSc student

" I think gender equality is more a topic for the whole society, especially in education of children already. It is necessary to teach them, that everyone can study, what he/she wants independent of gender. It is rather a difficult question, how to support women in STEM education without in parallel giving them the feeling that they wouldn't make it without support? For me these special offers can be misunderstood.
Sarah Leinitz, Bundesanstalt für Materialforschung und -prüfung (BAM), Germany, PhD student

"There is a misconception that STEM education is hard and is only men's job. However, some African countries like Algeria with free education and relatively strong economy where jobs are available in industry, the gender issue is not on the agenda any more. Free education and prospect for good jobs could give women economic freedom and help bringing more women to STEM in other countries. If successful women are put on the spotlight, they will be looked on as models and further women will step in.
Said Kenai, University of Blida1, Algeria, professor

"I believe that gender issues in education in general needs to take in account the culture and the history of the society where it is addressed. Moreover, an important point to discuss is the impact of the applied strategies on the economy and on the societal transformation. It will be quite interesting to investigate, if gender equality on the one side may possibly cause other societal challenges that some societies face today on the other side.
Inès Leana Tchetgnia Ngassam, Bundesanstalt für Materialforschung und -prüfung (BAM), Germany, postdoc researcher

"There is little difference between men and women engineers.
Bruce Raath, Consultant, Johannesburg, South Africa

Language barriers in African and international research and education

" Most of the highly regarded and revered international peer review journals use English language as the medium of communication. However, this could be a great source of concern to authors who are neither native speakers or have no knowledge about it, hence in the process of converting their research output to the accepted language during submission through third parties, some important details could be lost.
AKINYEMI Banjo Ayobami, Landmark University Omuaran, Nigeria, PhD lecturer

The language is an unavoidable element when we talk about research, economy or education in a country. Indeed, the link between these fields is only possible through networking and collaboration with other countries, which implies the need to be able to communicate among the partners. The reality is that the low inter-African collaboration in terms of research is deeply linked to lack of common language among the countries, since this not pursued as a key point in educational curricula.
Inès Leana Tchetgnia Ngassam, Bundesanstalt für Materialforschung und -prüfung (BAM), Germany, postdoc researcher

" When we hold a conversation about language barriers, I want to focus here on North Africa, where many residents speak French rather than English, which is the language of research. This matching problem with the developed world is adding up to the problem of research itself.
Chadlia Ounissi, Faculty of Sciences of Gabes, Tunisia, PhD student

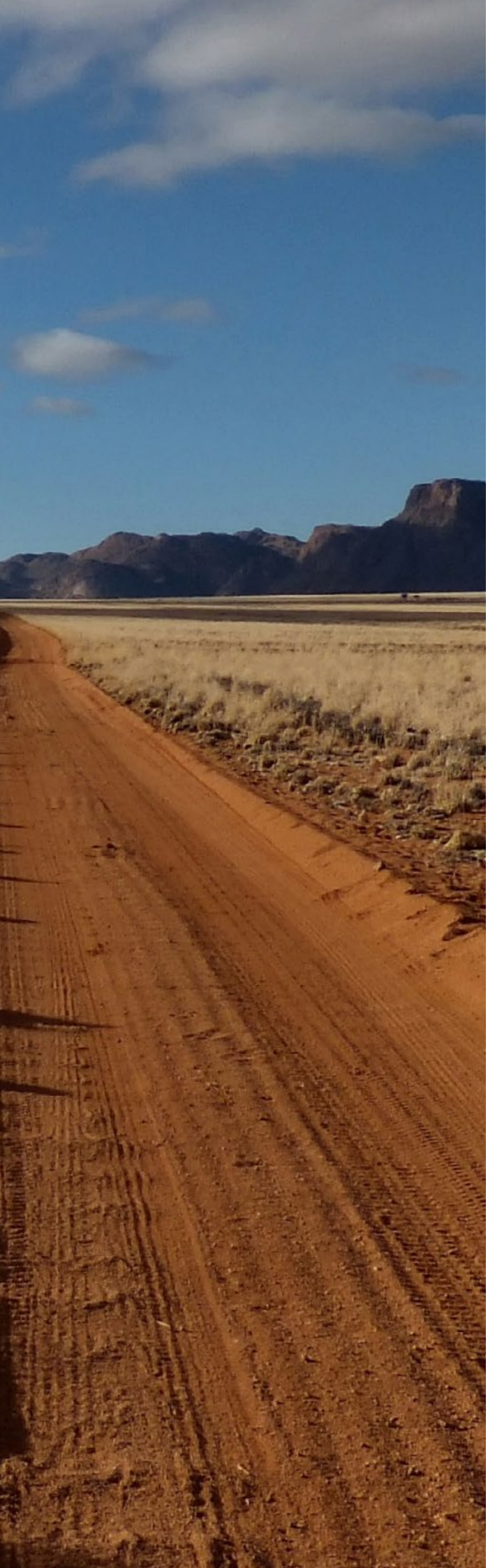
Language barriers in research and education kill the confidence and communication skills of individuals whose backgrounds are not founded in a particular language speaking. Various people who have great ideas are silenced by this language. Therefore, education and research institutes should focus on developing an individual's communication skills or providing alternative strategies such as graphic presentations which can help in presenting their ideas when the language barrier is encountered. Moreover, the education media of communication should be changed by either focusing on using and enhancing their national language or transfer it entirely to comply with international media of communication, i.e. English.
Alice Titus Bakera, University of Cape Town, South Africa and University of Dar es Salaam, Tanzania, PhD student

Recent surge in use of mobile devices in Africa has made possible to introduce mobile app technology to tackle issues of language barriers as well as geographic integration of research and education.
Prince Charles Osei, Alster Limited, Ghana, entrepreneur

The high impact research should impact positively to the contemporary society challenges not merely on the consideration that it is published in high impact journals. Enhanced collaboration in research will definitely unlock immense potentials for sustainable construction. Increased and diversified access to research findings that borders on construction activities by incorporation of various social media links besides the convectional dissemination media such as journals that are mostly restricted to academia will promote sustainable construction based on education.
Joseph Marangu Mwiti, Meru University, Kenya, researcher

"Communication of research is fundamental. The domain of common languages is therefore a critical skill to achieve this communication. In my experience, the knowledge of Spanish, English and Portuguese has allowed me to do research and participate in important projects and events. We should encourage language learning to be able to communicate with other groups and cultures, share our ideas and learn from the rest of the world.
Yazmin Lisbeth Mack Vergara, Universidade de São Paulo, Brazil, PhD student

Some French colonized countries in North, Central and West Africa are still relying on French language in their teaching and research. These countries are lacking high standard research and their universities' world ranking is low. The sole use of French language will increase the gap. There is an urgent need for shifting to English language as a second language. This will prosper education and research and the country will have a broader view of the world. Will they take this step or are there other barriers?
Said Kenai, University of Blida 1, Algeria, professor



Elaborate points of view

Henri van Damme retired professor and scientific director from France on vernacular architecture as a hidden deposit of high-tech knowledge and a wonderful source of inspiration for industrial construction materials and technologies.

" Africa (North, West, East, Central, South) is a treasure of vernacular skills and constructive cultures, either with geo-sourced (raw earth) or with bio-sourced (bamboo, straw, reed,...) materials providing often remarkable comfort in harsh conditions. From a cultural point of view, it would be a shame to wipe this rich heritage out with global uncultured practice. From a technical point of view, vernacular techniques may also be a source of inspiration for innovative industrial materials.

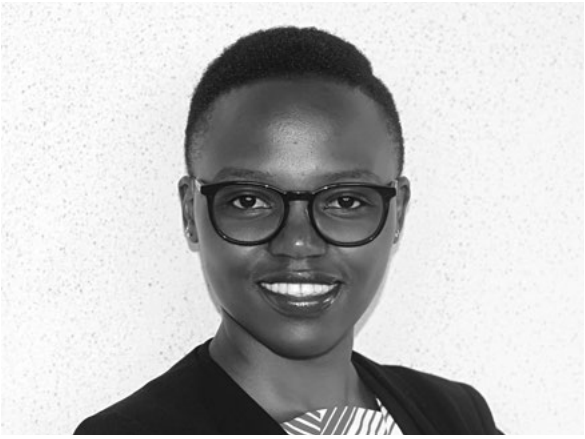
A simple example is the thermo-regulating behaviour of raw earth which, contrary to modern materials used in passive houses, is not based on thermal insulation (low thermal conductivity) but on active thermal control thanks to the coupling of a high thermal mass with the high latent heat of the liquid-vapor transition of water in the pore space of the material. This requires a totally open porosity and a well-defined pore size distribution. A concrete with similar properties would be a game-changing material will help cultivate and legitimize the practical skills needed by construction workers.

Nonkululeko Winnie Radebe, who was born in South Africa and currently does her PhD in Germany on various severe challenges in the global and Africa construction business.

" Quality as a local challenge - It is no secret that Africa has the most publicized corruption scandals. In South Africa, this manifests itself in building tenders/ bids being awarded to companies with no background in construction or companies that have strong ties to government officials. Often, they use cheap materials or the incorrect proportions to build roads and schools. This results in large potholes forming, speed bumps being washed away by rain and school building collapsing after a few months or years. The lack of proper maintenance also augments the problem.

Sustainability and 'future-focused' building material as global challenge and potential – construction should be a 'forever' investment and therefore it must be done in such a way that it does not disturb or dismantle and inhabitant's well-being. Roads cannot be built whilst neglecting river flow directions which can are perhaps a source of water or food (fish) for many. Building plans need to be really well thought through and the locals need to be better consulted and perhaps involved through teaching and job creation. Furthermore, there needs to be a change in the mindset of what a good, solid building should be made of. There should be a conscious move towards incorporating 'green' materials or waste materials into building material to ensure a lower carbon footprint.

Skilled labour for increases technological needs as a local and perhaps global-as technology evolves there is less and less of a need for manual skilled labourers and more technologically savvy skilled labourers. The world need to invest in more technical schools that will help cultivate and legitimize the practical skills needed by construction workers.



Alice Titus Bakera from Tanzania, who works on her PhD in South Africa, on the role of governments in education and lack of confidence as an obstacle for self-sustained education.

" Research and education is a challenging sector for most African countries who are still struggling to meet an acceptable international standard. As a sector which requires important resources, it has suffered from the lack of serious and ambitious development plans since the 1960s. Most African countries are still staggered towards development. Peoples in the continent are still suffering from poverty and ignorance.

However, few are given an opportunity to eradicate themselves from ignorance by being given a chance to widen and advance their knowledge in or outside their countries. Some never return to their countries nor deliver their expertise to assist their country in its walk toward social, economic and educational development. Moreover, few of them are willing to contribute efficiently to their countries development by accepting to deliver their knowledge enthusiastically and energetically. The question is why do their inputs never being recognised or manifested in their societies? The reasons for this are what expressed here. For these reasons, we can thus identify the African research and education requirements, and find the points to strengthen, and possibly to awaken our sleeping continent.

The first reason is the lack of general support from their governments. Many African governments put less emphasis on the research and education and thus less or never invest in these areas. They mainly prefer financing sectors that are mostly biased towards a short-term and rapidly seen achievements. They most often ignore that the foundation of their development is leaning on research innovation which can only be achieved via the excellent quality of the education system. Therefore, more and consistent investments in both education and research through the provision of funds are required to support and encouraged African researchers in solving the development challenges the continent is facing. This will also allow them to strengthen their capability by participating in different international conferences to broaden their knowledge and explore solutions to worldwide challenges. Moreover, the governments never recognise the advancements and contributions done by their people by at least advancing them from small scale to large scale application. It, therefore, shows that government involvement is a significant requirement for the research and education development in Africa.

Another challenge is more based on the lack of confidence and poor communication skills of individuals which associated with the quality of African education system. It is true that most institutes adopt the teaching curriculums from the developed countries which are not bad but do not satisfy African requirements. It is vivid that Africans are not confident enough to formulate what is their own. Because of this, our institutes create graduates who are not self-possessed to attack the industry and contribute their ideas and views towards development. Besides, language barrier (English) also kills the confidence and communication skills of individuals whose backgrounds are not founded in a particular language. Various people who have great ideas have been silenced by this ideology. Academic institutes are not focusing on developing an individual's communication skills or even providing the strategies which can assist to present their ideas when the language barrier is faced. It is, therefore, the best to decide the ways of enhancing this area to avoid killing the potentials that may possibly assist Africa toward development.

In conclusion, firstly, African governments should be seated, and educated and reminded about the importance of research and education in the government developments often. The focus and policies of their governments should be revised by putting more emphasis on education and research sector. Yet, this cannot be achieved alone, if the country lacks the influential leaders who are firstly aware of the problem and ready to fight and sacrifice to development. Moreover, educated people including engineers, researchers, and academics should be standby to implement their researches. Most importantly, individuals should also focus on increasing their confidence and improving their communication skills. Academic institutes should also review their mode of education transfer by making sure that they suit their countries requirements. Together, we can, therefore, shift this arena to better developments.

Rose Njeri Mbugua, born in Kenya working in South Africa and Jafta Malakhive from South Africa on the struggle of African civil engineering research for funding and international visibility.

" African researchers in the field of construction have a lot of challenges in disseminating and having their work acceptable to the first world researchers. These challenges are made worse when African researchers use locally available materials in an innovative way to improve African construction industry. African construction materials hardly attract any funding from developed countries unless there is collaboration between itself and a developed first world country. At the same time, funding entities in Africa are not interested in supporting research on locally available materials. Since most materials are not known to the developed world and are of little or no interest to them, publication of such research work is hardly accepted by top notch journals. High impact journals that publish civil engineering research based in Africa are scarce. Though there are excellent researchers in Africa from the construction industry, their work is hardly known in Africa. On the other hand, scientists carrying out research in topics of interest to the developed world publish their work in highly rated journals whose articles are available at a fee, making them out of reach for ordinary African researchers. This has discouraged most researchers. We can borrow a leaf from Literature Scholars, where African writers are known throughout Africa, some examples being: Professor Ngugi wa Thiongo – Kenyan (A Grain of Wheat), Professor Chinua Achebe- Nigeria (Things Fall Apart), Professor Keorapetse William Kgositsile (South Africa) (Random Notes to My Son), Professor Wole Soyinka- Nigeria, and many other renowned African Writers. How was this possible in literature world but not possible in civil engineering world? The big question is; How many of us can name African Professors carrying out research in the field of Civil Engineering in Africa? The challenge is how to make African Engineering research be as important to Africa as it is to the world. How do we sensitize African engineering scholars to uptake and appreciate research originated by their own? How do we disseminate some interesting research outputs gathering dust in some shelves in our African Universities, thereby positively transforming the civil engineering industry and the society? How can state-of-the-art research information be readily available to researchers who hardly use library facilities? A good example of vehicle to disseminate information was Knowledge Exchange for Young Scientists (KEYS) founded by BAM, which unfortunately lasted for three years but achieved a great milestone in bringing African researchers in civil engineering together and published their works. Other platforms are urgently needed where African researchers can exchange their research work in construction, encourage inter-country research and maintain a central database where future generations can access information. In addition, research outputs can be part of our curriculum in our Universities where young students can critic and also carry out further research in respective areas. African governments should support such initiatives by being consumers of research results and supporting dissemination of information from Universities. Let us celebrate our own great researchers and put them in the limelight they deserve.

Shirin Fataei Bolourchi, who was born in Iran currently doing her PhD in Germany, on regional peculiarities and global joint features in gender aspects.

" I decided to write a statement on gender issues in STEM education. Actually, I didn't have much to write about the others except that it is pretty exciting that we are planning to build houses on mars and at the same time, it's sad we are not working hard enough to save the planet we have now. But the main reason was I had a lot to say about gender issues. The biggest problem is I am supposed to keep it short, like I can do that! Anyway, we will give it a try.

What I often noticed is as soon as someone starts with gender issues or gender bias or gender inequality, most people categorize them as a "feminist". However, that's not always the case, some of us only explain what we went through and what we wish others can avoid. As simple as that. At least, this is my case. I'm not a feminist and the reason is I don't like to get labeled as part of a specific social or political group or a religion. I like my freedom of speech and group identity makes me feel restricted expressing my thoughts and I cannot have myself censored. Yet, I often find myself arguing for women's right.

So, I'm not gonna tell you about the challenges that women face in STEM education globally. I don't have a large enough database to research and evaluate that. Instead, I will tell you about the challenges I faced through my education. Don't worry, I have a point at the end.

I would say our definition of gender issues changes based on where we live, study, and work. The whole concept is highly dependent on our families, cultures, traditions, religions, politics and much more. At least this is what I've experienced. I studied my bachelor's in Iran and my master's in Germany. I'm telling you, two different worlds! Surprisingly, there were more female classmates in my bachelor class in Iran in comparison to my class in TU Dresden. You wouldn't have guessed that, would you?

While I was digging a little on women in STEM, I found some presentations and statistics about the female/male student ratio in different academic fields. Apparently, in STEM fields, the female students are much fewer than the males. And often as a conclusion to these statistics, I've noticed that the presenter argued for an equal admission rate and the necessity of having more women in these fields. Based on this argument, my bachelor class with higher female to male students ratio must have had less gender-related problems? Of course NOT! I agree that having an equal rate of admission is a great step towards solving gender issues in universities, but that's definitely not enough.

Personally, I don't think that gender equality in STEM means forcing universities to accept same number of female and male students. No! For me that's not it! Not all women want to be engineers or scientists! I think it means that for those women who want to choose STEM fields, there should be no gender bias obstacles. We mustn't feel frightened because of the men-dominating environment, instead we must be encouraged and empowered to pursue our careers in these fields. We must not be silenced in class because we are a woman. We shouldn't be presumed and called "stupid", "dumb", "slow", "weak", "incapable", "not smart enough", "not good enough", "not talented enough" only because we are a woman studying mechanical engineering! Similar behavior can be seen towards what I call "female-dominated" fields. Who says that a man cannot be "nurturing enough" or "gentle enough" to become a nurse! If he wants to, he must be able to and he must be treated the same as a female nurse. Of course, it's a different story if one is passing courses with minimum grades and not

studying hard enough. STEM fields are tough, but it is equally tough for men and women! It's not like there is an extra 8th generation intel core in men's brain! I heard every single one of those words and phrases at least 3 to 4 times during my bachelor, and not only from my fellow classmates, but also from my professors. Which is even worse! I had to give up a course only because I was "a woman with a big mouth"!

When I was in my bachelor's, I used to think that we lack enough good laws in my country. I thought that if our judiciary system empowers women enough and gives women equal rights, everything will be solved miraculously. Of course, it would have become better, but not fixed completely. I was young and naive indeed to think like that. Then I moved and started studying in a relatively "gender-equal university" in a relatively "gender-equal society". I mean coming from my background, Germany and especially the university atmosphere are pretty awesome for women. Yet the problems were still there. So all the laws and rights that are given to women didn't solve everything?! Shocking!!! It took me a while to start noticing the actual issues and few self-development books to help me see the main obstacles. Finally, I understood that they are two separate categories! We often face these two together and we should deal with them simultaneously. But they are definitely two! And I think, as long as you know what they are, it's easier to face them!

The first is the male-dominant environment and its issues. I call this the "obvious issues", since most people like to point out and talk about these. Here, we are trying to be considered and treated equal to men. This is what I went through in my bachelor; to raise my voice although some preferred me silent; to keep my hand up even though I was ignored; to give myself enough courage to talk and work with the people who were constantly thinking that "Women shouldn't study civil engineering". We've all faced this, maybe with different intensities based on where we live and study, but we've definitely faced this at least once by now!

The second issue is we are fighting our own demons, I would say! Our self-portraits and our judgmental opinions about ourselves. In this battle, we are learning to trust, respect and love ourselves. We are trying to increase our self-confidence and self-esteem. For me this battle was always the hardest! And that's my point. You've already read this much and I just reached my point! I told you I cannot talk short!
By the way, at some point I have to answer this question: do only women suffer from this issue? Of course not! But in comparison, it's more common among women. Probably you would say "men have been ruling the world since forever. Of course, we feel how we feel". I agree, but that can change.

So let me tell you about myself and the "self-portrait issue". In the past eight months, I started studying my self-portrait and noticed how often I belittle myself! I know that I am my worst enemy. I am self-destructive and judgmental. I criticize myself so much and so harsh that at the end I feel like jumping from a tall building without a parachute! You can't imagine how many times per week I tell myself, "no, you can't do it", "you don't know how to do it", "it was all luck that you could do that", "others can do it better"! The list in my brain goes on and on about my incapability and insufficiency! This bloody voice in my head which constantly tell me "you are not good enough"!!!

WHY? I don' know! Once I heard on a TED Talk by Reshma Saujani, the founder and CEO of Girls Who Code, about how we are raising the girls to be perfect and the boys to be brave! Probably that's why! It was then when I understood that it's not only about our rights, it's about our personalities as well. It is rooted in our culture and how we are raised and our self-portrait and OMG, it's gonna take us years to overcome this even if we start RIGHT NOW! If it is rooted that deep inside us, then it needs decades to be removed, it needs plan and practice and persistence.

In my bachelor class, you could constantly hear the guys talking and participating and so on. We could have talked and participated as well. Was it sometimes unpleasant? Yes. Were we silenced every now and then? Yes. But nobody would have cut our tongues off, you know what I mean! BUT DID WE? NO! We said almost nothing in comparison to the men! AND it was normal for us! We did not even WANT to TALK. We PREFERED to be silent! We were too afraid of saying something "wrong" or "dumb" or of "failing" or of being not "knowledgeable" enough!! And as a cherry on top, we were blinded by the bloody stereotype of "Men know it all". We were afraid of imperfections and failures! And the most annoying thing is WE WERE USED TO THAT!!!

The problem is, if you cannot overcome the "self-portrait issue", you cannot do much regarding the "obvious issues". If you don't have enough self-esteem and you think that it is pretty normal to be treated poorly in university and in your work place, only and only because you are a woman; then how's the situation gonna change?!

Finally, WHAT I DO NOW after finding out how self-destructive I am?

I respect myself more. I acknowledge my success and own them. At least I try to! Why can't I stand in front of a mirror and see a super heroin?! Most men see the Superman or the Ironman when they look in the mirror, depending on the comic universe they prefer! I admire them for this skill. We should learn from them. I'm trying to stop being disappointed in myself and instead be satisfied with who I am. Yes, there is always room for improvement (or at least my parents always insist of reminding me that) but that doesn't mean that I lack anything now (or at least this is something I tell myself every day). I am learning to ask for what I want and not apologize for it. And I'm trying to tell other women around me how awesome and successful and talented they are.

Now it's crystal clear for me that we all need to work on ourselves. We need to redefine NORMAL for our brains! We must be persistent if we want to change the situation. We need to constantly remind each other that we are good, and we are capable. We need to believe more and more in ourselves.

Anyway, imagine a world in which all of us are standing bold and confident and taking our destinies in our own hands. Do you think anyone would be brave enough to ignore and devalue us? Of course not! At the end, we are or will be the parents of the next generation and we need to raise them in confidence! We owe our kids a better future! Don't you agree?

Fatma Mohamed, PhD, Head of Department College of Engineering and Technology, University of Dar es Salaam, on challenges of transferring knowledge into tangible societal progress.

" Enormous progress for human kind has been made possible through knowledge gained from years of research. This progress, however, has not been transferred uniformly globally due to social, political, geographical and other factors experienced in different regions in the world.
The rapid population increase in Africa is real, and solutions to meet the resulting demand for resources and other social needs need to be planned and executed in urgency. Research tailored for Africa is a prerequisite in understanding specific challenges in the region. Education focusing in bringing about innovative solutions fitting for African communities is important in bringing the necessary sustainable development in the continent as well as the preservation of the African identity.

Luca Valentini working at University of Padova in Italy on innovation requirements due to urbanization, possible solution options and the necessity to train students with contemporary methods and tools.

" For the first time in the history of humankind, the majority of the World's population is living in urban areas. As the pace of urbanization is growing fast, it will be necessary to imagine sustainable cities for the future generations. Such a global challenge will require the implementation of innovative building solutions in different geographical contexts, with different availability of raw materials.

Clays are homogeneously distributed across Africa and represent a precious raw material for the sustainable development of this continent. Rammed earth, clay-OPC blends and alkali-activated clays are viable alternatives to Portland cement for an African sustainable building industry. However, the deployment of environmental-friendly strategies in construction will require extended scientific and educational collaboration within and outside the African Union.

Nelson Mandela's famous quote "Education is the most powerful weapon which you can use to change the world" is still relevant today. As our society evolves and becomes more and more interconnected, teaching methods must also evolve. The use of digital tools such as student response systems, learning platforms and multi-media environments represents a precious opportunity for both students and lecturers to interact within a stimulating and attractive framework. Africa's young population is naturally inclined to innovation and I believe "millennials" have a great chance to make Africa a world leader in innovative lecturing methods.

Efe Ewaen Ikponmwosa, Professor at the University of Lagos on pressing African research and education challenges.

" African research and education requirements could be viewed from the following perspectives, namely: 1) Development of common communication language, 2) Addressing poor funding, 3) Unification of standards for education, 4) Eradicating inordinate and inconsistencies in research and education policies formulation, 5) Developing trust among member nations, as well as 6) Removal of external influences of the colonial masters of the member nations among others.

For the African continent to harness her full potentials in research and education, deliberate measures to bridge the language barrier gag among member nations which has been in force since colonization of different parts of the continent by different external forces at different times in the past must be taken. Also of great importance is the challenge of inadequate funding of education and research on the continent generally. Many nations provide less than 26% of their annual budget for education, contrary to recommendations by UNESCO.

Without overcoming language barriers on the continent, without overcoming the challenges of inadequate funding of education and research on the continent, we cannot think of providing and guarantying seamless mobility and exchange of research and education ideas, researchers and academics among member nations.

The impact of colonization is also prominent in the areas of non-unification of standards for education and inconsistencies in research and education policies of member states. African countries still develop and operate policies under the indirect guidance of their colonial masters from whom they got their independence.

The direct resultant of this is the lack of trust in formulation of generalized African based policies on research and education, directed at more or less a unified rate of development of African nations. The African Union (AU) must consider the appalling state of education and research on the continent as a challenge that all member nations must address in order for Africa to experience accelerated development like other parts of the world.

Keynote review

Introduction to ISEE

Dr. Wolfram Schmidt | BAM | Germany

In the beginning a wrap up of the background and objectives of the conference was given through a short anecdote. The global threat of carbon emissions was compared to a super villain in a cartoon, which can only be beaten by a league of superheroes that merge their powers to make them greater than the sum of their individual powers. The objective of the conference was thus to combine the individual talents of various disciplines involved in construction to develop strategies how future generations of engineers can be trained to cope with the pressing challenges they will face.

The keynotes were introduced as foundation for the later workshops in order to provide the same level of background knowledge to all participants, and the workshop chairladies and chairmen were introduced along with the technical and housekeeping issues, before the conference could start.

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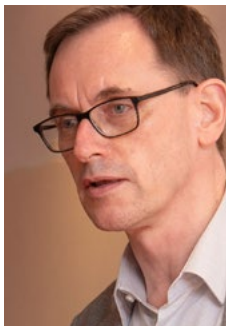
Future challenges of construction engineering and perspectives for Africa



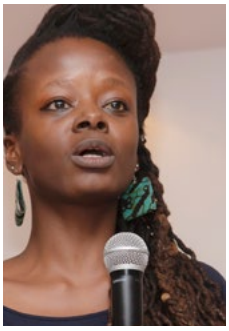
Dr. Andreas Rogge | BAM | Germany

Andreas Rogge summarised the pressing challenges in construction technology and the hot topics of the near future in a nutshell. The major questions to be solved are linked to topics such as digitisation and digitalisation, additive manufacturing, and predictive modelling. Research questions will focus more and more on safety, prefabrication and productivity increase. This can be supported by living laboratories. Knowledge exchange

particularly between Africa and Europe seems to be the best way to work hand in hand on the future challenges.

It was debated that digital prediction and real-life may vary greatly, but while this is true the trend to increase productivity permanently cannot be stopped. However, in complex fields as construction the major challenges have not yet been solved, such as data handling, interface management, data compatibility, and data protection.

Democratisation of form



Namata Serumaga-Musisi | The Griot Introspect | Ghana

In her colourful presentation, Namata Serumaga-Musisi talked about her life and work in various African countries, where despite the many cultural differences certain constants could be observed, from market life and public transportation, to colonial influences on urban growth. She clearly revealed that in Africa urban developments and demands of the urban dwellers diverge dramatically, and that urban planners should ask themselves whose utopia they are following. Eventually, the residents should be the ones who develop their space, facilitated by the creatives.

After the presentation the question came up, whether urban interstitial projects like the ones Namata presented can resist against the ongoing development of big capital business complexes, but Namata could show that also small-scale projects can become strongholds against marginalisation if they get the right attention and acceptance, which requires the involvement of design, music, architecture, and arts in general.

The future of materials technologies and how these can be communicated

Prof. Karen Scrivener | EPFL | Switzerland

Karen Scrivener made a statement that there is no alternative to cement-based materials, as no other mass material can be produced in the amount that is required to meet the global demand, and no other mass construction materials has lower carbon emissions on a global scale. However, due to the tremendous global production, concrete technology has to become more efficient. This includes the usage of limestone calcined clay technologies and other supplementary cementitious materials solutions, as well as more efficient usage of the material itself, e.g. by ready-mixed technologies and prohibition of bagged cement.

After the presentation a debate started about the market acceptance of the presented new technologies, as the implementation into the market happens only slowly. A major obstacle in this seems to be bias against new thoughts and longing for constants of the past, which goes thus far that people raise concerns only because the colour of concrete with blended cements may change, which has no technical relevance. Eventually, education is required at all level.

The right material for each job – the need for a toolkit of cements

Prof. John Provis | University of Sheffield | UK

The presentation of John Provis was focused on the idea of fit-for-purpose construction materials, and particularly the importance of a 'sense of place' in the selection and use of materials for construction. The world is the sum of its parts, and the best solution for each part may differ; there is no "one size fits all" in a sustainable global construction sector.

The discussion involved conversation around the role of standardisation in enabling - or failing to enable - innovation and the use of locally appropriate materials. A key highlight is that innovators need to be willing and able to engage with policymakers, to drive standards development in the future toward a basis of material performance, rather than just providing limitations based on recipes.

http://isee-africa.com/wp-content/uploads/2019/03/20190312_Right-Material-Toolkit_ISEE.pdf

Engineering skill requirements to cope with the local and global challenges of the future

Dr. Wolfram Schmidt | BAM | Germany

The presentation of Wolfram Schmidt criticises that today's curricula still try to develop civil engineering profiles of a past era, although the challenges of today and in the future are different. Since civil engineers are so important for the global climate and societal developments, it is a must to attract the smartest candidates, but this requires advertising civil engineering with more attractive and interdisciplinary job profiles, that go far beyond the classical disciplines. Teaching methods have to become more contemporary to develop new generations of conscious engineers.

It was critically discussed if it can be realistic that teachers will change from textbook teaching to inspiration and mentoring easily, and whether the new civil engineering knowledge will have a chance to permeate into all construction related disciplines and businesses. However, though this may become a challenge, it was very clearly agreed upon the fact that the global climate cannot wait for a slow change in mindset, and that radical change towards conscious engineering education is inevitable.

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The blue-sky research – applied science and engineering interrelationship in an African context

Prof. Ghada Bassioni | Ain Shams University | Egypt

By elaborating on various periods in her career in which the fundamental understanding of processes helped her and the society, Ghada Bassioni pointed out the importance of blue-sky research. Blue sky research cannot replace applied research which is also an important foundation for societies, but societies who acknowledge the value of fundamental natural sciences are typically those that function better and are prepared for changes.

In the discussion after the talk it was stated that most people often begin acknowledging the value of fundamental research knowledge too late when they already find themselves in alternative career paths. Hence, it was concluded that young people need to familiarise with natural sciences much earlier. Science education ideally already start early at school and in kindergarten.

International research networking and the role of Africa within the international research community

Prof. Mark Alexander | University of Cape Town | South Africa

Emerging researchers must understand the 'success drivers' for good research, as well as the research landscapes in which they work, and identify opportunities for active networking or collaboration with like-minded researchers, particularly in Africa, but also abroad. In Africa, there is a need to develop research clusters and networks that are viable and sustainable, in construction materials. Research must reflect credibility, and should be embedded in a framework of building the institution. African researchers can bring a different perspective to their work, which means that, suitably networked and resourced, they could make major and qualitatively different types of research contributions in the future.

After the presentation the questions came up about the challenges finding suitable networks and partners in Africa and the importance of choosing the right institution and supervisor. The challenges cannot be denied all over the world, but emerging researchers need to avail themselves of the growing opportunities on the African continent. Also funding and support requirement were discussed, which eventually requires that the research agendas have to be brought to the notice of decision makers and particularly university leaders at every level.

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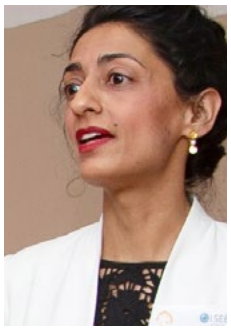
Engineering design: an approach towards sustainable site-specific solutions with global considerations



Prof. Daman Panesar | University of Toronto | Canada

Worldwide, nations are experiencing challenges with the current status of infrastructure. The challenges, deficiencies or vulnerabilities can relate to several factors such as: capacity, condition, maintenance, safety, and resilience. The quality of infrastructure has a direct relationship to the quality of life. Although, it is necessary for students to be proficient in fundamental engineering knowledge and design calculations, now more than ever, there is a need to educate civil engineering students to think more broadly about engineering design problems to account for economic, environmental, aesthetic, and societal considerations with a life-cycle perspective. The Engineering Design Capstone Project course and its methodology as detailed in this presentation allows for the opportunity for students to develop a design solution to an open-ended, multi-faceted design problem.

The key discussion items focused on the evaluation criteria and the challenges associated with assessment of group projects owing to the fact that each design group proposes a different design solution and there is no single correct answer. Developing a rubric for each deliverable in the course, which qualitatively describes the 'graduate attributes' and 'outcomes' is one approach that helps to ensure consistency and transparency in assessment. It is imperative that the instructor be able to effectively assess several of the unique aspects of the design, including: (i) design solutions which reflect 'thinking outside of the textbook', as well as accounting

for practical and creative aspects; (ii) consideration of the benefits, risks, professional responsibility, and ethics associated with truly innovative designs that 'push the envelope'; and (iii) the adequacy of effective communication (verbal, written, drawings and schematics).

http://isee-africa.com/wp-content/uploads/2019/03/2019_Engineering-Design_ISEE.pdf

Crossroads: sustainable infrastructure + entrepreneurship + online engineering education in 21st century Africa

Murray Metcalfe and Nadine Ibrahim | University of Toronto | Canada

The presentation noted the intersection of key issues in Africa – rapid growth of mega-cities, sustainability challenges, and the need/opportunity to scale up engineering education. The speaker noted that infrastructure could be an entrepreneurial activity, despite the seeming contraction in those terms. Examples were noted from the transportation sector, and enabling conditions were discussed. A video insert described recent efforts by the University of Toronto and a team of African academics to create online content and ultimately a Global Classroom. The great African cities of the 21st century will be built by engineering students being educated at African universities today.

Questions centered on how entrepreneurial activities might fit within the broad spectrum of enterprises – governments, multi-lateral bodies like the World Bank, corporations, etc. The speaker argued for the unique power of entrepreneurial activities to build brand new industries – but only if financing sources attuned to taking risk were available. The ability of information technologies to enable entrepreneurial business models was noted.

http://isee-africa.com/wp-content/uploads/2019/03/20190312_Crossroads_ISEE.pdf

The discipline to pursue less (but better)

Tina Nyamache | Freelancer | Kenya

The presentation of Tina Nyamache was challenging our society's perception on the definition of success and the pressure we give ourselves and the youth today. It dived into how we can live by design and not by default. Inner motivation and ownership of work and life is required for productivity. In order to be in control of one's choices, focus on important items is required. Trade-offs are part of life - instead of asking what the sacrifice is, it is better to ask what to go big on. Life can be designed in our own way, our own time, on our own scale. We can all live a life not just of simplicity but of high contribution to society, and of meaning. When we empower ourselves, we then empower and motivate others. We are designed to be human centric, making solutions for, and creating value for your company and community. We should strive for a world where everyone can play a part in solving key problems by doing what we are great at.

A most important question to answer was, when would be the right time for strategic trade-off, but the answer is case and life sensitive. Priorities on e.g. work, health, family change over the course of a professional and private lifetime. Tina Nyamache found her own success changing with age, and one success can be defined as having clarity of own purpose and inner motivation to do what can be enjoyed.

http://isee-africa.com/wp-content/uploads/2019/04/20190415_Discipline-to-pursue-less-but-better.pdf

Laid back mentality

Busisiwe Legodi | Former CIMERWA Ltd CEO | South Africa

Busisiwe Legodi gave interesting insights into the cultural environment in which she grew up and built her career. She emphasised how important common language and values are, and that certain attitudes and rites are important to keep the society and business functioning. In this context she explained that laid back mentality and due diligence played an important part in her life, but can be misunderstood in business life, although she clearly pointed out that laid back must not be mixed up with laziness.

After the talk there was discussion about how it can be possible to succeed in business life and still stick to one's own roots, and Busi could prove based on own experiences that careers can definitively be successful without bending the own convictions, also as a woman in a male dominated environment such as construction business.

Reflections on the civil engineering curriculum for engaged social development in the 21st century

Prof. Yunus Ballim | Sol Plaatje University | South Africa

The presentation expanded on the idea of a curriculum that is more than the content knowledge of the programme but also an integrated part of a broader academic plan. The argument is that curriculum development should focus on competence development more than contend knowledge delivery. A mechanism for developing a "curriculum coherence map" in programme planning and management was described as an instrument for improved engineering education that allows greater accountability from individual academics to the community of learners and scholars involved in the programme. The presentation also considered the opportunities for learning development in the "second curriculum", outside of the formal contact with students.

There was some discussion from the audience on the usefulness and the process used in developing the competency matrix of the curriculum. However, there was much discussion on concerns about lack of accountability of academics who teach in engineering programmes at some universities. Students and emerging academic mentioned very bad practice amongst academics such as being absent from class without notice, poor pedagogical approaches and a focus on teaching without attention or concern for learning. Furthermore, academics were not held accountable for such poor practice.

http://isee-africa.com/wp-content/uploads/2019/03/20190312_Engineering-Curriculum_ISEE.pdf

Fostering innovation through research and education for infrastructure development: a call for synergy between town and gown

Dr. Kolawole Adisa Olonade | University of Lagos | Nigeria

The concept of Town and Gown represents the university environment and off university campus, respectively. A brief background on the conceptualization of a university environment as distinct in all ramification from the town as well as the consequent of building wall between the Town and Gown were presented. Urbanization of cities made

the town to encroach the university, creating unplanned relationship. Nevertheless, global challenges such as climate change, infrastructure deficit, and depletion of natural resources, economic quagmire beg for focused research, innovation and education. These tripartite factors can only be provided by the university with the support of the Town. The presentation gave the way to go to create synergy between the Town and Gown for addressing common challenges.

During the discussion session, it was identified that both the Town and Gown have their own peculiarities, which must be recognized. In view of this, there was a call for caution not to completely break the wall between the Town and the Gown but to make the wall porous/pervious. Creating avenue for the town and the gown to meet was seen as more of necessity than require. By this, a common interest can be identified where both sees each other as more of partner in progress than a benefactor. Therefore, every effort must be geared towards sustaining synergy between the Town and Gown to be able to adequately address global challenges.

http://isee-africa.com/wp-content/uploads/2019/03/2019_Town-and-Gown_ISEE.pdf

Knowledge transfer from universities: to students and to practice

Prof. Ole Mejlhede Jensen | Danmarks Tekniske Universitet | Denmark

Ole Mejlhede Jensen explained that civil engineering materials are ill-defined materials subject to ill-defined exposure conditions and handled by ill-defined workers. This poses a challenge in relation to knowledge generation and knowledge transfer. University teaching of civil engineering materials, however, can be improved by strengthening the scientific coherency. A stronger scientific basis ensures the "durability" of the learning outcomes.

An intensively discussed item after the discussion was the challenge to get students' attention as lecturer and vice versa. Too often teachers put stronger focus on research than on teaching. There was common agreement that pedagogic skills should be mandatory for lecturers, which is even enforced by the educational institutions.

Educational Tools and Curricula Development for the Advancement of Engineering Education in Africa

Prof. Funso Falade | University of Lagos | Nigeria

Funso Falade elaborated on weaknesses of existing teaching tools and requirements for higher efficient learning. In his talk he emphasised that the choice of the right tool is extremely important and that teachers need to understand this and have to be equipped with adequate pedagogic skills. A major drawback he identified in recent curricula for engineers is the lack of entrepreneurship skill developments.

The discussion afterwards circulated around the challenge to make engineering more attractive and more contemporary, and it was concluded that it is more important to study what offers potentials. Many students tend to study what sounds attractive despite the lack of a local demand. This requires better synchronisity between societal demand and academic offers.

http://isee-africa.com/wp-content/uploads/2019/04/20190412_Educational-tools-and-curriculum-development.pdf

Appropriate high-level physics solutions in developing countries – a cooperative approach to bridge scientific education and engineering

Prof. Robert Tchitnga | Université de Dschang | Cameroon

The presentation of Robert Tchitnga focused on the interface between physics and engineering. The talk brought out that physicists can not only have a tremendous impact on the society but should also have to have it. For physics teachers this means it is important to raise the students' awareness about their potentials and to adhere physics education to real life problems. In this context a variety of showcases were presented from mobility to construction solutions, where physics could facilitate solution finding for specific problems.

After the presentation there was particular interest in the projects that were presented, such as a low-cost health care device and a bamboo bike. The most striking point for the success of these projects was that they brought physics down to the population, not as a secret language but as something tangible.

http://isee-africa.com/wp-content/uploads/2019/04/20190411_High-level-physics.pdf

Networked and unified innovation system roadmap for African smart, green and integrated development in the 4th Industrial Revolution

Prof. Mammo Muchie, Tshwane University of Technology, South Africa

Mammo Muchie developed the idea of a networked African innovation system to bring the tremendous future potentials within Africa from spark to ignition. Africa is on the verge to step into a new age coined by digital, knowledge and value driven, environmental technologies that serve the populace. These potentials could make Africa global game changer and role model, but this transformation requires networking, inclusions and radical innovation.

The discussion after the talk pointed out that many obstacles exits, but Mammo Muchie explained that revolutionary processes must not be linear but can develop exponentially, and that history has already shown hoe effectively in Africa technologies can be leapfrogged and that many examples exist, where Africa is technology leader already today.

http://isee-africa.com/wp-content/uploads/2019/04/20190415_Integrated-networked-smart-Africa.pdf

Workshop impressions

In the third day of the conference, eight workshop groups were formed to discuss relevant items, identify challenges and develop solution strategies jointly. The results were later presented and discussed in front of the entire audience followed by a podium discussion.

Based on the workshops, each group derived conclusions, which were compiled and elaborated as papers by some authors. These papers are presented after some impressions of the workshops in the next chapter.

Global and local challenges and/or potentials in construction

moderated by Chadlia Ounissi, Mareike Thiedeitz, and Banjo Ayobami Akinyemi
http://isee-africa.com/wp-content/uploads/2019/04/20190415_Global-and-local-challenges_ISEE.pdf

Future skill requirements in civil engineering, architecture and materials

moderated by Yazmin Lisbeth Mack Vergara, and Cyrille Vincelas Fohagui Fodoup
http://isee-africa.com/wp-content/uploads/2019/03/20190312_3Future-skills_ISEE.pdf

Potentials for sustainable construction based on education

moderated by Akindehinde Ayotunde Akindahunsi, Joseph Mwiti Marangu, and Bruce Raath
http://isee-africa.com/wp-content/uploads/2019/03/20190312_2Sustainability-based-on-education_ISEE.pdf

Global research and education requirements

moderated by Olukayode Olawale Alao, Nonkululeko Winnie Radebe, and Rose Njeri Mbugua
http://isee-africa.com/wp-content/uploads/2019/03/20190312_4Global-research-and-education_ISEE.pdf

African research and education requirements

moderated by Joyce Wanjeri Njoroge, Solomon Adomako, and Chinedu Francis Ekechukwu
http://isee-africa.com/wp-content/uploads/2019/03/20190312_5African-research-and-education_ISEE.pdf

Contemporary teaching methods

moderated by Alice Titus Bakera, Loudon Luka, and Vusumzi Malele
http://isee-africa.com/wp-content/uploads/2019/03/20190312_5African-research-and-education_ISEE.pdf

Gender issues in STEM education

moderated by Maboea Dikeledi, Shirin Fataei Bolourchi, and Said Kenai
http://isee-africa.com/wp-content/uploads/2019/03/20190313_7Gender-Issues-in-STEM_ISEE.pdf

Language and communication barriers

moderated by Ines Tchetgnia Ngassam, Muzafalu Kayondo, and Henri van Damme
http://isee-africa.com/wp-content/uploads/2019/03/20190312_8Language-and-communication_ISEE.pdf

Panel discussion

Andreas Rogge | BAM | Germany

After three long days of intense discussions, the conference was finalized by a panel discussion on some special issues to be emphasized regarding the next project steps.

The initial question to the panel addressed the issue of a possibly reduced acceptance of so called "low-cost housing" in society. Although the phrase is mainly related to more efficient building processes, people may equate it with a reduced quality or stability of these buildings. A bad reception of the possible outcome of the project with developing tools for sustainable and economic materials and constructions would hamper the reception of the entire project. The clear answer was the demand for integrating the perspective users into the development and design process from the start to foster their sense of ownership. The input of the inhabitants and the integration of their needs and ways to live into the project aims will become key to success. Everything should start with the people!

Another question raised was how to teach students the informal aspects of the construction sector. "Informality" in that context means the absence or negligence of regulations, in contractual or employment issues as well as in the construction or product regulations themselves. Today informality seems to grow especially in developing countries and a university education not dealing with these items would leave the students not ready for practice. It was concordant view in the panel, that the first step would be the training of the teachers and their will and ability to prepare their students for the "real world". The aim would be a mindset change from pure teachers to becoming trainers and mentors, listening to students and their needs on one hand and giving them a voice on the other.

In the following, all panel members addressed other necessary skills that may be not (sufficiently) taught in university. The very broad scope reached from basic personal and societal qualities to special technical proficiencies, which should be all fostered or integrated into the curricula to provide a comprehensive fundament for being an engineer: the necessary personal skills range from listening, communication and negotiation abilities to emotional intelligence, teamwork and leadership qualities, from innovative and critical thinking and the power of imagination to a general requirement for personal integrity, empathy and respect to all other humans; or in other words:

supporting the students in effective socialization. The classic engineering skills like knowledge of materials and structures as well as the design of infrastructures of all kinds must be widened by digital knowledge of data analytics, internet technologies and programming. Today's education must without doubt integrate the modern digital solutions into traditional science and technology to allow the students taking part in modern building processes and technology platforms when leaving university.

The concluding part of the panel discussion was dedicated to the chances and expectations of a "Massive Open Online Course" (MOOC) as one prospective outcome of an ISEE project continuation. The technical requirements would be developed during additional workshops, but several basic challenges were already addressed here: the digital infrastructure and the investments in hardware and software at African universities seem to be very different and it becomes clear that a wide spread of a MOOC can only be achieved by addressing different platforms and audiences from university classes to personal teaching on handheld devices. Possible forms of contact or reflections between students and teachers when using a MOOC outside a regular university structure will then be an important issue in the general structure of such a system.

At university level, MOOC could be part of a regular curriculum or an addendum to it; regarding the available infrastructure and since it would be not realistic to create an all-embracing curriculum by voluntary contributors from the beginning, the structure of the MOOC should be organized in a proper way for integrating additional contents of all kind to create a relevant knowledge platform, but nevertheless as an additional tool to regulars lessons. The problem was discussed that an additional tool would perhaps only reach students deeply committed to their topics anyway, but it was agreed upon in the panel that proper self-motivation and dedication of the students to such an innovative educational concept would be crucial for its success anyway. Further questions addressed language issues (which should be overcome by a successful MOOC), financial aspects (which could not be clarified at this stage) and the best age or level for starting sustainability education (which should be in school or even kindergarten to create

awareness but will probably be at university level for the start of a MOOC for practical reasons).

As a conclusion of the panel discussions, the fundamental interest in the development of educational tools besides all remaining practical questions and the widespread willingness among all participants to cooperate in such a project was extremely impressive. The wide professional variety of architects, engineers, teachers and societal experts, all willing to contribute to a joint educational project, created a kind of inspiring community and a firm conviction of the huge chance of a successful continuation of the ISEE project.

The workshop groups were represented by Fatma Kassim Mohamed, Børge Johannes Wigum, Namata Serumaga-Musisi, Chinedu Francis Ekechukwu (all left column, top down), Loudon Dalitso Luka, Muzafalu Kayondo, Akindehinde Ayotunde Akindahunsi, Moses Onyango Opiyo (all right column, top down), respectively.

ISEE Advancements

Global and local challenges in buildings and construction

[1]Mareike Thiedeitz | [2]Chadlia Ounissi | [3]Banjo A. Akinyemi | [4]Elise Berodier

[1]TU Munich, Germany | [2]Faculty of Sciences of Gabes, Tunisia | [3]Landmark University Omuaran, Nigeria | [4]Ecole Polytechique Federale de Lausanne, Switzerland

1. Introduction

Fast urbanisation around the globe is challenging the construction sector at both the global and local scale. Today, buildings and constructions account for 32% of the global energy expenditure and are responsible for 19% of the global greenhouse gas emissions. We are all aware that the situation will worsen significantly in the next decades if we carry on current building practices in our efforts to provide sufficient settlement to the burgeoning population. While the danger of urbanisation is a reality, constructions have enormous potentials – largely unrealised by the society – at the local and global level. From our perspective buildings are source of challenge and solution at the same time. Indeed, they impact with so many critical areas which are identified by the United Nations as Sustainable Development Goals (among them Climate Action, Infrastructures, Sustainable cities ...). The history of architecture has shown that construction materials evolve with the society. We have been developing new technologies for thousands of years and we will continue adapting to new resources and to a new digital world. However, we will do it, will determine our progress toward sustainable development.

This paper provides a review about the challenges and potentials that we, but also governments, policies makers, and cities must address urgently. We propose practical solutions at both local and global level. Our common vision is that cooperation and partnership are key. We hope to inspire collective actions for our future.

2. Global and local challenges: status quo

It can be identified that the main obstacles towards sustainable construction fall in three major fields.

Economic challenges

- Corruption in construction industry
- Affordable sustainable construction
- Unequal distribution of natural resources between countries
- Slow implementation of new technologies and innovation in construction industry

Social challenges

- Negative mindset on low-carbon, local construction materials or practices: vernacular building is seen as buildings for 'poor' and new low-cost housing as of poor quality
- Lack of interdisciplinary connections between actors which limits knowledge transfer and development of efficient solutions
- Lack of awareness on corruption and the misuse of available resources at the society level
- Poverty or unemployment and builders with poor and limited skills
- Artisan skills poor or limited
- Recognition of engineers: avoid exclusion of key engineers and other relevant specialists during feasibility studies and issuing of contracts
- Misalignment of curricula with the application on the ground

Environmental challenges

- GHG emissions from construction
- Importation of materials resulting in inefficient application
- Allocation of financial resources
- Lack of exploitation of locally available and sustainable materials
- Modernisation of construction with the use of new technologies
- Inadequate international standard to many local contexts
- Tendency of construction sector to promote mainstream solutions

3. Global and local potentials

With the massively increased rate of urbanisation worldwide, construction can be a driving force with a significant positive impact on sustainable development of the countries. From a global economic angle, the construction industry is a dominant force in any nation's economic growth as a significant contributor to the gross domestic product. On the environmental global aspect, it is estimated that the building sector can contribute to the mitigation of the climate change by reducing more than 50% of the energy consumed for buildings. However, most potentials are at local scale. They can be summarised as follows:

- Sustainable design can increase the blend of traditional and conventional building materials. We have the knowledge and the technologies.
- Natural and local building materials such as hempcrete, cob, earthbags, straw bale construction, construction waste etc. There is a tremendous volume of natural and local materials that are suitable for construction. Why are we limiting ourselves?
- Leapfrogging technology: urbanisation happens in emerging and developing economies where high-carbon and unsustainable construction are not yet dominant, these countries can take a different pathway then Western countries and leapfrog towards sustainable construction methods and materials.

- Formulating national policies and strategies to implement the adoption of green building materials into the construction industry through the use of incentives and waivers for the industry.
- Re-thinking bidding process towards more open and transparent, as well as encouragement of sustainable construction practices
- Stage by stage monitoring of construction works which would serve as a check and balance to curtail sharp practices in the industry
- Give voice to engineers! They are key actors towards solving the challenges of the construction.

4. Possible solutions

With respect to the discussed global challenges and potentials, solutions in different fields have to be found. Generally, the "Think global, act local" attitude is necessary in each action. Following, possible solutions for different areas are presented:

Politics and corruption

A direct approach to politicians is not applicable. In many countries, governments will not apply direct solutions for environmentally friendly and sustainable engineering without gaining tangible advantages for themselves or the economy. Still there is the possibility of influencing the local politics by either influencing the clients or proceeding in "interdisciplinary undercover lobbyism". As in various movements through history, it is possible to mobilise groups of **passionate** people armed with information and resources in order to impact national policy around sustainable development in construction.

Moreover, engineers and more largely all actors in construction, could form lobby groups to impact on politicians, holding them accountable at every stage of development. Indeed, a smart transportation of our knowledge to politicians in good lobby work could transform consumption and building behavior even if we must sell it from purely economic or other publicly relevant market friendly perspectives. Building interdisciplinary bases for policymakers to transport our knowledge will surely have an impact. We have to be clear that we all are the politics of the world. We built our today's society and each one of us as well is able to change the society, even if it takes more effort in our today's world than maybe in ancient times.

Standardisation

Standardisations can be a powerful tool for the implementation of environmentally friendly building. Nevertheless, to be efficient, standards should be appropriate to local context (avoiding predominance of international standards against local standards). Standards should request the use of local available materials and not standardised imported materials as today. Engineers should participate in standard committees and promote local standards in their work.

Information to the public

Not only politics has to be informed but public as well. Engineers and engineering should be more present in society. Information about building and constructing have to be more accessible. Keeping information back, will not stop elites in engineering. With showing engineering methods to the public, construction and living standards will change from bottom up.

Education

Appropriate education is the basis that will support the development of the aforementioned solutions. It is the most powerful tool to create a prospective impact.

Possible educational tools were figured out: Basics have to be taught; not standards or rules. Engineering students should know about the basics and be able to apply them for thoughtful building.

Direct teaching about sustainable building solutions, e.g. low cost materials and the use of wastes makes sustainable building not extraordinary but normal and thus can become the new standard.

5. Creating impact

Influencing the people's minds about construction and its influence on the environment, sustainability and culture is the most important impact to be reached. **Starting from the bottom, impact will eventually be reached at the top**: People will consider their behavior and interaction with the built environment, consumption behavior and political actions.

As engineers and other built environment professionals, we all should start to create impact by using easy but strong channels:

- Start social media! We underestimate the influence of social media accounts, short videos and podcasts on the young generation.
- Try to engage policymakers in the public eye.

Make your point clear! Be short! Use easy words! Do not be exclusive, rather be accessible!

6. Conclusions

Do you want to make a change?
Do you want to create impact for more sustainable construction methods?
Can you implement at least one of the direct approaches?
Will you implement this NOW?

Potentials for sustainable construction based on education

[1]Akindehinde A. Akindahunsi | [2]Joseph M. Marangu | [3]Bruce Raath | [4]Karen Scrivener | [5]Mark Alexander

[1]Obafemi Awolowo University, Nigeria | [2]Meru University of Science & Technology, Kenya | [3]B. A. Raath & Associates, South Africa | [4]EPFL, Switzerland | [5]University of Cape Town, South Africa

Abstract

The sustainable construction concept is concerned with the phases of a project from design through construction to use, in a way that it is economically efficient, socially compatible and environmentally responsive. In order to harness the full potentials for sustainable construction through education, there is the need for a proper learning culture that will address both the formal and informal sectors. The formal sectors of construction, including the professional bodies, should embrace learning on sustainable construction in related engineering and construction fields. There should be inclusion of sustainable construction concepts in educational curricula, liaising with relevant government bodies for appropriate legislation on the issue. The other sectors such as artisans in the construction industry can be reached through their associations and unions, setting up educational and advocacy programmes. The public can also be reached through the media, and through educational programmes that will inform the populace on how to undertake sustainable constructions in the environment. This is expected to give a boost to sustainability of the environment through construction based on education.

1. Introduction

Sustainable construction may be referred to as a concept of construction processes/activities, as it affects phases of a project from design through construction to occupation or use, in such a way that the resulting infrastructure is environmentally receptive, economically efficient, and socially compatible. The players in construction industry need to be have a deep understanding of how designs and construction activities positively impact the environment, methods of utilizing earth resources in a sustainable manner, and the influence of materials and workmanship on the final product. The Department of Economic and Social Affairs of the United Nations (2013) noted that over 1 billion people in the world live in live-threatening poverty, and the gap between the rich and the poor in many countries of the world is on the rise. This problem puts the system under massive social and economic stress and threatens the healthy existence of the planet, because these categories of people live in informal settlements in the cities. A concerted effort is required for development that is sustainable, reduces poverty and vulnerability of the extreme poor, in the form of affordable housing that is also environmentally sustainable. To address this problem, a programme that takes care of the poor and the vulnerable needs to be put in place in the form of sustainable housing and infrastructural development. Another major problem found in local communities in the developing world is lack of infrastructure, and where this is available whether in the rural or urban environments, its use is being stressed beyond capacity.

Infrastructure requirements are on the increase especially in cities of the developing world, because of increase in population, including the effect of populations migrating from rural areas. The surge in urbanization is illustrated by figures from the United Nations Habitat (2016), which put urbanization at 54% in 2015 from 43% in 1990. Housing and physical infrastructure therefore are critical needs of growing cities to take care of increasing urban populations. Provision of this infrastructure must be affordable to the growing low to middle income people in the cities and social compatibility in the form of services afforded because of the provision of this

infrastructure. It is unacceptable that such urban populations begin to struggle with infrastructure deterioration problems within a short time after the structures are put in place. McKeown (2002) reported that it is recognized worldwide that the existing economic growth pattern cannot be sustained, and there is the need to sensitize, educate and train the populace in order to shift society towards sustainability.

Education of the public can be divided into two aspects: formal and informal education, discussed below.

2. Education

Physical infrastructure that is constructed in a way that is energy efficient, offers environmental benefits and is cost effective in construction and maintenance can be termed 'green infrastructure'. The need to create eco-friendly green construction is very important because of the problem of climate change that is leading to unprecedented global rise in temperature due to increasing use of energy, and higher operating costs of maintaining facilities. However, before the formal and informal sectors of the construction industry especially in Africa can move towards sustainable construction, education will have to play a vital role, hence the need to harness the potentials for education in sustainable construction. For development to be sustainable it must be able to meet requirements of the present population without jeopardizing the effectiveness of the future population to be able to address their own needs, as noted in the report from the World Commission on Environment and Development (1987). The report further viewed sustainability to be a future in which environmental, economic and social factors are matched by development and value-added life. This is depicted in Figure 1 where the triple aspects of sustainability intertwine with each other to give a better quality of life; when these three big factors meet, it gives rise to sustainability. The tripod of sustainability needs to be taught in educational institutions and particularly as it relates to construction. Hence, the education of the public can be divided into two: formal and informal education.

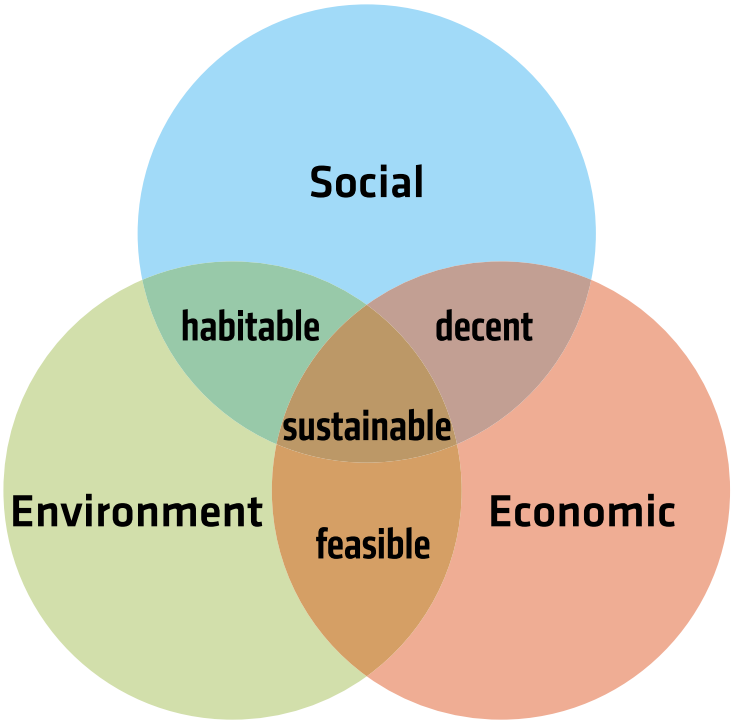


Figure 1: Tripod of sustainability

2.1 Formal education

Formal education will involve teaching and training of students on sustainability issues in construction in proper recognized setting such as schools, colleges, universities, and public institutions, and this will include the following:

i. University Education and Curriculum Development
ii. Continuing Education through Professional Development
iii. City Councils and Governments
iv. Dissemination of Scientific Research
v. Training and Retraining for Workers in Construction industry

2.1.1 University education and curriculum development

COM (2007), opined that sustainable construction is a dynamism of developers, the construction industry, professionals, investors, and other service providers, in the creation of new solutions for sustainable development taking into cognizance socio-economic and environmental factors. Sustainable construction should include design and management of physical infrastructure, materials selection, construction, operational maintenance, and service life of the infrastructure, that sits well with the environment. This shows there is the need to set-up formal teaching and training on sustainable construction in tertiary institutions for a start. The products of such teaching and training will be the professionals themselves, who will implement this knowledge and skills in the market place. Teaching approaches should be based on local socio-economic and environmental factors. COM (2007) noted that in some cases, importance may be given to use of land, materials, water, energy and other resources, while in other instances, it may have to involve socio-economic inclusion and interrelationships in sustainable construction. The teaching of sustainable construction should encompass the design process of a structure, management of such structures and other built assets, material choices, and functionalities of structures vis-à-vis the interface with economic and urban management and development.

The need to revise existing curricula to include sustainable construction cannot be over-emphasized. The present curricula in most tertiary institutions of Africa cannot adequately take care of the subject of sustainable construction in their present form. In most cases sustainable construction is not included as a subject to be taught, or if it is present, it is not given the desired status. Tertiary education is expected to give impetus to resource development that will produce manpower skilful enough to inspire sustainable practices in construction. Iyer-Raniga et al (2010) noted that to give complete consideration of the importance of sustainability to upcoming professionals in the construction industry, it is necessary that they personally connect with and be motivated to handle sustainability issues. In order for this to be the case, curricula and courses offered in tertiary institutions must ensure such outcomes. Recent innovations in the construction industry occur primarily in materials development and improved technology and this brings to the fore the need to understand these materials and how they affect design and construction processes. Schmidt et al (2018) noted that the development of flowable concrete leads to quicker methods of construction and newly developed concepts in materials development requires teaching the both at the tertiary level and continuing education in the industry.

2.1.2 Continuing education through professional development

There is the need to get professional bodies involved in sustainable construction through education. The professional bodies organise regular workshops for their members, and there is the need for professionals in the construction industry to be kept abreast of innovative developments in the industry, hence the need to work with such bodies for continuing education through professional development. Iyer-Raniga et al (2010) noted that professionals in the construction and building industries are supposed to create environmental landscapes that give an indication of decent habitation and work. However, Iyer-Raniga et al (2010) opined that the construction industry lags behind in issues of sustainable construction and are slow at embracing practices that are environmentally friendly. Resistance to change has been identified as one of the major problems of the

construction industry, such as the need to adapt to new materials and methods of construction that will enhance sustainability of the environment. Another factor identified as a cause of unwillingness to accept environmental sustainability in construction is corruption and incompetence. These identified problems show the need to incorporate professional bodies into the mainstream of sustainable construction via education. Professional organizations should set-out sustainability practices in the construction industry, that are expected to be adopted by each component of the workforce and must have guidelines on how such outcomes can be measured in order to improve output of the industry. The introduction of sustainability principles and practices into codes of practice and regulations are further ways of implementing sustainable construction. Iyer-Raniga et al (2010) noted that implementing sustainability issues will depend on human resources to drive through this change.

2.1.3 City councils and governments

City Councils and local governments will need to make laws and policies that will enhance sustainability initiatives in the construction industry. The present rate of slum development in urban centres in the developing world is not sustainable, and this is due to migration of people from rural areas into the cities in search of opportunities. However, the existing infrastructure in the cities cannot cope with the rate of migration. The quickly built shacks that are typically built are not a sustainable way of construction for high density environment such as slums in cities of developing world. Irurah (2002) discussed unsustainable construction as depicted by shacks in informal settlements in urban areas and noted that such constructions are prevalent in most cities of developing countries. The author pointed out that conventional shack construction sourced constituent materials from waste building materials (Figure 3), and others available from the immediate surroundings. Shacks are built by locals from within the community hence, the skill and technology that are used are made available from within the community. Another problem of informal dwellers is that they are unlawful tenants that put up illegal structures on illegally occupied land, with a high rate of overcrowding of occupants living under poor and unhygienic conditions. Lack of water, incessant power outages, lack of basic health care, poor waste disposal and an uncontrolled polluted environment are some of the other challenges facing dwellers in such environment (Plessis, 2002).

2.1.4 Dissemination of scientific research

There must be a way to disseminate proven scientific research and innovations to the professionals and the skilled labourers in the construction industry. Academics, professionals in the construction industry, and government must have regular interactions in order for academia to be able to disseminate new proven research and for the professionals to discuss the implementation and limitations of such research, and the relevant government agencies to back up such with adequate support in the form of policy. In some cases, it may necessitate an amendment to existing codes of practice where necessary.

Material selection and usage is very important in the service life of structures in any environment. The correct cement type, mineralogy of aggregate, size and shape of aggregate along with permeability, bleeding and appropriate mix proportions of concrete must resist the ingress of airborne sodium chloride and carbon dioxide, which are both aggressive to reinforcing steel. Thus, the principles of materials selection, mix proportions, placement, compaction and curing to name only a few are indispensable to the production of high-quality concrete that will safeguard the reinforcing steel against corrosion. Structural units are subject to degradation when exposed to aggressive environments such as extreme temperatures, acids, salts etc., and as a result reduce their service life. The cost of repair and maintenance of structures has become a factor in the procurement of construction materials as well as the overall structural designs.

The contribution of the construction materials towards the ultimate durability of structures is of essence in the construction industry. Education based on the deterioration mechanisms is crucial in mitigation of the deleterious effects posed by aggressive media such as:

i. Alkali silica reaction
ii. Corrosion- due to chloride ingress
iii. Carbonation
iv. Sulphate attack

Deterioration of concrete products/ structures may be caused by:

- The use of inappropriate materials
- Poor construction practices

Environmental factors that can cause problem of deteriorations are:

- Temperature
- Moisture
- Physical factors
- Chemical factors
- Biological factors

Deterioration of structures puts a lot of stress on scarce resources available for development, disfigure the environment, and ultimately may cause catastrophic failure which may result in loss of life. Hence there is a need to educate the relevant professionals in sustainable materials that will endure various aggressive environments to which the structures may be subjected, reduce embodied energy consumption, ameliorate greenhouse gas emissions, built at an affordable cost, and socially responsive to meeting the need for which it is built. This is the reason why durability properties must be taken into consideration from the design and materials selection stages of the construction process.

2.1.5 Training and retraining for workers in the construction industry

Practical training of construction workers and professionals in the construction and building industries, on implementation of new materials and methods of construction that will be sustainable, is very important. The energy requirements in construction materials either directly or indirectly ought to be considered when choosing the materials for construction purposes. Special emphasis should be made to promote construction activities that require minimal energy for production. Education activities geared towards assimilation of energy saving projects is envisaged to ensure sustainable construction. A publication named Construction 2020 (2014) opined that training and retraining of construction workers will help the industry to be up-to-date with uptake of innovative methods of construction and materials characterization.

The designer is perhaps in a better position to specify materials and installation on the structure, but frequently leaves this function to the contractor who is assumed to be experienced and capable of performing this task. The result of lowest tender selection is that materials selected are not often of the best quality for the structure and the structural durability or sustainability are compromised. Properties such as permeability, absorption, chloride conductivity, shrinkage, elastic modulus and flexural strength are ignored, and the service life of the structure is reduced.

From inspection of numerous structures that have enjoyed limited durability, it becomes evident that structural designers do not have an adequate grasp of the properties of the materials they use for structural applications. The designers produce excellent structural designs but are incapable of producing a proper specification for the materials, and simply leave material properties to the contractor and ready-mixed supplier to the detriment of the structure.

2.2 Artisans in the construction industry

Artisans of various categories that work in the industry who are used to the traditional ways of doing things and are not educated. Reaching out to these workers on sustainability issues may be challenging, but there is the need to devise effective means of educating them on sustainability issues. These artisans have unions and associations where they meet regularly, these unions and associations can be platforms that can be used for the education of these groups of people on sustainability issues in the construction industry. Regular workshops can be organized through the unions or associations for creation of awareness on sustainability in construction.

2.3 Advocacy through mass media

For the public, the need for sensitization on issues of sustainability in construction is very germane because it will enlighten the public on what it means, impact on the environment and the benefits if properly implemented. There is the need for the public to know that there are new or existing materials that can be used with other alternatives to give similar or better properties for construction materials. Innovative construction methods are also being developed to provide enhanced construction process that may be faster, which needs to be brought to the knowledge of the public in a way that will be understood.

3. Conclusions

The benefits of sustainable construction through education cannot be over-emphasized. Development of new sustainable construction materials or modification of existing materials to give improved characteristics that can positively impact the environment will only come through research and appropriate education. This is because the impact of some material properties on concrete may only be obvious later in the life of a structure. Therefore, education is an indispensable means of attaining sustainability in the construction industry.

References

COM (2007). Accelerating the Development of the Sustainable Construction Market in Europe.

Report of the taskforce on sustainable construction. Composed in preparation of the Communication. "A Lead Market Initiative for Europe".

Chrisna Du Plessis (2002). Agenda 21 for Sustainable Construction in Developing Countries. Published for CIB and UNEP by CSIR Building and Construction Technology, Pretoria, South Africa.

Construction 2020 (2014). A Strategy for a Renewed Construction Sector. Published by the Stationary Office, Government Publications, 52 St. Stephen's Green Dublin 2, Ireland.

Department of Economic and Social Affairs of the United Nations (2013)

Irurah (2002). Agenda for Sustainable Construction in Africa. Agenda 21 for Sustainable Construction in Developing Countries. WSSD edition Published by the CSIR Building and Construction Technology P O Box 395, Pretoria, 0001

Iyer-Raniga U., Arcari P. and Wong J. P. C (2010). Education for sustainability in the built environment: what students are telling us? Association of Researchers in Construction Management, ARCOM 2010 — Proceedings of the 26th Annual Conference

McKeown (2002). Education for Sustainable Development Toolkit. http://www.esdtoolkit.org. Accessed on the 20th January 2019.

Schmidt W, Alexander M. and Alexander V. (2018). Education for sustainable use of cement based materials. Cement and Concrete Research 114, 103–114

United Nations Habitat (2016). Urbanization and development: emerging futures. World Cities report. United Nations Human Settlements Programme (UN-Habitat) P.O. Box 30030, Nairobi, Kenya

World Commission on Environment and Development (1987). Our Common Future. United Nations.

Future skill requirements in civil engineering, architecture and materials

[1]Yazmin Lisbeth Mack-Vergara | [2]Cyrille Vincelas Fohagui Fodoup | [3]Jule Anniser

[1]Universidade de São Paulo, Brazil | [2]University of Dschang, Cameroon | [3]Hochschule Düsseldorf, Germany

1. Introduction

Global population is rapidly increasing. Only in Africa, 26 countries are expected to double their population by 2050[1]. With this rapid population growth there is also increasing demand for housing and infrastructure. Together with climate change, another important challenge is to propose more sustainable and proper materials[2]. Academia and the industry have been working on potential strategies to tackle these issues[3].

For instance, concrete is the most produced substance in the world. This material entails many environmental impacts from its production. However, concrete is needed for housing and infrastructure due to population growth and there is not enough of other materials to replace its demand[4]. Therefore, this material should be produced in the most sustainable way possible and to do so innovation, science, engineering and education are crucial[3]. Global and local perspectives should be considered as well.

To attend the challenge of more sustainable and proper materials, the collaboration of everyone is needed. Scientists, engineers, construction workers, and the society should participate together in decision-making. A scientific discovery could be "useless" due to construction methods restrictions, standards restrictions, lack of specific materials in certain regions, lack of labor training, etc. that the scientist did not know. And this is why everyone should participate together, since everyone has different perspectives and knowledges. This synergy is what society needs.

The aim of this work is to identify and discuss future skill requirements in civil engineering, architecture, and materials. Current requirements were listed mostly focused on the African perspective to identify potential strategies. The results from this work are relevant for the industry and academia as well as for society in general which must be the ultimate beneficiary.

2. Results and discussion

This paper provides a variety of opinions and discussion items on future skill requirements in civil engineering, architecture and materials. The main challenges and future skills requirement to address these challenges – proposed and discussed – are listed in Table 1.

Challenge	Future skill requirement
Environmental issues Resources, environmental impacts, CO2 emissions	Deepen **awareness** for sustainability already in undergraduate education.
Choice of **material**	**Durability, sustainability, functionality** must be leading aspects in design and construction. Value the **appropriateness** of materials new, better, greener materials, traditional materials.
Aging infrastructure Predictability of the behavior of the structure during its life cycle and under extreme conditions	Basic skills in forensic engineering. Focus more on existing buildings instead on new design. **Maintenance and repair** must be considered in the design.
Question of **broadness or depth**	**Interdisciplinarity** in: – Education – Internships – Work – Communication and collaboration.
Inhibiting **regulations**	Existing regulations must be tailored towards sustainable construction to **promote** the use of **sustainable materials**.

Table 1 Challenges and future skills requirements for civil and material engineering and architectures

The challenge of building in the future comes predominantly from potential environmental impacts. The building industry consumes large amounts of resources. In addition, produces waste and emissions. To allow sustainable construction, awareness of these issues must be deepened in the education of civil engineers, architects and material scientists.

The choice of material will be the most important aspect of a building. Durability, sustainability and functionality must be considered from design to construction. The predictability of the behavior of the structure during its life cycle and under extreme conditions will be of great importance and designs might be led by these limitations instead of a vision. Architects and engineers must be able to evaluate the appropriateness of materials and consider unconventional options.

Maintenance and the ability to repair existing structures must both be part of the education and of the design. Sustainable design is not only based on durability but also on the possibility of simple repairing. It is common to have courses on building design. However, courses on existing buildings maintenance and repair should also be implemented. Recycling and reusing should be taught as well, for instance to reuse building parts which could be more sustainable than building new ones.

Since many professions related to construction will face the same challenges, interdisciplinarity is fundamental and should already be incorporated at the undergraduate level. The conflict between broadness and depth in the training and education of skilled workers can only be answered with a collaborative effort of all occupational fields. Soft skills will be thus of great importance.

For sustainable materials to be used on site it is essential that legislation keeps up with new innovations and encourages their use. Passing laws that regulate construction should advocate the use of green and sustainable materials. The role of government should not be underestimated.

3. Conclusions

It is inevitable to focus on some additional skills that are going to be essential in the future. Key challenges concerning sustainable building in the future were identified together with the necessary future skill requirements to handle these challenges.

Communication and collaboration of all people involved is fundamental for success. Soft skills and social aspects must be considered in the education of civil engineers, architects and material scientists. Basic skills such as math, physics, chemistry and English are still very relevant.

There is a need for a new paradigm in civil, material engineering and architecture to address these issues. Furthermore, developing countries have great potential in education, science and the application of both.

References

[1] World population projected to reach 9.8 billion in 2050, and 11.2 billion in 2100. UN DESA | United Nations Department of Economic and Social Affairs (2017). Available at: https://www.un.org/development/desa/en/news/population/world-population-prospects2017.html. (Accessed: 4th March 2019)

[2] Steffen, W. et al. Planetary boundaries: Guiding human development on a changing planet. Science 347, 1259855 (2015). doi: 10.1126/science.1259855

[3] Visvizi, A., Lytras, M. D. & Daniela, L. Chapter 19 Education, Innovation and the Prospect of Sustainable Growth and Development. in The Future of Innovation and Technology in Education: Policies and Practices for Teaching and Learning Excellence 297–305 (Emerald Publishing Limited, 2018). doi:10.1108/978-1-78756-555-520181015

[4] Scrivener, K. L., John, V. M. & Gartner, E. M. Eco-efficient cements: Potential economically viable solutions for a low-CO_2 cement-based materials industry. Cement and Concrete Research (2018). doi:10.1016/j.cemconres.2018.03.015

Global research and education requirements – in construction

[1]Nonkululeko Winnie Radebe | [2]Olukayode Olawale Alao | [3]Rose Mbugua

[1]Karlsruhe Institute of Technology, Germany| [2]SusCrete Infrastructure Consulting LTD, Italy | [3]Walter Sisulu University, South Africa

Introduction

Global research plays an important role in the innovation and development of new materials, with particularly strong impact in the construction industry. It can span between different continents, countries, cultures and even researchers speaking different languages. Global research can make an impact on education requirements by resulting in training engineers who are more sensitive to innovation and local requirements. Universities can focus on research-rich education that encourages critical thinking and problem solving both globally and locally. Lack of research-oriented education will impact negatively upon the future direction in civil engineering education. Three critical subject areas where global research can be applied in construction materials sciences are in cement, aggregates and concrete admixtures.

Research and industrial challenges and potential opportunities

Within the context of construction, three materials are of utmost importance to the structural integrity and the durability performance of infrastructure. Cement, which is the binder, the admixtures which improve the workability and decrease the amount of water added as well as aggregates that make up most of the concrete's composition (about 75% of the concrete matrix). Below we discuss the challenges with using these materials and potentials when it comes to carrying out research on them.

Cement

Cement is a vital and virtually irreplaceable element of construction materials. This is because it is made from readily available raw materials from the earth's crust. However, due to the excessive release of CO_2 during the manufacturing process, it is essential to look towards supplementary cementitious materials (SCMs) as a partial substitute to reduce the carbon footprint [1]. In addition, waste materials or renewables can be investigated as an energy source for cement production to decrease the carbon footprint. Cement is a material that has enjoyed a lot of attention on the global research level. However, it is still not fully incorporated into the curriculum of undergraduate engineers where topics such as cement chemistry and technology are still yet to be fully implemented.

Admixtures

Currently, admixtures are produced from crude oil (which has a negative impact on the environment) or are by-products of industries in developed countries. All admixtures currently in use in Africa are imported from developed countries as finished products. Therefore, it is important to look for alternatives using locally sourced raw materials as opposed to importing them. For example, research has shown organics adhered to the waste peels of cassava, Nkui a gum from barks of Triumfetta pendrata A. Rich and Gum Arabic Karroo and Seyal species from South Africa and Kenya have potential as admixtures in concrete to reduce the water

needed whilst retaining workability [2]. The main challenge that developing countries face is the lack of research in this area. This is hindered by several factors including funding for the actual research and infrastructure such as equipped laboratories to test such materials.

Aggregates

Aggregates constitute the largest percentage of concrete and a civil engineer could benefit from learning more on this subject. Aggregates can be anything from industrialized manufactured crushed sand, with an accurate controlled homogeneous amount of fines, to natural fluvial sand and gravel of variable grading and composition. All these materials have different performance properties; both in the fresh rheological phase of the concrete, but also on durability performance, and as a result must be understood at a mineralogical and compositional level. Unfortunately, this civil engineering material is not studied to the depth at which cement and admixtures are by undergraduates. This creates a knowledge gap for civil engineers which can only be sufficiently closed through functional and interdisciplinary education.

Aggregates are typically always sourced locally. Many supplementary cementitious raw materials and chemicals can also be derived from local sources. Each local material has properties that are linked to performance. Therefore, this would be a good opportunity to fund local students to study these materials to suit local needs as closely as possible. Furthermore, there are opportunities for increased industrialization of these constituents within the local communities. This will ensure shorter supply chains, local value chains and saving of energy used to transport these materials from a long distance.

General requirements

- Global interdisciplinary research – Research between different disciplines is encouraged to come up with meaningful and practical research. For example, to study aggregates, geologists, chemists, material engineers, as well as civil engineers can work together to close professional gaps.
- Functionally educated researchers – It should be expected that through education, a construction professional should have geology, applied chemistry, as well as material science in their arsenal. This is simply not the case today because we see that there is a poor link between industrial needs for multidisciplinary professionals and the actual professionals being churned out of universities every year.
- Mobility and exchanges between institutions – Well equipped laboratories could share equipment with less well-equipped institutions to bring to speed the level and quality of research in little known and emerging materials, especially from developing countries.
- Creating awareness through teaching and research methods – Targeted change in the curriculum so as to focus on improving or creating awareness to use and research on materials for local needs.
- Legislation changes like incentives or tax penalties – Governments can award or fund research for the innovation of new materials that promise to reduce the carbon footprint in the construction industry.
- Private sector or universities and institutes could also motivate the transition of research knowledge into industry solutions through the entrepreneurship training of engineers to develop products from their research. This can be in the form of incubator labs, which have usually focused on technology company start-ups.
- Fostering and funding the active participation of researchers from emerging economies to international committees for the establishment of internationally recognized standardized tests. Adapting international standards through local regulatory authorities.

Education requirements in the context of universities

Only very recently have universities started working towards changing and adding creative teaching methods to incorporate sustainability and critical thinking into the curriculum. It is important to add the sustainability component to generic courses.

Solution strategies

Solutions for all the above-mentioned challenges can come in the same form. Having mentioned interdisciplinary learning and research, only through collaboration and mobility opportunities can many of the challenges be addressed short-term. In the long run, once facilities are available, there will be a need for sufficient training to produce well-rounded civil engineers.

Major players

In the continuum between global research and education, there are several major role players as seen in Fig. 1. There is a strong and equal relationship between all the major role players.

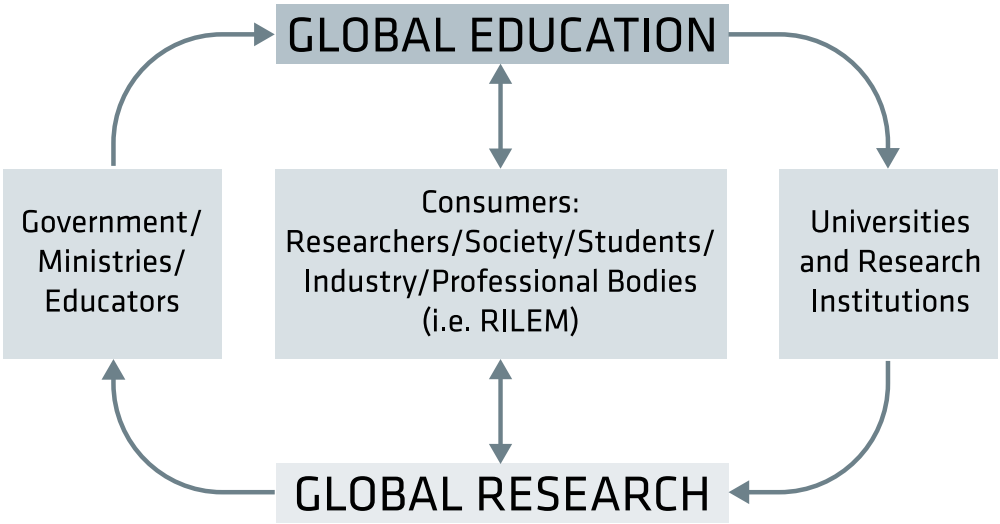


Figure 1: Major role players in propelling global research and education requirements towards being sustainable

Conclusions

On a global scale, there is a need to localize admixture, industrialize aggregates and reduce the amount of cement used in construction.

References

[1] K.L. Scrivener, V.M. John, E.M. Gartner, Eco-efficient cements: Potential economically viable solutions for a low-CO_2 cement-based materials industry, Cem. Concr. Res. 114 (2018) 2–26. doi:10.1016/j.cemconres.2018.03.015.

[2] W. Schmidt, I.L.T. Ngassam, R. Mbugua, K.A. Olonade, Natural rheology modifying admixtures for concrete, (2017) 1–13.

ISEE Advancements

African research and education requirement – a paradigm shift

[1]Adomako Solomon | [2]Ballim Yunus | [3]Ekechukwu Chinedu Francis | [4]Maina Tabitha Wangoi
[5]Njoroge Joyce Wanjeri | [6]Oluwaseye Onikeku

[1]LAS-Roads Laboratory | [2]University of the Witwatersrand, South Africa | [3]Wiltshire College and University Centre, UK | [4]Hochschule Rhein-Waal, Germany | [5]University of Ulm, Germany | [6]Jomo Kenyatta University, Kenya

Abstract

Education, research and development (R&D) has, since knowledge inception, been the backbone to sustainable economic, social and environmental development. All over the world, education and research activities are fundamental to national development. Unquestionably, Africa's dynamism in terms of global wealth contribution is significant, yet it is one of the continents that is characterized by low research activity and capacity. Currently, the continent contributes about 3.6% of world's research, and has high education exclusion rate. This paper explores some of the reasons for these challenges and suggests practical and constructive solutions towards ameliorating them. These suggestions were the ideas of keynote speakers, resource persons and contributors at the ISEE-Africa Conference (2019), held in Nairobi, Kenya

Introduction

Africa, the second largest continent with an estimated population of 1.3 Billion according to the United Nations estimate, produces less than 3.6% of global scientific research output [1] despite her young population and vast natural resource base. These low numbers can be attributed to the high education exclusion rates, grossly underfunded researches, dysfunctional systems and poor resource allocation among others.

Research is key to the development of any nation and a significant determinant of health and productivity [2]. Without proper, efficient and robust investment in education and research, the challenges facing Africa cannot

be resolved. Some suggested solutions include collaboration between educational institutions and industries to enrich overall learner experience; improved funding of research projects; motivating the academia by stimulating relevant research outputs and curriculum harmonization could all contribute to improve education and research significantly.

In the following sections, we take an in-depth look at the nature of the problems and challenges facing the progression of education and research work in Africa; highlight the parties responsible for these issues; outline the key strategies to solve these problems and the long- and short-term impact it will have on educational institutions and the economic sector. Lastly, we recommend some solutions that may assist in addressing these problems.

Problems and challenges

The greatest challenge facing education, research and development in Africa is that of funding. Academic institutions are grossly underfunded. In 2018, Nigeria, Africa's most populous nation allocated a paltry 7 % of her national budget to education much lower than the 15-20 % recommended by the United Nations [3]. With her demographic challenges- e.g. proportion of young people, etc, the demand for university-level education has its own fair share of impact. For students who cannot get into the tertiary education system, the other pathways to knowledge through vocational training and work-based learning are almost non-existent. Those who are privileged to acquire higher education are yearning for an urgent need for a redeveloped curriculum that better prepares them with the knowledge and skills needed to meet the African economic challenges [4].

Responsibilities

To improve on the current state of education and research in Africa, a lot is expected from the state, regulatory agencies, independent professional bodies, the university community and the industry. These bodies must work together to address the identified challenges. A symbiotic relationship where the state, in addition to providing funds, is expected to champion policies and initiatives that will encourage wider collaboration between all parties and should drive R&D in Africa. Policies like the Nigerian Content Policy (NCP) and the Nigerian Oil and Gas Industry Content Development (NOGICD) are typical examples of such growing synergy between such parties [5][6]. If these policies are sustained, it will have positive impacts on the infrastructural base of the learning environment, promote the creation of research endowment funds and continental research linkages.

Requirement and key strategy

The uniqueness and diversity of educational curricula frameworks in Africa, poses significant challenges to possible conceptual integration of courses and qualifications. Indeed, Africa is diverse in terms of culture, yet coherent and integrated educational policies on the continent are feasible. In educational settings like Europe, there is cohesiveness of subject matter at the university level [7]. Significantly, this influences degree generalization all over Europe based on the framework of curricula settings in the continent. If all African countries adopt a common conceptual educational curriculum irrespective of language barriers, it would enhance research and development in the continent and the global attractiveness of local research outputs. Certainly, this can be done through the Association of African Universities (AAU).

Further, increased discussion amongst university vice chancellors is encouraged. Ideally, this is expected to create effective cooperation and partnership. It is proposed that, students and academic staff may, on defined periods, visit the industry for placements and secondments respectively to improve on their practical experience and skills development. This will create more work-based learning opportunities and enrich the social engagement with knowledge in general. This is also expected to better negotiate the gap between student competence and industry expectations. Finally, reconceptualizing the role of education and research training in developing agency amongst young entrepreneurs in African countries is also considered an important factor. The focus is to educate citizens on the importance of taking "ownership" of what belongs to the society which is commonly referred to and treated as government property. It is believed that, developing our students and graduates to "work and act simultaneously for personal and common good,'' shall enhance human capacity development both in the public and private sectors.

Pains and gains

The pains that have ensued as a result of deficiency in the educational system in Africa will demand a focus on training and upskilling. Skills are valuable contribution to any organization, and upskilling presents an opportunity for organizations to increase productivity. In order to revive the educational system in Africa, there is need for most teachers to engage in content and pedagogical training programs which in turn will help them develop their own contribution as academics. Most academic staff in the educational sector will be affected because of a sense of resistance to this new change. restructuring and overhauling of education institutions can also be expected.

Furthermore, to develop their research capacity, writing retreats for new and existing researchers will be necessary. Such retreats require funds and time to improve overall planning and writing skills within academia. It will create avenues for the teacher/lecturer to focus and dedicate more time to research student supervision in a supportive environment and so improve the quality of student research work [8].

Lastly, Intra-Africa academic mobility is a scheme which brings about support for higher education cooperation between countries in Africa. This can promote mutual research development that alleviates poverty through increased accessibility of qualified and trained high-level professional human capacity in Africa. As a result of this, some teachers/lectures will be compelled to shift from their comfort zone and visit other Africa countries in order to learn from others [9].

Conclusions

Africa's rich resource base which is estimated to around 30% of the earth's remaining mineral resources [10] and the influx of foreign investors to the continent should have a massive impact on education and research, yet it produces less than 3.6% of global research [1]. To help improve the situation, governments of African countries should prioritize funding for research and education and put control checks in the institutions to fight misappropriation of funds. The Association of African Universities (AAU) should address curriculum challenges. All other parties involved should make necessary changes and strictly monitor progress to ensure a win-win situation. Education institutions should also place a focus on research development of academic staff through resource provision, research capacity development, writing retreats and intra-African mobility for collaboration.

References

1. The United Nations Department of Economic and Social Affairs Population Division (2017). "World Population Prospects The 2017 Revision". In: United Nations New York. [Accessed 18 February 2019].

2. Department of Researcher Development (2018). Collaboration for Research Excellence in Africa (CORE Africa), Douala, Cameroon. "Research challenges in Africa – an exploratory study on the experiences and opinions of African researchers". In: bioRxiv [Accessed 10 February 2019].

3. UNESCO (2001). The Right to education: an analysis of UNESCO'S standard-setting instruments: 2001. Paris: UNESCO. Available from: https://unesdoc.unesco.org/ark:/48223/pf0000123817 [Accessed 22 February 2019].

4. BudgIT (2018). Public Education Financing: Issues and Recommendations. Nigeria: BudgIT. Available from: http://yourbudgit.com/wp-content/uploads/2018/04/Public-Education-Financing-Issues-and-Recommendations.pdf [Accessed 22 February 2019].

5. Nigerian Society of Engineers NSE (2019). Nigerian Content Workshop https://nse.org.ng/downloads/send/13-workshops-lectures/79-2019-nigerian-content-workshop[Accessed 22 February 2019].

6. Nigerian Content Development and Monitoring Board (2016) Handbook of Operational Guidelines. Abuja: NCDMB.https://www.ncdmb.gov.ng/images/GUIDELINES/NCDMBHANDBOOKOFOPERATIONALGUIDELINES.pdf [Accessed 22 February 2019].

7. The Structure of European Education Systems (2018). https://eacea.ec.europa.eu/national-policies/eurydice/sites/eurydice/files/the_structure_of_the_european_education_systems_2018_19.pdf [Accessed 25 February 2019].

8 Intra Africa Academic Mobility Scheme. Kick –off Meeting, (2014). Brussels, pp1-18. [Accessed 18 February 2019].

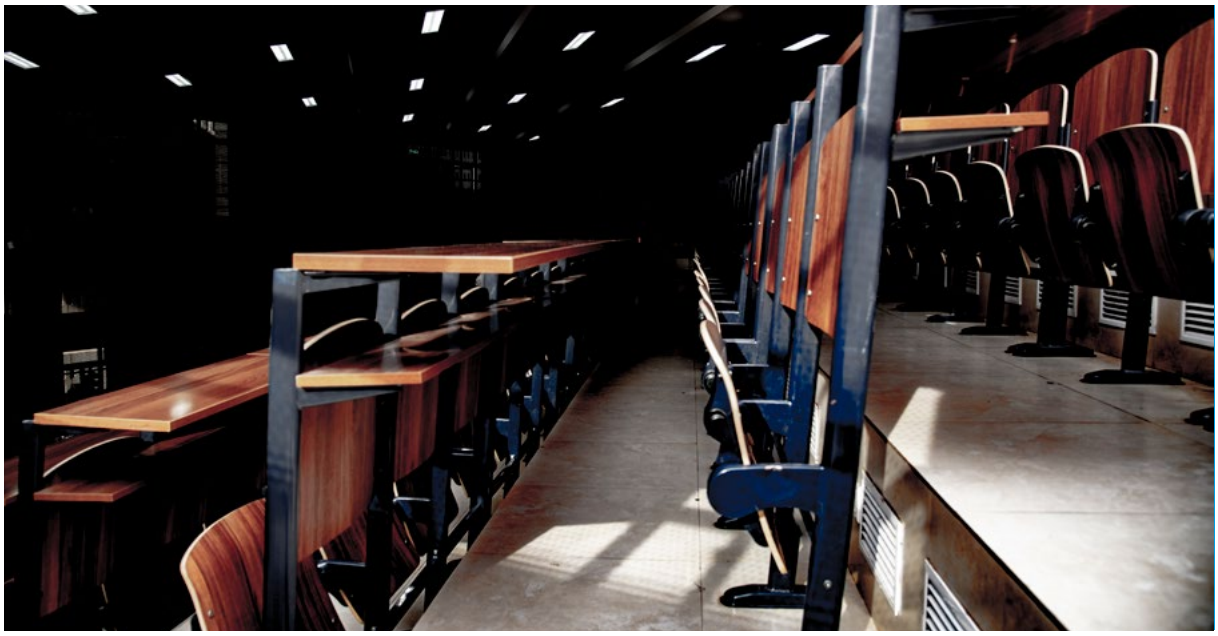
9. Petia, P. and Annika, C. (2012). International Journal for Researcher Development Emerald Article: Using Structured Writing Retreats to Support Novice Researchers, 3: 1, 1-8.

10. Aljazeera (2018), Mapping Africa's natural resources-An overview of the continent's main natural resources. Available at https://www.aljazeera.com/indepth/interactive/2016/10/mapping-africa-natural-resources-161020075811145.html [Accessed 23 February 2019]

Contemporary teaching and learning methods for engineering education

[1]V. Malele| [2]A.T. Bakera | [3]G. Bassioni | [4]F. Falade | [5]L. Luka | [6]M. Hussein | [6]J.K. Mbugua | [6]V.O. Omwenga

[1]Tshwane University of Technology, Pretoria, South Africa | [2]University Cape Town, South Africa | [3]Ain Shams University, Egypt | [4]University of Lagos, Nigeria | [5]Mzuzu University, Malawi | [6]University of Nairobi, Kenya



1. Introduction

Contemporary teaching and learning methods are important aspects in engineering education. They are the teaching/learning techniques that assist in the implementation of learning activities by drawing upon students' experiences, both in and out of the classroom; thereby helping in developing specific skills that have significant impacts in developing the world. These techniques, when effectively applied, increase the level of student engagement and retention of knowledge while maintaining educational quality. Moreover, techniques aim at integrating technology, science and engineering with traditional means of educating.

Bull, Knezek, and Gibson, (2009) observed that the 21st-century global economy requires facilitators who understand and can contribute to the literacy and preparation of students for full participation in the science and engineering fields. They also found that science is often drove by a passion associated with objects. Because of this, they emphasize on providing more opportunities for students, from the lowest level, to interact with objects during learning. Doing so increases familiarization and communication with the surrounding environment which enhances the synchronization of their thinking with the high technology advancement.

However, the techniques that are still in use in the current education systems, especially in many countries of developing economies, do not satisfy the need of the global economy. This is associated with a rapid technological advancement. It is vivid that the technology in growing faster than the rate of changing the teaching curriculums. Before introducing the subject to the students, they already ahead the facilitators, which results in missing connection since the curriculum does not allow them to fully engage in learning. Besides, current education system is time consuming, inflexible and question-answer oriented. These characters encourage

student trailing interest in learning as well as killing their creative thinking mind. Thus, there is the need to change to have a valuable and useful education.

Therefore, this short paper answers few questions relating to contemporary teaching methods (CTMs) in engineering education, like what it is, who is responsible for implementing it; what would be its pains and gains; and how could it be assessed.

2. Contemporary education

Contemporary Education is the implementation of learning activities which draw upon students' experiences, both in and out of the classroom, thus helping them to recognize that they are developing specific skills which they perceive to be significant for the world outside of school. In this regard, contemporary education is an implementation of the sociocultural theory which describes learning and development as being embedded within social events and occurring as a learner interacts with other people, objects, and events in the collaborative environment (Wang, Bruce and Hughes, 2011).

Contemporary education requires agile learning spaces (which are flexible and have an ability for easy and quick configurability) where academics and students can collaborate to learn and work together. It requires a pedagogy (a combination of knowledge and skills required for effective teaching) that allows for the usage of various teaching practices that aim at developing the curriculum intent to provide multiple opportunities for students to engage in intellectually challenging and real-world learning experiences. It demands for teaching and learning that embrace intuitivism, creativity and innovation be aspect of (Grigorenko, 2019).

3. Contemporary teaching methods (CTMs)

Contemporary education has opened up research that seek to determine innovative approaches for resolving issues in present-day education from the perspective of various sciences, scholarly paradigms and methodological approaches (Harvey, 2011; Grigorenko, 2019). The latter contemporary education discussions could be drawn from dedicated research journals such as: Journal of Comparative Education, European Journal of Contemporary Education, Journal of Contemporary Educational Research and Innovations, International Journal of Contemporary Educational Research, International Journal of Contemporary Education, Perspectives in Education, etc.

4. Discussion

The CTMs do not allow the lecturer to practice poor communication skills (i.e. using poor and difficulty vocabulary to teach), casual teaching, disrespect of students and time. However, they are good methods which allow the lecturer to be reviewed by students and colleagues (i.e. through some feedback mechanism) and allow students to be involved in teaching.

To define CTMs one needs to understand students' approach to learning. According to Kavalari, Kakana, and Christidou (2012), there are three learning styles (i) surface approach to learning – there are those students with a reproducing orientation, (ii) deep approach – those with a meaning orientation and tend to adopt a deep approach, and (iii) strategic approach – those with an achieving orientation.

Surface approach allow for rote memorization and mechanical formula substitution is the learning style linked to passive teaching. Deep approach which allow for probing and questioning and exploring the limits of applicability of new material is linked to active teaching. Strategic approach which allow students to doing whatever is necessary to get the highest grade they can, taking a surface approach if that suffices and a deep approach only when necessary. The CTMs are at the center of passive, active and proactive teaching methods (see Figure 1).

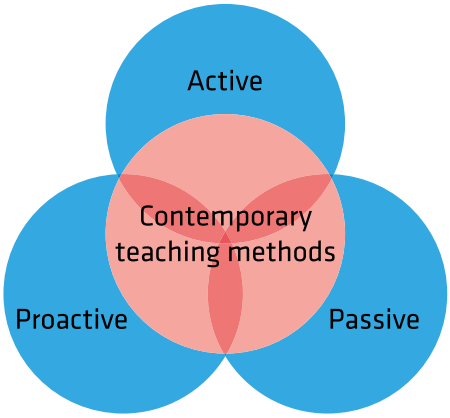


Figure 1: The contemporary teaching methods

The implementation of CTMs need a Quintuple Helix innovation model which stresses the necessary socioecological transition of society and economy in the 21st century and is driven by the elements described in figure 2 below. Quintuple Helix is ecologically sensitive. Within the framework of the Quintuple Helix innovation model, the natural environments of society and the economy also should be seen as drivers for knowledge production and innovation, therefore defining opportunities for the knowledge economy (Carayannis, Barth, and Campbell, 2012). Figure 2, illustrates the elements that are necessary for implementing CTMs.

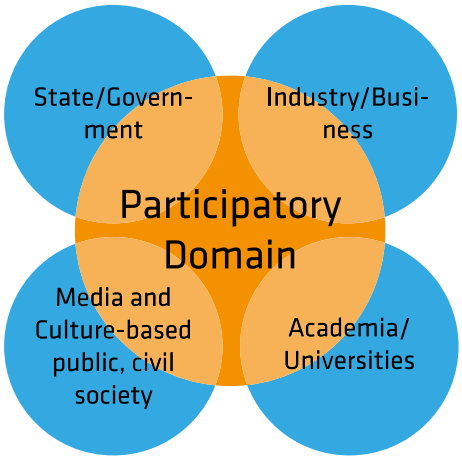


Figure 2: The elements in the Quintuple Helix innovation model (Van Waart, Harbers, and Visser, 2015; Carayannis, et al., 2012)

There are pains of implementing the CTMs in today's classrooms; for example, there could be: (i) resistance by people towards change, (ii) the need for more resources, and (iii) older generation losing employment leading to shortage of lecturers then affecting performance and productivity. However, there are also gains that could be achieved; for example, there could be (i) immediate impact on students, (ii) learning and development for the lecturers, and (iii) innovation and creativity for all participants.

The implementation of CTMs in a classroom require the lecturer to practise different assessment techniques. For example, in engineering education activities in project, problem or challenge-based learning is carried out by student teams. The evaluation and development of teamwork competence is especially relevant in engineering contexts, because in this case most of the professional tasks are addressed by teams. In engineering, teamwork could be used to instil practical components of real-world scenario through simulate theory.

5. Conclusion

The 21st century engineer needs to be trained using contemporary teaching and learning methods that will make them relevant in hybrid sectors. Those methods challenge and embrace culture aspects, dynamic teaching method, involve peer teaching/tutors as an assessment technique, creation of entertaining classes by balancing the use of technology, change of mindset through different world views.

The contemporary teaching methods open up good researchable topics that could motivate for future studies. For example, issues of co-teaching, embedding other fields (i.e. indigenous education, entrepreneurship and innovation education) while teaching, assessment approaches, and teaching tools as affecting the contemporary education should be investigated.

References

Bull, G., Knezek, G., & Gibson, D. (2009). Editorial: A rationale for incorporating engineering education into the teacher education curriculum. Contemporary Issues in Technology and Teacher Education, 9(3), 222-225

Carayannis, E.L., Barth, T.D., and Campbell, D.F.J. (2012). The Quintuple Helix innovation model: global warming as a challenge and driver for innovation. Journal of Innovation and Entrepreneurship, 1(2)

Grigorenko, E.L. (2019). Creativity: a challenge for contemporary education. Journal Comparative Education, Vol. 55, Issue 1: Pages 116-132

Harvey, J. (2011). A Sociocultural-Theory-Based Study of the Impact of Mediation During Post-Observation Conferences on Language Teacher Learning. Graduate Theses and Dissertations. http://scholarcommons.usf.edu/etd/3727

Kavalari, P., Kakana, D.M., and Christidou, V. (2012). Contemporary teaching methods and science content knowledge in preschool education: searching for connections. Procedia - Social and Behavioral Sciences 46: pp. 3649 – 3654.

Ørngreen, R. and Levinsen, K. (2017). "Workshops as a Research Methodology" The Electronic Journal of e-Learning, Vol 15, Issue 1, (pp. 70-81 [available online at www.ejel.org, last accessed February 10).

Ruutmann, T., and Vanaveski, J. (2009) Contemporary Teaching Methods Emphasizing Conceptual Understanding Adapted for Engineering Education at Estonian Centre for Engineering Pedagogy. Problems of Education, Vol. 11: pp. 159 - 169 2009

Van Waart, P., Harbers, M., and Visser, E. (2015). Value Sensitive Design of Smart Cities. (2015). Value Sensitive Design of Smart Cities. Proceedings of 5th Decennial Aarhus conference, Charting the Next Decade for Value Sensitive Design Workshop , Critical Alternatives 2015, at Aarhus, Denmark.

Wang, L., Bruce, C., and Hughes, H. (2011) Sociocultural Theories and their Application in Information Literacy Research and Education, Australian Academic & Research. Libraries, 42:4, 296-308, DOI: 10.1080/00048623.2011.10722242

Gender issues in STEM education

[1]Dikeledi Maboea| [2]Shirin Fataei Bolourchi | [3]Said Kenai

[1]University of the Witwatersrand, South Africa | [2]Technical University Dresden, Germany | [3]University of Blida1, Algeria

Introduction

There has been a global underrepresentation of girls and women in science, technology, engineering and mathematics (STEM) (Stoet & Geary, 2018). The Society of Women Engineers stated that among the new engineers in 2003 only 20% (~12,000) were women, which was not in line with the world gender statistics of 50.8% female and 49.2% male. Although the participation of women in STEM increased to ~30% globally (UNESCO, 2016), there is still much to be addressed regarding STEM education. This paper presents and discusses some of the major challenges and possible solutions.

Major challenges in gender issues in STEM education

There are numerous intertwined problems and issues regarding the gender issues in STEM education that can be listed and categorized into four major challenges. The major challenges have to be overcome, alleviated or eradicated in order to reach a balance in STEM education. It is worth mentioning that they can be identified disregarding specific demographics.

1. Misconceptions and masculine favouritisms

The misconception and masculine favouritisms are two of the major challenges in STEM and are highly influenced by the society. For instance, there are beliefs that "females need to have male characteristics to partake

and survive in STEM education", or "boys are better at STEM than girls", or "women are too emotional, illogical and irrational to be effective performers in the field". Unfortunately, these wrong beliefs and assumptions not only discourage and repel young women from pursuing a career in STEM but also keep many young talents hidden and unattended.

2. Societal context

Girls and boys are raised and treated differently. This is generally based on preconceived ideas of gender roles, where girls are often groomed and expected to be gentle, perfect, delicate, nurturing and non-domineering. As a result, it is difficult to attract young women into a field which is considered to be hard, dirty and emotionless. Women in STEM education are seen as an anomaly to the norm. The patriarchal system does not have time for women who do not conform. As a result, women feel like they are betraying their nature if they continue in the field. The ideas of gender roles and socialization relate directly to the gender gap of the STEM field because researchers continually find evidence of gender stereotypes related to STEM professions. The stereotypes and socialization practices prevailing in the United States and in other countries revolve around male dominance and female submissiveness (Reinking & Martin, 2018).

3. Lack of female role models and mentorship programs

Greater number of men in STEM fields resulted, consequently, in a huge gap between the number of male and female mentors and role models. The absence of female role models even negatively influences the misconception regarding the "male-atmosphere" of the STEM. In addition, many of the current female speakers who are encouraging women to join STEM are not even educated in this field and therefore lack real-life experiences and lessons for young female audience. Microsoft performed a study in 2015, documenting the views of 11,500 young women in 12 countries across Europe. 52% of the women aged 11-30 who looked up to either fictional or non-fictional people involved in STEM, said they were interested in pursuing STEM education. Whereas among women without female role models, less than a third (32%) did say the same. In UK, there is 20% more chance that a woman with a female role model can imagine a career in STEM in comparison to a woman without one (Microsoft, 2017).

4. Self

The mind-set of a person plays an important role in partaking and staying in STEM education. The background, self-esteem, environment and experiences of a person influence her/his decision making. Many studies in different fields indicate that self-doubt, low self-esteem and imposter syndrome are more common and more intense among women, which unfortunately results in prudent and facile education and career field (Sandberg, 2013). However, there is no evidence that women perform poorer in STEM in comparison to men. A study investigating the gender differences in mathematics showed that there are no difference between the performance of boys and girls in classwork. However, girls experience higher level of anxiety during exams which consequently affect their scores (Gjersoe, 2018). Even if we address and solve all other challenges, we won't be able to flourish and utilize our full potential if we don't truly believe in ourselves.

Practical solutions to gender issues in STEM education

To tackle the identified major challenges, few possible solutions can be derived, which are discussed herein. It needs to be emphasised that executed solutions need to be demography specific. The same solution will

not yield the same results for all people. The implementation and maintenance plans need to be thoroughly thought of and carried out accordingly in order to achieve success.

1. Education and training

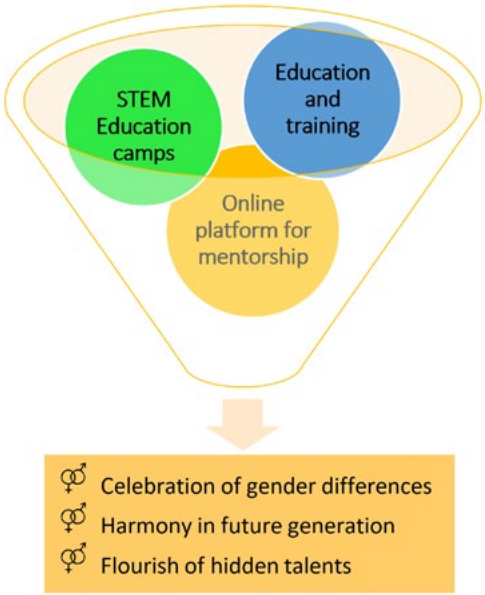
Education and training are unanimously the first identified solution. Parents need to be knowledgeable about the impact of socialising their children to gender roles and stereotypes. STEM teachers have the responsibility to change misconceptions in classrooms. People (lecturers, stakeholders, executives, heads of schools, faculties and education politicians) need to be educated/trained to challenge their negative long-held beliefs about women participating in STEM education and empower them to effect change.

2. Online platforms for mentorships

Internet is highly accessible for the young generation and undoubtedly shaping the personalities of this generation, and it can be used in advantage of STEM. The development of contemporary and local mentorship programs which is accessible for high-schoolers, university students and STEM alumni can increase the interest and participation in STEM. It is note-worthy that the final goal is to encourage women to study STEM as well as to work in STEM fields after graduation. These platforms not only attract the young generation to STEM but also show women a promising future in STEM.

3. STEM education camps

The constructive exposure of children to STEM would positively impact their impression. Education camps with challenging and practical STEM tasks for secondary and high school students motivate them to study STEM and flourish hidden talents. To overcome the stereotype that boys are better than girls in STEM education, organising healthy competitions between mixed groups could be helpful. This would teach the children to celebrate their gender differences and to work together in harmony in future. No matter the outcome of the competition the participants should be motivated and encouraged.



Conclusion

Calculated and intentional actions are required from parents, teachers, decision makers and financial institutions in order to tackle gender issues in STEM education. Positive changes would be witnessed from the ease of accessing role models and mentors sharing their experiences, embracing individuality than gender stereotypes and increased interest. Once these actions take place, more girls and women participate willingly in STEM education.

References

Gjersoe, N., 2018. Bridging the gender gap: why do so few girls study Stem subjects?. [Online]
Available at: https://www.theguardian.com/science/head-quarters/2018/mar/08/bridging-the-gender-gap-why-do-so-few-girls-study-stem-subjects
[Accessed 16 February 2019].

Microsoft, 2017. Why Europe's girls aren't studying STEM. [Online]
Available at: https://news.microsoft.com/uploads/2017/03/ms_stem_whitepaper.pdf
[Accessed February 2019].

Reinking, A. & Martin, B., 2018. The Gender Gap in STEM Fields: Theories, Movements, and Ideas to Engage Girls in STEM.. ournal of New Approaches in Educational Research, 7(2), pp. 148-153.

Sandberg, S., 2013. Success and Likeability. In: Lean In. s.l.:s.n., p. 230.

statista, 2019. Number of mobile phone users worldwide from 2015 to 2020 (in billions). [Online]
Available at: https://www.statista.com/statistics/274774/forecast-of-mobile-phone-users-worldwide/
[Accessed 117 February 2019].

Stoet, G. & Geary, D. C., 2018. and Mathematics EducationThe Gender-Equality Paradox in Science, Technology, Engineering, and. Psychological Science, 29(4).

UNESCO, 2016. Women in Science - UNESCO INSTITUTE FOR STATISTICS. [Online]
Available at: http://uis.unesco.org/apps/visualisations/women-in-science/#overview!view=map
[Accessed 23 02 2019].

Language and communication barriers

[1]Ines L. T. Ngassam | [2]Ibrahim Balogun | [3]Kayondo Muzafalu

[1]Bundesanstalt für Materialforschung und -prüfung (BAM), Germany | [2]University of Lagos, Nigeria | [3]Stellenbosch University, South Africa

Introduction

When we think about parameters that are considered an important "measure" of the power of a state, most people think of its economy, army or population. However, the culture of a state is also an important parameter to be taken into account. It is impossible to describe a culture without its language. Currently, it is easy to see that some countries like USA and France are respectively concerned about the use of their languages; English will be less spoken on US territory than Spanish in the next years, and France tries to keep French as much as it can with "la Francophonie", having a special interest on the African continent. The importance of the language in research is also visible. Looking back a few centuries ago, when Egypt with Alexandria was the scientific hub of the world, English was not the major language. It was still not the case at the apogee of the ancient Greece or of the Chinese empire. Nowadays, it has however started to move, English often qualifies as the research language, and annual famous university rankings easily highlight this fact. Therefore, it would have been a mistake to have a conference about the development of research and education on the African continent without talking about language and communication. This article deals with the barriers that affect communication among countries in Africa in the research framework.

Why is this topic important?

During the ISEE conference in Nairobi, Kenya, a survey was carried out about the language abilities of the participating audience. This survey showed that of over the 52 persons that responded to the questionnaire (see Table 1), most had at least once experienced a language and communication barrier in their field and felt that this topic must be addressed.

Question		Yes to a.) and b.)	Yes to a.) or b.)	No to a.) and b.)
a.)	Have you ever experienced any language and communication barrier in science, engineering, and research?	21	17	14
b.)	Based on the presentations of this conference so far, do you think it is important to address the language barrier issue?			

Table 1: Result of a questionnaire from the ISEE conference attendee

Various points can explain the need to address language and communication barriers while the evolution of research and education is being addressed in Africa. Some of these points were discussed during the ISEE conference workshop:

Communication in research is vital

A good researcher should be able to communicate his/her research in the same way that she or he must be aware of the studies realised in its field, and to not repeat the same. This is similarly applicable in industry.

The importance to develop collaboration among African countries

Structures like RILEM, and fib show how it is almost impossible to run ones own research alone. Sadly, the collaboration between African countries is still very weak. One of the reasons is that collaborations with developed countries' institutions is highly privileged. Therefore, to be able to establish such structures around Africa, countries should be able to speak the "same language", a common one. Another result of the survey presented in Figure 1 is the large variety of the native languages on the African continent. But according to Professor Mammo Muchie, most of these native languages have the same roots. This is perhaps why some of the attendees of the conference were able to speak more than three of these native languages. Even though English seems to be the international language for the research and based on what is written in the introduction of this article, it should be necessary for African countries to own their language continentally or regionally if they really aspire do develop African research and education.

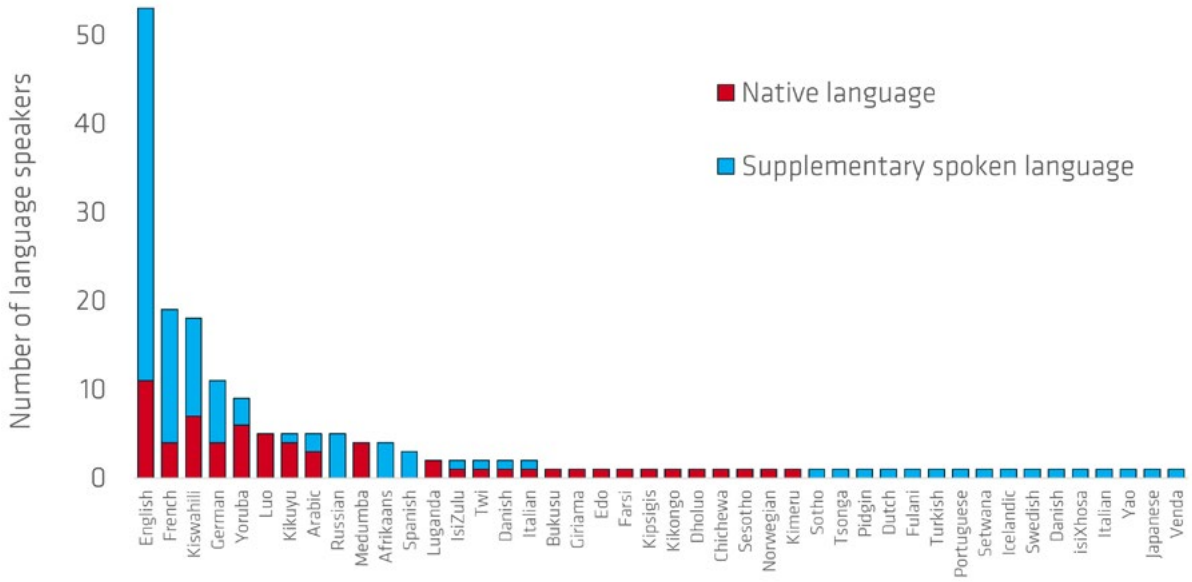


Figure 1: Survey on the number of language spoken by ISEE conference attendee, 2019

To own our culture, heritage, knowledge transfer

Language is a part of the identity of any country, entity, and person. This is why it is so important for African people to reclaim their culture, tradition, values, and languages so that these become the backbone of their research and their education. This will also help to transfer such heritage to the next generations.

Reasons for language and communication barriers

Too many languages, no common unifying languages

Cameroon alone has more than 300 native languages; South Africa has 11 official national languages. This can easily limit communication and exchanges among the continent. However, there are some languages which are spoken in different countries of Africa and even from different regions. For instance, Swahili is spoken in the Eastern Africa (Tanzania, Kenya and Malawi) and in Central Africa, Pidgin in West Africa (Ghana, Nigeria) and Central Africa (Cameroon).

Forbidden native languages and accents

In some African countries, native languages are seen as vernacular and therefore, people/children are usually prevented from speaking these languages. In some cases it is even forbidden. With time, the use of these languages began to phase out and natives began to find it hard to communicate with upcoming generations that were forced not to speak these same languages. This shows the communication barrier due to use of language.

An approach to address this issue

Selection of a common language

The need for Africa to embrace its own languages has been well understood, the only question that remains now is how to teach in African language(s). The African Union has tentatively selected the Kiswahili language as the common language for the whole African continent. The problem of implementation however still remains. Other regional blocs could be selected and used, such as the Zulu or the Ndebele in Southern Africa, Berber in the Northern part, or Yoruba, Pidgin or Peul in the western parts.

The implementation of the teaching of these languages will start by their introduction in curricula. Thus, learning can start early for the children who will learn at least three native languages plus a foreign one. This should easily be realised since children start to learn their parents' languages (one or two), and at school the regional language and a foreign language. When children are conversant with these African languages, it would be easy for them to comprehend courses, subjects in these languages.

Creation of language hubs

Language hubs should be created to improve language versatility and adoptability across the continent. These would help to reduce the language learning price, improve the tourism sector by ensuring easy access of these hubs to everyone who is interested either in towns, cities, suburbs or villages. This should be coupled with

adequate funding for education and health, as these too would help to push and fasten the cause of reducing communication barrier. The responsible parties for this implementation are shown in Figure 2. There is already some initiative around the continent on this topic such as the African Indigenous Knowledge (AIK) (Project by Mammo Muchie) or Hi-tec language translators: Electronic calendar for the revival of African languages (Project of Achille Tchahou and Robert Tchitnga).

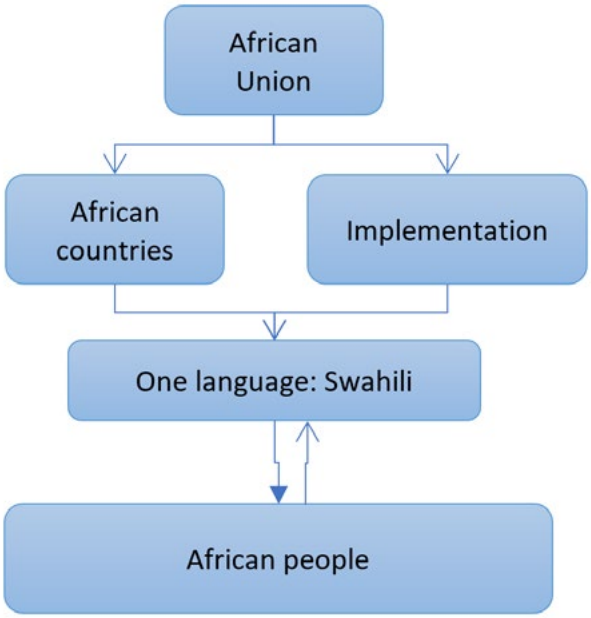


Figure 2: Implementation strategy

Conclusion

Language and communication still remains an important factor in the realization of African research and education strides. Various knowledge from Sciences, Technology, Engineering, Arts and Humanities, etc, should all be integrated into all native African languages. There is thus need to create an African Academy of languages to facilitate this, and to update African vocabularies. The financial independence and strength of the African Union, as well as the willingness of other identified stakeholders will be key in eliminating language and communication barriers on the African continent.

Response

I am Alex Ndibwami, and I was until recently a lecturer and researcher in Architecture in the Faculty of the Built Environment, Uganda Martyrs University, where he was also the Undergraduate Programme Coordinator. His teaching and research interests included: approaches to architectural education; user behaviour and how it shapes or is shaped by architecture and; sustainability in the built environment. Most of this work has been cross (and) inter-disciplinary in nature, encompassing built environment pedagogy, urban policy, development processes and urbanising communities. I am now moving on to settle in Kigali, Rwanda and will be involved in essentially the same areas.

What was your motivation to attend the ISEE conference?

" Two keywords/phrases – engineering education and interdisciplinarity were instrumental in getting me to sign up to the ISEE conference. In addition, the profiles and interviews of the main facilitators scoped a number of issues of interest to me. They addressed issues about curricula and pedagogy that will go a long way in transforming future practitioners.

What was your major private or professional contribution to the objectives of the conference?

" To a great extent through the Q/A sessions, I feel I gave some context about what is going on already and the existing potential of engineering education

with particular focus on architectural education. I was involved in curriculum development as the Undergraduate Programme Coordinator and exploration of different pedagogical processes in an effort to promote better learning outcomes and teaching experiences with my former faculty. Recent attempts and publications on these cover the broad areas of design-build, empathy education and the place of site based building construction workshops. My view of these three areas thus is in the potential outcomes over the future of built environment education in the region and the interaction with society as part of the education process.

How did you benefit from attending the conference? What will it bring you in the future? Were your expectations fulfilled?

" It was rewarding to see and know that there are a number of academics/researchers especially those from Africa that share the same interests. Indeed, my expectations were fulfilled. What is key for me however, in future is how a peer-to-peer review network can be established such that there is a way of checking how far we are able to implement the resolutions from the conference. In addition, even engage exchange visits for best practice where good lessons exist and support where help is needed.

I am Caroline Mwende Athman, a Kenyan citizen with a Bachelors Degree in Civil Engineering from Kenyatta University and joint MSc degree in civil engineering (structural option) from Jomo Kenyatta University of Agriculture and Technology and Pan African University. My research title was "Effectiveness of gum arabic as a superplasticizer in self compacting concrete". I have been a teaching assistant at Machakos University since January 2018. I have key interest in using the locally available materials in solving local and global construction challenges and I am looking forward to doing more extensive research on bio materials with key interest on gum arabic which is readily available in Northern Kenya.

What was your motivation to attend the ISEE conference?

" Being a staunch believer of the rich resources and expertise present in Africa, ISEE conference was the place to be. The different professionals drawn from different disciplines further steered my desire to be part of the conference which would further light the fire for focusing on the next frontier which is Africa. Having already attended the 3rd KEYS symposium for young researchers in June 2017 at the University of Witwatersrand, South Africa which was organised by BAM, made me learn a lot and therefore, when the ISEE conference was advertised, I knew, I had another chance of science and civil engineering exchange right on my door step!

What was your major private or professional contribution to the objectives of the conference?

" My research on gum arabic opened my eyes to a self sustainable Africa still chained by Western dependency mentality. The ISEE conference gave me a platform to share my thoughts on the need for change in African mentality.

The society is rigid on adopting new methods, technology and materials of construction. There is need to sensitise people on the dynamic concepts of engineering and the effects of climate change. The society needs to be educated on other properties of concrete which make it more sustainable and not just compressive strength.

It's not about the biology, it's about the potential, the drive, the input and the desire towards making the planet a better place than it was yesterday! Let's fold the sleeves and STEM.

How did you benefit from attending the conference? What will it bring you in the future? Were your expectations fulfilled?

" A castle is built by joining individual elements! Africa has those elements and by joining hands with Europe, the world would be a sand beach to bask everyday! This is my conclusion from the conference. More of similar conferences across the continent will pull more researchers, professionals on board to build this new fascinating scientific world.

I am Firehiwot Kedir, born and raised in Addis Ababa, Ethiopia. Currently, I am working as a research assistant and PhD student at the Swiss Federal Institute of Technology (ETH Zürich). The overreaching theme of my research is identifying the potentials of constructing buildings using industrialized construction for sustainable resource consumption and its contribution in achieving circular economy. Moreover, it looks into the construction ecosystem such as building codes and polices.

I am hoping to continue carrying out research addressing key issues in the construction industry. Furthermore, I hope to use the knowledge and skillset to propose and implement improvements in construction, operation efficiency and associated environmental impacts.

What was your motivation to attend the ISEE conference?

" Looking at the combination of terms used, Innovation, Science, Engineering, and Education were enough to intrigue me to look into the content of the conference. I knew the addition of education as a key component of the conference meant a broader perspective is intended to be addressed.

What was your major private or professional contribution to the objectives of the conference?

" My current project with Prof. Daniel M. Hall titled 'sustainable transition to industrialized housing construction in developing economies' looks into current and alternative housing typologies, construction materials and methods used in three case study cities, namely Addis Ababa, Nairobi, and Cape Town.

As we have seen repeatedly, the most sustainable solutions do not get enough tractions. This can be attributed to mismatch with the current level of skillset, economic performance, cultural preference, and many more other reasons. A holistic look is needed when identifying problems and solving them. Alternatively, vital contribution also comes from society representatives such as politicians or experts like engineers nudging communities into an optimal solution. The role of public-private partnership is also key in ensuring the successful completion of projects. In the global context, international accords also play a role in initiating action.

How did you benefit from attending the conference? What will it bring you in the future? Were your expectations fulfilled?

" It was an interesting combination of topics that were rightfully addressed at once. The diversity of keynote speakers was impressive. The discussions that followed thereafter were also very intriguing. Attending the conference widened my perspective on the current built environment in Africa and further. Why things are the way they are, what must we not neglect when planning infrastructure, how can we look at not only how to build new infrastructure but how to upgrade and integrate what exists. This does not only require science itself but also innovative thinking that must be learned and acquired by us students and experts in the industry.

I am Natalia Wambui Muigai. The I AM AFRICA national director Kenya and a student at Jomo Kenyatta University of Agriculture and Technology pursuing a course in Bachelor's of Science in Public Administration and Leadership and in my second year of study. My professional aim is to work together with the rest of Africa in creating a more vibrant and united Africa.

My personal aim is to interract with the rest of world in learning and engaging people from all walks of life on how best to build a better world together. I AM AFRICA is a pan-Africa grass-roots campaign driven by the energy and aspirations of the continent's young people.

I want to inspire, educate and engage young Africans to be the solution to Africa's problems. I want to motivate a generation of Africans to accept and assume responsibility for the future of their countries.

What was your motivation to attend the ISEE conference?

" The conference was nothing if not amazing and I am very thankful that I was privileged with the opportunity of attending it. I took it as a chance to acquire more skills that would help me in developing more competences to help in the advancements of my campaign. I also took it as an opportunity to familiarise myself with the engineering and achritectural world and to see how best they could contribute to building the Africa we want. I was also able to increase my campaign network and learn how best to go about it.

What was your major private or professional contribution to the objectives of the conference?

" With being able to interact with professions from different worlds helped me in understanding where the world in specific Africa is heading. Through connecting with many people from different countries and races, I was able to create a small picture of where Africa currently is and how best to engage everyone in the campaign. I am glad that a section of the world is looking for more sustainable environmentally friendly ways of growing and that Africa was also engaged in this discussion.

How did you benefit from attending the conference? What will it bring you in the future? Were your expectations fulfilled?

" Apart from the skills I gained and the networking and the amazing people I met, this conference gave me a different scope on a better way of handling my own campaign. I met a lot of people who were willing to teach me what they know and some were willing to join in the campaign.

It made the Africa's future look a lot brighter, as many were willing to contribute their share in building the Africa we want. My expectations were indeed fully fulfullied and I carried home a lot more knowledge for my engineering friends to use.

My name is Philadelphia Kigera-Patrick Kaniu. I am a Kenyan citizen and I want to become a conscious material engineer. I am currently a 5Th year finalist student at Kenyatta University Kenya pursuing a BSC in civil engineering. My life has revolved around materials and my first internship was at The Ministry of transport and infrastructure-materials section. I had worked for my fees as a lab technician in the material laboratories of Nairobi and Kisumu Kenya before going back to complete my BSC.

I am a poet, a singer, a politician and mostly I am a material engineer in becoming. My concern has been in marrying material colour and material compressive strength. My professional aim is conscious engineering and global sustainability based on a PESTLE model. Can politics marry engineering and produce a baby that is never crying over milky scarce resource here on earth and space?

What was your motivation to attend the ISEE conference?

" My motivation is anything material. Before going back to the university to finish my degree course for ten years I had been carrying home materials of all form, physical, chemical and biological composition. Many thought I was mad, but someone did not believe them!

I was aspiring to attend the conference to meet today Noahs. Today engineers and access the engineering situation as at now and understand global challenges facing the engineering realm in a general PESTLE model. I would also understand the importance of education, the current curriculums merits and demerits and which way to go in the future interdisplinarity or specialisation. Of pure importance to me also was to understand the

nature of occurrence of cement replacement materials, their adequacy and sustainability using future demand curves.

What are the changes necessary to create a sustainable global future and to understand my role as an engineer towards achieving global sustainability was also part of my headache.

What was your major private or professional contribution to the objectives of the conference?

" Privately, I asked one professor about the relationship between material colour and compressive strength. I do not think she was evasive, she just did not have an answer! My personal skill is to through experience look at a material colour and predict its strength before lab tests. The only professional skills I possess and possessed were the contributions by the professors at the conference. Even if they do not come back to Africa, I think they left their mind in Kenya.

The battle between sustainability and the world the curriculum and society is a behemoth and the solutions lie in the problem. There is nothing wrong with the current world, curriculum or society but the problem is their insufficient sustainability for the coming generations. Language and communication barriers can be solved by children learning a foreign language and sign language. The curriculum must include soft skills, software design, leadership, emotional intelligence and writing skills for researchers, who must translate research into developmental projects.

How did you benefit from attending the conference? What will it bring you in the future? Were your expectations fulfilled?

" I think I wrote the most! Not to say I understood the most because I am still going through the notes I took from the oldest professors to the youngest students. I learnt so many things from so many people. This does not mean that I did not learn from my excellent supervisor before, but this time the experience was real and tangible.

I learnt that I can make an engineer and a politician to fit into the global business environment. I learnt discipline and professional beauty and to encourage women to study STEM who often do not get the adequate respect they deserve in many cultures. Further the gap was discussed between basic and applied research. Here I paused and reflected on the viability and fundability of my own research and projects on water wars and the investigation of whether rice husks ash can treat contaminated water to avert water borne diseases.

Response continued

"I would like to congratulate you on the success of the ISEE Africa conference. I am very happy to have attended a not so common conference with such relevant topics and an amazing group of people. Thank you for this unique opportunity, I'm looking forward to meeting you all in the next ISEE Africa conference.
Yazmin Mack Vergara, Panama

"It is just beginning to sink in what an incredible event I was part of this week. Especially the young African women, were truly an inspiration. I really hope we can take it forward and I hope I can support.
Karen Scrivener, Switzerland

"The event was an absolute highlight, especially for the younger people. To see them integrating so enthusiastically, thinking through the issues, and engaging with a range of challenging topics was a rare treat. I have no doubt these young people went away highly inspired for the future. The challenge now is to turn this into something more long-lasting and impactful.
Mark Alexander, South Africa

"I appreciate the energy and passion that all the delegates had and they were very welcoming!
Krystina Nyamache

"To say the least that was one of thought-provoking conference I have ever attended. Speakers touching on different topics from cement to education to utilising spaces as defined by communities left my mind with roller coaster ideas on ways we can be more innovative in teaching and practising Engineering. Thank you for the well-chosen speakers who had different and awesome topics focusing on Africa as well as global issues. The conference made it very clear that engineers need to interact with people from other disciplines to have a meaningful change and innovation to civil Engineering education and research. I hope we the people who attended this conference can start the to make changes in our small spaces and hopefully infect others. I wish our policy makers can attend this kind of conferences.
Rose Mbugua, Kenya

"The conference was a huge eye opener and made me see the world of construction from a different perspective. Looking forward to working with you when the opportunity arises in future and keep up the good work you are doing to make the world a better place.
Jonathan Situma, Kenya

"This was by far the best organised, widely networked and most engaging conference I have ever attended.
Loudon Luka, Malawi

"For me and my students ISEE was an eye opener.
Moses Opiyo, Kenya

"It was a great experience for me, having been benefitted with knowledge exchange, mentorship and opening for future networking opportunities.
Ibrahim Balogun, Nigeria

"The conference was an eye opener for me given the honest fact that I wish to become a conscious material engineer.
Kaniu Patrick Kigira, Kenya

"Thanks for the ISEE conference. It gave me a chance to interact and build friendship with a lot of people beyond my country's boundaries.
Vusumuzi Malele, South Africa

ISEE compact

The ISEE conference brought about a lot of discussions. Many conclusions and statements were heavily discussed, depending upon multiple parameters, such as global region, cultural background, normative framework, and many more. This shows that technology learning and teaching can function in many different ways and that no single ultimate best practice exists. Nevertheless, and despite the ambiguity among the speakers, discussion leaders and audience from all generations, all career levels and all nations a few simple common solutions could be found.

Without any doubt today's curricula in architecture, civil engineering, and materials science do not satisfyingly prepare students on the following aspects:

- Entrepreneurship
- Social responsibility
- Environmental awareness
- Adaptive thinking
- Digitalisation

These simple items which are so relevant are too often neglected, although they would lift the chances of students to develop an independent, responsible, and flexible career path. In order to teach the right messages and equip the students with the right tools, it is required to also change the way of teaching.

Many methods were discussed and debated, and what applied for the content also applies for methods. Multiple ways can function, and no single ultimate best practice solution exists. Nevertheless, a few common conclusions were agreed upon:

- Teaching has to be up to date, using contemporary tools and methods
- Teachers have to be skilled and equipped with pedagogic knowledge
- Teaching has to be in the language of the students

In conclusion, contemporary teaching is not marvel, but future oriented engineering education requires more emphasis on the development of conscious personalities. Like a good medical doctor needs more than just medical knowledge in order to effectively heal a patient, a good engineer needs more than equations to solve a problem to the benefit of the societies and environmental frameworks she or he is acting in. In order to get there, teachers, university administrations and politicians have to step out of their comfort zones, invest time and invest money. Considering the pressing social and environmental challenges in the world there is no better investment today than into education of the future generations.

Entrepreneurship

The best technology solutions will fail, if they are not marketed and do not bring economic value. Particularly in economies with high unemployment, technically skilled personalities that can economise their technologies are backbones of sustainable development. Business opportunities are the best way to keep talents on the ground.

Social responsibility

Architects and civil engineers coin the appearance of human habitat like no other discipline. While architectural students typically come along with a sense of beauty, engineers often neglect the impact of their actions on the society. However, engineering means thinking in systems, and this should include the human societal system. The cheapest or best technological solution, if it neglects the demands of the people, is not automatically the most people-friendly solution, but if it is not, it cannot be the best solution.

Environmental awareness

No other area but construction has stronger impact on the global environment. Engineers exploit massive volumes of global resources, which are processed and re-shaped with tremendous influence on the global environment. Typically, engineers do not automatically leave university with the awareness of their global responsibility. However, this awareness is key to changes.

Adaptive thinking

Standards vary from region to region, they are adapted over the course of time, and they serve to the stakeholders and societies in which they are applicable. Furthermore, standards are written to govern existing technologies and, hence, by nature they cannot regulate future technologies. Today's engineers have to operate in multiple regional environments, and they have to adapt to rapidly changing knowledge and technology. While standards can be quickly internalised in an engineer's career, academics should reflect whether a university is the right place to teach standards, or whether they better prepare students to cope with future challenges.

Digitalisation

Unlike most people responsible for curriculum development and educational policies, students today are all digital natives. Hence, university education should not focus on how to deal with digital tools in an academic way. Most students will know much better than their teachers how to use them, but digital tools should be part of lectures as a matter of course.

Reflections

The ISEE conference had a strong focus on education for innovation and sustainability in engineering, science, materials and architecture. During the discussions after keynote talks and during the workshops certain questions arose repeatedly that do not directly affect engineering and science education. Rather can they be linked to it indirectly on a larger societal and global scale.

These were questions such as "how can knowledge be transferred into society?", "how can technology create markets?", "how can science and education cooperation be facilitated?", "what is the impact of role models?", "which biases affect technology development?", and many more.

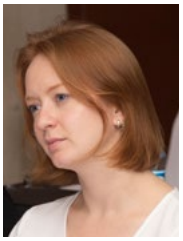
To give these topics a space, in this chapter some thoughtful reflections are presented that were addressed during the conference. The reflections are individual short essays by single or more authors. They are a real and tangible output of the conference, as all the essays were written after the conference, on reflection of conference. The reflections are driven by the motivation to express and share some thoughts that can complement the content in this book.

They represent the authors' personal opinions and are written in individual text styles. They may appear humorous or sad, very personal or rather generic, polarising or commonplace, but their common ground is the attempt to spark reader's reflections.

ISEE Reflections

A sustainability point of view on horizontal and vertical urban growth

Wolfram Schmidt | Jule Anniser | Kuukuwa Manful

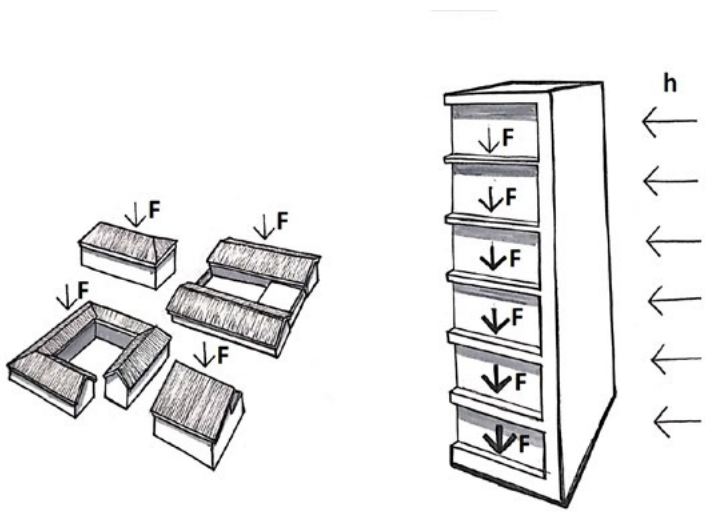




In many regions of the world the urbanisation process is accelerating dramatically. This puts pressure on urban planners but also politics to develop strategies for sustainable city growth. With the rapidly increasing demand for living space in urban areas, cities typically grow vertically. This is largely driven by real estate markets and sometimes also by the desire for status symbols.

Certainly, vertical urban growth makes sense, when horizontal growth destroys important flora and fauna (e.g. in rain forest regions), but in many cases vertical growth is result of real-estate business and expansion limitation due to state or country borders. However, economics and borders are made by humans. They follow human-made rules. Gravity does not. Therefore, from a point of view of sustainable materials and resource use, the trending vertical growth of cities may come under scrutiny.

The following aspects should be considered, when a decision is taken between a new quarter with limited number of storeys or a new skyscraper.

Material demand and technical specifications

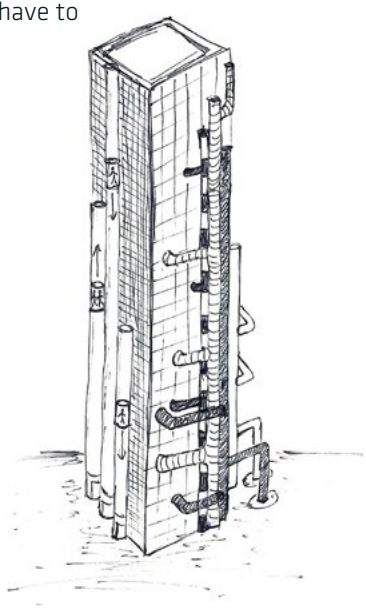


The volume that needs to be surrounded by materials for walls and ceilings or roofs is identical, whether single units are build or units are stacked. Nevertheless, in case of a skyscraper the cumulative loads of each unit have to be considered. In addition, horizontal loads like wind add a severe momentum that is negligible in small buildings but very high in large structures. In total, this demands for either larger cross sections, thus more materials consumption, and materials with higher strength specifications (e.g. higher reinforcement degree and more cement). Hence, vertical city growth automatically demands for more resources.

Infrastructure requirement

Both, vertically or horizontally grown cities demand for infrastructure. Only in vertical structures, this is often not so visible. However, also the top storeys of skyscrapers have to be accessible by elevators, they need to be supplied with water and energy and their waste has to be disposed of.

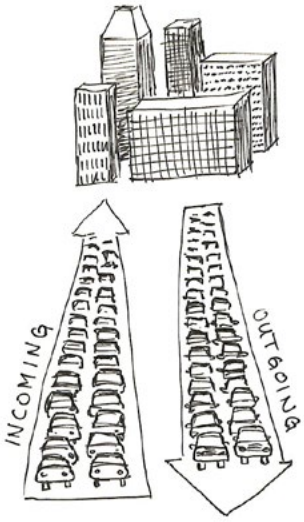
The difference is the energy demand. Horizontal infrastructures largely only have to overcome frictional forces. Vertical structures have to additionally overcome gravity forces, which can even help to save energy in horizontal infrastructures (e.g. in water supply and sewage management).



Traffic management

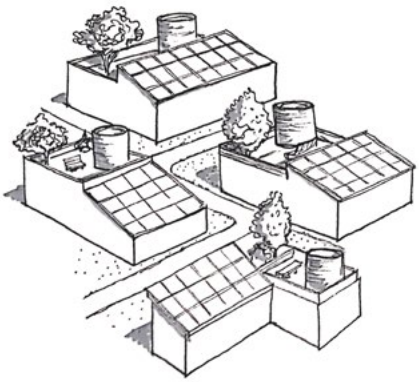
Vertical structures centralise work places. People have to approach and leave their work every morning and evening, respectively. This happens every day and often over long distances, since residential areas and business centres are typically far away. This inevitably causes inefficiencies, since many people waste lots of time stuck in traffic jam, time they could better spend with families. And even a highly efficient public transportation system runs significantly below its capacity outside the peak hours in the morning and the evening. Permanent traffic congestion, that can be observed in cities like Lagos, Douala or Dar es Salaam, causes avoidable hazardous exhausts and carbon emissions, but it also has a social component, as both, daily business and private life have to be synchronised and adjusted permanently with the urban traffic.

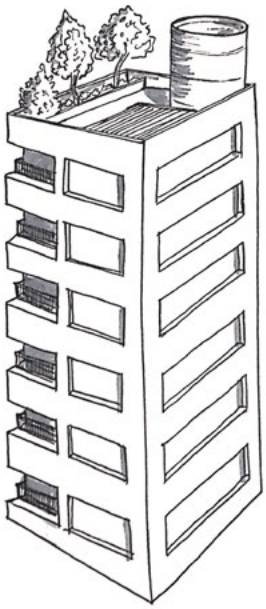
In horizontal structures work places are dispersed. Business and residential areas can be merged, which makes it easier for people to live close to their work place. The traffic can be more diversified, shorter distances are possible, and more people can can opt for means of non-motorised traffic.



Potentials for environmentally friendly technologies

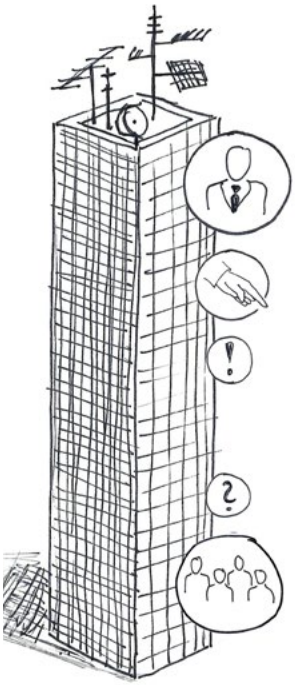
Roofs can be useful spaces for either living or environmentally friendly technologies. Roofs can be covered with solar panels, they can be water supply, or they can bring back some nature into cities with green roofs or urban farming areas. Horizontally grown urban areas provide much more potential and versatility for efficient use of roofs than vertical structures.

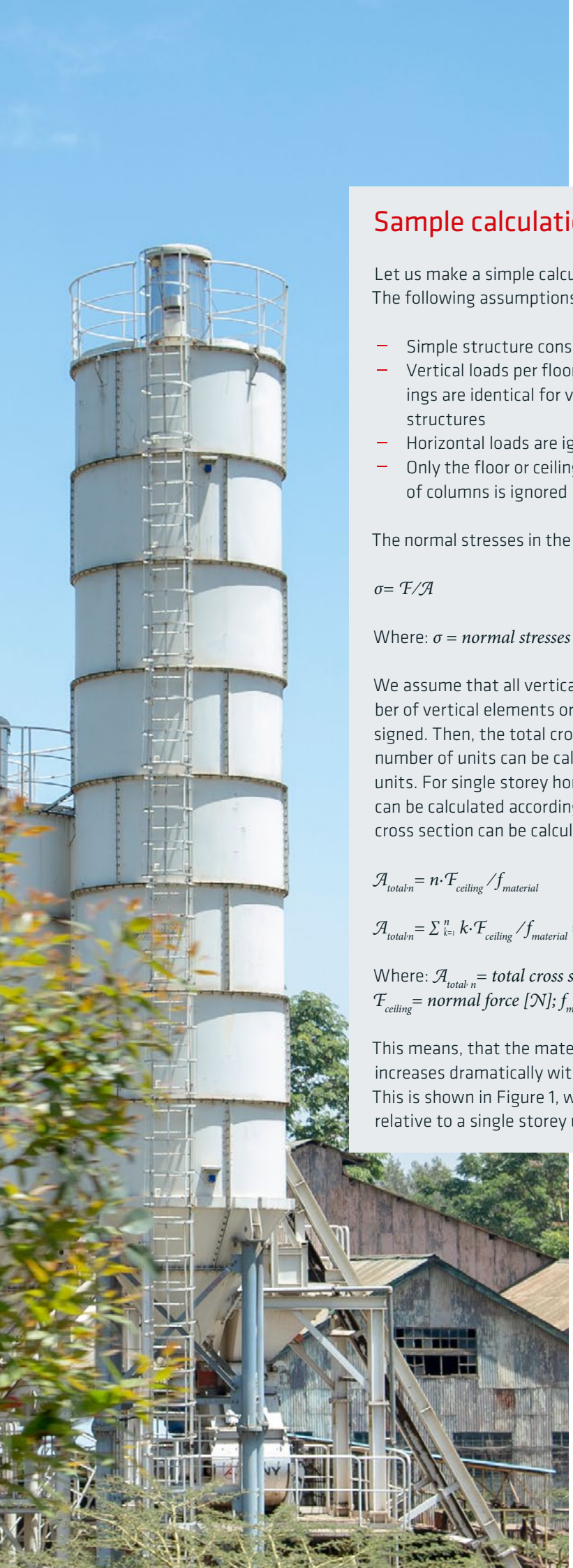




Communication and social cohesion

In vertical structures the major communication direction is also vertical. Not seldomly the storey number correlates with either wealth or power. In horizontal structures the communication options are diverse and at eye level. The multi-lateral communication without symbolic hierarchy and power demonstration can be a spark for local business and public activities that strengthen the social cohesion.





Sample calculation

Let us make a simple calculation on a very simplified system.
The following assumptions have to be made:

- Simple structure consisting of only ceiling or roof slabs and vertical columns
- Vertical loads per floor including traffic loads and structural loads from ceilings are identical for vertically stacked structures and horizontally dispersed structures
- Horizontal loads are ignored
- Only the floor or ceiling structure contributes to vertical loads, the own weight of columns is ignored

The normal stresses in the columns are calculated according to the simple equation 1.

$$\sigma = \mathcal{F}/\mathcal{A} \qquad (1)$$

Where: σ = *normal stresses [MPa]*; $\mathcal{F}$ = *normal force [N]*; $\mathcal{A}$ = *cross section [mm²]*

We assume that all vertical elements consist of the same material, and the number of vertical elements or the dimensions of the cross sections are not overdesigned. Then, the total cross section for vertical elements depending upon the number of units can be calculated for horizontally dispersed and vertically stacked units. For single storey horizontally dispersed buildings, the sum of cross sections can be calculated according to equation 2. For vertically stacked units, the total cross section can be calculated after equation 3.

$$\mathcal{A}_{total \cdot n} = n \cdot \mathcal{F}_{ceiling} / f_{material} \qquad (2)$$

$$\mathcal{A}_{total \cdot n} = \sum_{k=1}^{n} k \cdot \mathcal{F}_{ceiling} / f_{material} = (1+2+3+4+\ldots+n)\mathcal{F}_{ceiling} / f_{material} \qquad (3)$$

Where: $\mathcal{A}_{total \cdot n}$ = *total cross section for vertical elements [mm²]*; n = *number of units*; $\mathcal{F}_{ceiling}$ = *normal force [N]*; $f_{material}$ = *Material's compressive strength [MPa]*

This means, that the material requirement for the structural vertical elements increases dramatically with every stacked storey compared to single storey units. This is shown in Figure 1, which is independent of the material, as it is expressed relative to a single storey unit.

Since for cement, within certain limits, the strength of concrete also depends on the cement content, the same picture would apply in case the cross sections are kept identical but higher strength concrete is used for the lower storeys. Without the simplifying assumptions the difference would become even more dramatic.

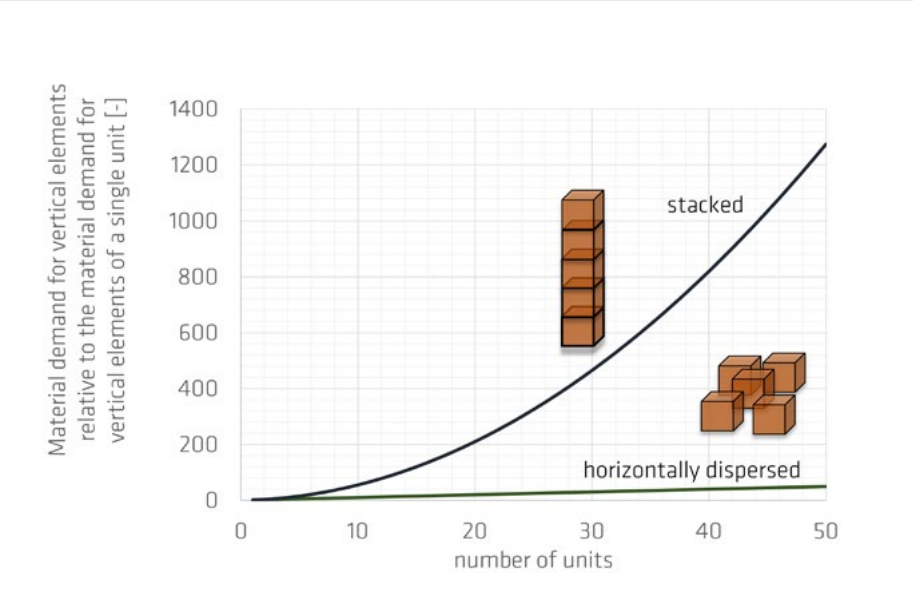


Figure 1: Cement demand for vertical elements of stacked units compared to horizontally dispersed units depending upon the number of units

For a ten storey building, thus, the carbon emissions for vertical elements are 5.5 times as high as for the same number of units horizontally dispersed. For a thirty storey building, it would be already 15.5. times as high. While these number sound dramatic, it has to be considered that the vertical elements often only make out 5% – 10% of the total material volume. However, for a ten storey building this still means 22.5% – 45% and for a thirty storey building 72.5% – 145% higher carbon emissions in comparison to the same number of units, horizontally dispersed.

ISEE Reflections

Learning from the future – how children of Mukuru fancy the city of tomorrow

Meike Barucker-Sturzenbecher | Wolfram Schmidt

Major traffic axes are colourful and tidy

Sustainability means meeting the needs of today without compromising the needs of the next generations. How can we meet the needs of the next generations, if we do not even know what these needs are? If we do not listen to the next generation and learn from them? Do we even meet the needs of today for everyone on earth?

Esther Kamaara, who founded the Star Kids Initiative, a home that provides mentorship and a place to be in Mukuru for street kids, gave us the opportunity to meet and learn first-hand about the children's utopia of the city of tomorrow.

Above the roofs of Mukuru

Esther took us through Mukuru. An overwhelming moment for most Europeans, who are typically not familiar with the impressions, and typically only know pictures of slums from newspapers and television. The expectation, then, is to see colourless huts, malodour, dirt, disease, pure poverty, and sad, hopeless people. Expectedly, all this can be found behind the shelters made of corrugated metal and stacked blocks. The more surprising is the first impression: many facades are painted in colour, blue, pink, red, green, in between clothes lines with colourful dresses. The residents are not running around erratically. Those who can be seen are busy. Colourfully dressed women walk determined, elder siblings care for the younger ones, hand in hand. Men engrossed in serious communication. We see chemist's shops, general stores, mobile phone shops, coal dealers, and hair salons. The major roads are well-structured and clean, beautiful in a fragile way. Hardly any plastic rubble can be found – the result maybe of the environmentally conscious decision of the Kenyan government to abolish plastic bags.

Nevertheless, the perception of this artery diverges from the truth behind, where families live in tiny, ramshackle shelters without sanitation and electricity. The open canals and gullies are sewerage and waste disposal. The children wear worn out clothes, often with no shoes or shabby plastic slippers. They have runny noses, many have lost gazes without much expectation.

Street is the place to be for the children

It is Saturday. School is closed. The kids are sitting on edges in the street, mostly in groups. Maybe, together they feel stronger, less exposed to the risk of abuse and violence. For us who grew up in Germany, it gives a disturbing feeling, not knowing whether looking at them could be perceived as respectful or disrespectful. Realising to apparently have everything while others seem to have nothing, the stroll through Mukuru feels like violation of the inhabitants' privacy. None of the children comes to solicit, they just stare at us. No appeal, no surrounding. The camera stays in the bag. It does not feel right to take pictures, unwanted, like starring at an attraction. Yet, we take a few decent shots with the mobile phones, as it seems too urgent to show back home, how life can be, how the real world is like, in other places. The facades in the central roads may look colourful to us, but it cannot plaster the daily struggle of the people behind it.

When we entered the Star Kids campus, it was like a small beautiful island within an ocean full of hardships. The kids had space to play, run around and mingle with each other without disturbances. The tutors were caring and full of love, and it seems they knew all the children's peculiarities and stories and gave special attention to it.

Diligently, the children craft their dream houses

When we went to the classroom, the kids were only reserved in the very beginning, but after Esther's warm-up exercises, the kids were very sociable with no fear of contact. They were quickly very warm and welcoming, full of heart-felt interest.

The kids were given all kind of handicraft tools such as scissors, glue, paper and pens and the task to create their individual utopias of the city of the future. For about one and a half hour, they created, built, cut, formed and drew all kinds of houses, vehicles, and structures that came into their minds. The results were very variable in their appearance, but the expectations were very similar, just varying in the location, where the houses were supposed to be built, in town, in nature, in wildlife, or close to the sea.

After handicraft work with paper, some material experiments were conducted with mortar

The utopias of the children were smaller than expected. No exaggerated skyscrapers, no speedy vehicles, no

The children created small cosy places where they feel they belong to

impressive underground structures, but rather small and cosy places where they feel they belong to. Just with a little bit more space for their parents, siblings, and best friends, maybe a tree and some animals, and in addition tiny items like stairs in front of the house or a separate cooking place.

Their expectations were so low compared to the utopias of the children in the developed countries of the Northern hemisphere, yet, it was tangible that most of these kids will probably never even experience this tiny little expected betterment. They are too far away from the focus of global and local politics to benefit from any economic upswing. They seek for small portions of luck, a small business like a hair salon, a small hostel or a shop.

When we talk about sustainability in a political, economic or scientific context, we always sit high up in the ivory tower, we use numbers, statistics, technical data, predictions. These kids on the ground are real. Their utopias are the utopias of about one third of the global population. They do not have a voice, they do not have a choice. They are typically forgotten by those who define sustainability.

But if we want to take the word by its meaning, we must accept that they are the generation, whose needs must not be compromised by our today's behaviour. Without any question, it is inevitable to develop and find concepts for the sustainable use of global resources in order to maintain climate conditions that keep the Earth a comfortable place to live also in the future. However, for a large part of the population, the Earth already today has never been a comfortable place to live on, with or without the threatening climate change.

If sustainability means meeting the needs of today without compromising the needs of the next generations, it automatically includes the concern about today's generations. And already today, the demands of large global population parts cannot be met. Sustainability always starts here and today. It starts with our children, it starts in our neighbourhoods, and it starts with including those who are marginalised in our societies. This should be the driving force for us to act, tomorrow anyway, but already today.

Small portions of luck, a small business like a hair salon, a small hostel or a shop

Star Kids Initiative

Kenya is often considered as paradise with its extraordinary sunsets, diverse wildlife and breath-taking landscapes. However, the reality for most people in this country is less romantic. Kenya has a population of 44 million people, 42% of which, unfortunately, live below the international poverty line. As a blossoming product of the state, this statistic weighs me down. Heavy hearted, I founded Star Kids Initiative, a community-based organization that exists to provide children from urban slums access to quality education, in a bid to have my own significant share in mitigating poverty. In five years, Star Kids Initiative has partnered with four schools in Nairobi, impacting 1973 children. We run a bi-weekly mentorship program that focuses on exposing kids to life outside of the slums through experiential mentorship sessions, inspirational trips to landmark destinations, training in economic empowerment and life skills. We also run a scholarship program enabling up to 30 children to remain in school. Beyond this direct tuition support, we believe the children's learning environment contributes to the quality of their experience. We therefore support infrastructural projects in our partner schools. We have facilitated the refurbishment of a library, toilet facilities and most recently, an ongoing playground development project.
Esther Kamaara, Founder of the Star Kids Initiative

ISEE Reflections

Africa brain-drain and brain-gain continuum

Nonkululeko Winnie Radebe

Proverbial greener pastures (i.e. the USA and western Europe)

Brain-drain is often discussed in the light of the emigration or the loss of skilled labourers and professionals from developing countries to their relatively more developed counterparts. Very rarely, if ever, is it considered as the migration from one developing nation to another because that is seen as a lateral move. However, South Africa is unique in that within Africa it is considered one of the most developed countries which means that other Africans are likely to and do in fact migrate to South Africa as skilled labourers.

The irony is that in as much as it is a gold mine to other Africans it is a sinking ship to many of its own citizens. South Africa like many developing African countries has very limited economic freedom, which means that people are constantly looking for opportunities for a 'better' life. This either manifests itself as people moving to urban areas and overpopulating the cities. Or moving to another country where urban areas are perhaps just as overcrowded but have more opportunities for growth. It is of my opinion that Africans who move outside of Africa to other continents often move with the intention of someday coming back. However, when one leaves without having had adequate medical coverage, access to opportunities, or even safety and security it is believable that they would be hesitant to return to their home country once they have accustomed that level of comfort abroad. Most people do not consider 'downgrading' their lifestyle for the sake of being patriotic. This is obviously not the case for everyone who leaves but it can be generalized that people migrate because they imagine proverbial greener pastures or at least short-term opportunities that will catapult their careers.

Intracontinental brain circulation?

To the question of why Africans, on average, do not move to other African counties has a simple answer. Lack of opportunity. This combined with political unrest, limited intercountry knowledge and economic stability can discourage intracontinental migration of professionals. However, even when opportunities do present themselves well packed with the safety and economic reliability stamp, there are still some hoops that are more difficult to manoeuvre. This result from the restriction of movement of people, goods and services due to closed borders between African countries. Nearly all Africans require visas for both long-term and short-term stays to other African countries with the exception of countries within regional economic communities such as the ECOWAS, SADC and countries such as Kenya and Ghana leading the freedom of movement campaign.
I would imagine that these kinds of restrictions are discouraging for researchers who would like to take part in collaborative studies or short research visits. It is very possible to spend the same, if not more, time preparing for the stay than the stay itself will take you. These kinds of systematic hinderances, combined with the lack of infrastructure, economic stability, and general safety boosts Africa's brain-drain problem.

The tyranny of the urgent

In truth, it is difficult to develop future-focused strategies, formulate and implement policies on regaining brains when you are faced with more dire issues of poverty, inefficient health care systems, good elementary education, and inequality. Many governments in Africa are on survival mode and remain that way because of the discontinuous nature of the political landscapes. Countries with National Development Plans need them to be implemented within defined timeframes and followed to the letter. This is not possible in countries where

there are shifting political interests and continual reshuffling of governments and officials that often nurse the needs of the corrupt few. It is discouraging, to say the least, to expect such governments to take the lead in bringing back questioning minds that will help grow the economy. It's all about the votes, and the more uneducated the voter, the easier to manipulate them into thinking the plans you have will benefit them when they are only there to keep you in power. However, the domino effect of viable economies and stable democracies results in brain-gain.

As a South African who is building a career within the field of science, it is important to consider that when I go back home, I will only have my two feet to stand on. There is no institutional system in place that will accept me with open arms to ensure that my plans for growing the science and technology reach are possible in my community. I have to return home with a solid plan of integrating myself back into society and contribute positively. I do however imagine that this is easier said than done because of a little thing called inertia. I now live and study in Germany and being here comes with many opportunities, many of which are based in Germany. Therefore, I imagine that when I do finish with my studies, I may apply to a job that pays well. Well enough for me to be able to send money home and sustain a comfortable life. Twenty years down the line, I am may still find myself in Germany. I say all that to say this, the intention to go back home is hindered by many factors and unless a few of them are resolved, people will remain despondent to move back to their home countries.

Changing the gear

A car in the first gear, cannot be expected to compete in a formula one race because its maximum velocity is low and clearly limited. So, like a car, countries need to shift to higher and better gears to get the best out of its human capital. Essentially, it is the responsibility of the citizens of the countries to make it conducive for them to go back home if they see the need. It's not all doom and gloom because there are initiatives like MoveMeBack and Homecoming Revolution which are Nigerian and South African based, respectively. This target experienced labourers and highly skilled African professionals. They assist them in the move back home by searching for good schools for their children, suitable employment, investments and entrepreneurial opportunities within mostly the financial sector. Similar initiatives are needed for other sectors like science, engineering, research or the arts. These platforms may very well already exist. However, without a collective effort from different stakeholders like the professional, policy makers, governments, other influencers and beneficiaries, it is not feasible to expect such initiatives to work efficiently and to their maximum capacity. Essentially for this gear to be changed, all parties need to contribute.

ISEE Reflections

Research networks and strategies in an increasingly globalized world

Inès Leana Tchetgnia Ngassam

Since I left my country just after high school, I do not have a personal African experience on graduate studies. However, for a couple of years, I had the chance to frequently be in Cameroon, to interact closely with some Cameroonian PhD students, academics and researchers and to be involved in some collaborative projects between Europe and Africa. I also had the chance to work for 2.5 years in an African University of highest renown in South Africa and to interact with many people from all around the continent. This aroused some of the following thoughts.

Globalization vs. culture and tradition

Nowadays, globalization is generally seen as 100% positive. As a result, there is a trend to do the same things or to have the same behaviors all over the world, despite of the cultural, traditional or environmental differences. In fact, too often the so called "developed countries" are the ones to give direction to the rest of the world. Sadly, in the same way, the "developing" countries tend to copy these countries blindfold, because of a silent but present inferiority complex and the constant thought that "what comes from abroad is always better than what is local".

For instance, the standards used in most African countries are either from developed regions or their copies. However, luckily this is not the case for the whole of Africa. The Southern part has developed its own standards and I can observe a certain level of collaboration between the countries in this region. From my point of view, the most important damage of the excessive globalization is extinction of some cultures and traditions, which are rich in knowledge, science and which could possibly solve many local problems. Let us take the example of housing. This is still a major issue in many parts of Africa. Due to the price and the misuse of cement it is still a big challenge for citizens with an average income to build a decent concrete house. However, there are many traditional construction techniques and materials that can be much cheaper, but they are denigrated and, thus, not really studied.

Fundamental research vs. applied research – what is the best for a developing country?

From what I have observed in too many cases in Africa, there are still a lot of research topics which are too fundamental. My point is not to say that fundamental research is not important, it definitively is! However, I believe that applied research is more important, simply because it can solve current issues quickly. It will show the importance of research to the communities, thus, it facilitates its permeation into the society. Moreover, regarding the way research is organized and considered in some countries like mine (Cameroon), it is utopia for an African scientist or academic to dream of a similar career as it would be possible in a developed country; with same facilities and without lifelong sacrifices. There is a lack of equipment, funding, the government does not care about research and on top of that, the economy of the country is still struggling. Eventually, the government does not pay employees adequately.

So, why do most PhD students or researchers and academics ONLY run for a position in a governmental institution instead of thinking to create their own business for instance? This could be a solid way to build a real collaboration between the research field, the academic field and the industry. This is what is desperately missing from my point of view in Africa, and it could have a high impact on the economy.

Collaboration between developing and developed countries in research

There is a lot of programs, calls for grants, funding "sponsored" by the developed countries for Africa. They are all commendable and my point is not to put all of them in the same box. I really appreciate the ones that offer possibilities to African researchers to set up their own lab in their home countries. Sadly, research in Africa does not seem to progress that much, while there are new calls every year. Maybe the approach is not the right one. I remember exchanging with some 1st year PhD students in Douala few years ago. One of them explained me that they must always change their research topic according to the call they wanted to apply for and their hope was to be accepted in a program that will give them the possibility to leave their country. Another observation is that African research organizations and universities still put a lot of energy into finding collaborations with non-African ones. What if they were focusing on working together and to develop an African research philosophy? This will surely be more efficient to reduce the brain drain of the continent and to focus the research in Africa more on the actual need: the development of Africa.

To conclude, from my experience as young African female researcher with experiences in Africa and Europe, I agree that there is a lot of issues that slow down research in Africa (lack of everything, poor governance, etc.). However, I believe that those issues will only be solved when we Africans will stop complaining about them, when we will count on the other African countries, when we will start to believe in our own capacity to solve our own problems, which means counting on our own strategy, our own resources, funding and our own people. There is an urgent need to change our mindset. As much as the Cameroonian experience is valid for Cameroon, and other countries may be different, some aspects are shared among most African countries and often neighbors share similar conditions, which may deviate strongly from regions in other parts of the world. Therefore, there is no point trying to globalize everything everywhere. To me it does not make sense to enforce a mindset, principle or way of working in a far-away region without really knowing the local realities.

ISEE Reflections

Research in different environments – experiences from two continents

Solomon Adomako

The knowledge and scientific research gap between Africa and Europe served as personal benchmark for my travel oversees to pursue academic work. After some years abroad, and moving from one country to another to study, I can confidently say, my travel is worth it. Africa's research capacity is insignificant, partly due to low commitment both from the government, and private institutions. The despondency as a result of Africa's failure in human, and research for development amidst her incomparable wealth signifies her total disregard to developing the continent. Comparatively, Europe, a continent with insignificant wealth has demonstrated a remarkable research capacity that is honored by the world. Spates of scientific development begin majorly from Europe, and history tells that the continent is a hallmark of excellent scientific research.

A question rises about the growing number of graduates, who literally become incapacitated, because of the indirect dreadful-nature of education and research environment in Africa. Growing up in Africa, I observed that a lot of graduates couldn't put into practice as research module what had been taught in school. As result, Africa's market never encouraged the "can do" spirit, let alone to trust small and meaningful beginnings of these graduates- which I belonged. Realistically, low research input sparks no enthusiasm to pursue research career on the continent. Imagine doing research with no incentive motivation, and recognition of scientific results. This demoralizing status governing Africa's research environment gives a solid impression to look elsewhere. Research is purely a practical outlook into subject matters. This means facilities are indispensable. I wonder how young researchers like myself could succeed in a scientific environment that lacks necessary equipment to carry out research; such was the case when I started out in Africa. This indeed is defective. Research career in Africa is stigmatized due to these reasons.

Europe has a peerless scientific research policy aimed at sustainable development across all sector. This I believe, is why there is high spate of development. For example, in Germany, DFG (German Research Foundation) established and funded by the government, oversees research affairs between academic and non-academic institutions. Africa must begin looking deeply into research policies established in Europe and to follow-suit. Unquestionably, research career in Europe is flourishing because of high monetary investment, and practical demonstration of scientific results on the ground. Bringing such measures to bare in Africa shall revamp her research system and make the continent great.

ISEE Reflections

Biased by analytical equipment

Wolfram Schmidt | Nonkululeko Winnie Radebe


Today, in scientific events often a certain separation between researchers from laboratories with highly sophisticated equipment and those from less privileged laboratories can be observed. It is not an uncommon situation that results presented at conferences are rubbished or ridiculed because the investigator only used low-end analytical methods. The assessment of the study is then biased based on the equipment, regardless of the actual quality of the study.

There are also many similar biases regionally, e.g. regarding gender, origin, age and hierarchy or position, etc. Nevertheless, the difference is that (fatal enough) the latter biases are rather regionally or culturally driven, while the perception that high-level research requires high level and often exclusive equipment seems to be global. This can lead to a situation that excellent research on a highly relevant topic, but with standard methods, is often considered as unsound and will be less appreciated in the scientific community than poor research on a topic with negligible relevance and lower excellence, only because the latter study used some fancy and scarce equipment or a device from a certain producer. While this equipment battle also affects institutes within one and the same country, institutes of the global South are automatically more dramatically affected, since the investment in research is generally much lower. This gives a perceived higher credibility to institutes of rich economies, regardless of the quality of the scientific approach or the ambition. In return this sets back the ambitions of many excellent researchers from developing countries, who give their best to provide the best possible results within their environment, and despite all the limitations.

In many African countries it is very common to have universities with professors who teach, and only teach. Scientific output is strongly limited by the lack of equipment that is standard in European or an American universities. For example, a Fourier Transform Infrared (FTIR) Spectrometer is a basic piece of equipment used to do structural analysis in a fast and efficient way. It is also considered relatively cheap compared to more sophisticated techniques like Nuclear Magnetic Resonance (NMR). Nevertheless, spectroscopy is unavailable in many universities across the African continent. Unless you are either fortunate enough to be at an institute that has such instruments or know someone who works in such an institute, you are likely to never see or use a spectrometer in your studies. In such extreme cases, researchers have to opt to do mostly theoretical studies or reviews. In as much as there is a real struggle for equipment, it is not to say that science is still not being done through collaborative methods. The top three universities in Africa are all in the same country and even there, researchers are constantly reminded of the cost of equipment. In as much as this could make you a cautious researcher, it can hinder you from exploring different ideas because of the cost factor being a burden. However, with or without the expensive analytical method, solid scientific output is still possible, and this needs to be acknowledged.

The needlessness of arrogant manners for working in a sophisticated laboratory environment is getting very clear, considering that most fundamental scientific milestones were made more than 80 years ago with equipment that today could only be described as shabby and antique. Yet, we admire the brilliance and clarity of the researchers of these days. In fact, we admire them, because they were excellent researchers with incredible intellectual properties that made the maximum of their capacities within the given framework. In this context we must not mix up research excellence with excellence of the laboratory facilities. In other words, excellent equipment does not automatically make an excellent researcher! Good analytical equipment can only help lifting good research to a higher level, it cannot convert dispensable research to quality research.

While public discussions in conferences are extremely important, it is also important to follow some rules of good conduct, in order to rather close than widen the gap between researchers with different equipment levels.

- The assessment of a study should focus on the scientific approach.
- A study should always be considered within the context of the boundary framework of the researcher. In this context, one can learn from every study.
- Conference discussions are no vanity fair for the questioners at the cost of the presenter.
- It is better to offer support (e.g. with a final investigation that could be the cherry on the cake) than to dispose a study, because of their lack of sophisticated methods.
- Socially determined expectations should be examined. If within a scientific community, a special kind of expensive technique is often used but within some scientific studies it cannot be used due to inaccessibility, then that specific equipment cannot be used as bar for whether a piece of research is good or not.
- Scientists holding a position of authority in a specific field have the responsibility to encourage an unbiased and purely scientific view of research being presented by those who may not have been able to follow a sophisticated method but still managed to get a result worth discussion.
- If we consider that the publishing community is counterintuitively becoming more and more exclusive, it is very likely that very good research may not be published in an 'A rated' journal. This cannot be a base to discredit the science.
- Difference in historical and conceptual perspectives also can affect expectations about standards of research practice and research. That should also be considered when examining scientific work.

There are certain values, practices and scientific principles that guide research. If a piece of research has integrity and can be defended on the basis of a sound hypothesis and a systematic study to prove the hypothesis then it should be judged solely on scientific merit and not the complexity of the equipment used. Instead of ridiculing scientist for not using the most expensive lab equipment, question whether you can follow the science and how you can contribute to it being better.

Nevertheless, without any doubt the research questions of today increasingly demand for some highly sophisticated methods. If they are hardly accessible, e.g. for many African researchers, this automatically means that there is demand for cooperation with other laboratories. This has implications. Research works have to be planned in a different way right from the scratch. Researchers must be trained on very methodologic skills as they cannot afford trial and error experimental approaches once the need for cooperation is there. If a colleague is asked for a friendship service to do testing with fancy equipment, the credit that is given should not be overburdened by useless experiments. Eventually, it also means thinking about what to give in return, and possibly it comes along with the need to include further co-authors, who may not have had the strongest intellectual part in the study. And due to the existing better publication platforms in Europe or North America the European or American researchers might (on intention or unintentionally) receive greater attention than the inventor.

Eventually, international cooperation is required and important, but there are implications. Research excellence does definitively not depend on excellent equipment, but this must not be an excuse for politicians to avoid investments in research facilities. A good research infrastructure makes life easier for local researchers and helps lifting running research to a higher level. And it helps to master the technology transfer into society. Therefore, African governments are well advised to see the benefits of investing into a functioning research infrastructure.

ISEE Reflections

Building upon women's progress

Faudhia Yusuf Zando

As part of a very old culture, most people in my community of Tanzania's coastline possess discriminatory attitudes towards girl children and women in general. There have been no high expectations for many girls here despite their exhibition of considerable talents such as academics at an early age given that they were born into families which genuinely do not believe in women's competence. This bias has been reflected in the frighteningly high prevalence of child marriages, where 3 out of 5 girls have been getting married before the age of 18, and in less than 30% of girls attending secondary school.

There are further mental or psychological restrictions which have been placed on the few girls who currently attend secondary school. They are misled into believing that doing science related subjects in school, for example, is a preserve for boys and so is embarking on a career in Science, Technology, Engineering and Mathematics (STEM).

Information campaign for prolonged school education for girls in the village of Zinga, Bagamoyo. The earlier the capacity is built, the more benefit it brings to the whole society.

In order to transform the trend of widespread ignorance on women's potential, I have advocated for equality of opportunity and facilitated initiatives to empower marginalized girls and women in my community. I have embarked on this mission to alter the lack of education, gross poverty, and powerlessness among women which confronted me at the age of fourteen.

Coming from a background of championing inclusion for women, I was recently immensely inspired by the ISEE Africa Conference I attended in Nairobi, Kenya. Unlike other conferences I have ever been to, female intellectuals made more presentations than men without seemingly outnumbering male intellectuals in attendance.

There, I chanced to meet and mingle with nationally diverse, academically accomplished women in the field of science, technology, engineering and academia. The women in attendance were intellectuals involved in research to find innovative and sustainable solutions in order to resolve the world's most pressing social, cultural, educational, economic, scientific and technological challenges such as gender disparity, overpopulation and pollution.

This was one affirming sign that women have made meaningful progress claiming hitherto men dominated endeavors and fields of work. To build upon this success, we need to encourage young women to consider careers in STEM starting as early as possible. We should engage their parents and educators alike to speak in unison about their undoubted ability for this option. This will also raise confidence among women to learn from each other and to rely on and look out for one another. This is so important. For example, through my networking during ISEE Africa, a female German concrete engineer has resolved to come to Bagamoyo and help building a learning center at my organization by using alternative local materials such as rice husk ashes to the benefit of the entire population. This simple example shows how mentorship and equal opportunities in STEM disciplines pays benefits many times over for a society.

Smart life and smart learning

Alice Titus Bakera

Pursuing a PhD in Cape Town while attending courses in Switzerland – no challenge with smart devices.

I am from Kagera, the North-western region of Tanzania, which is about 1,400 kilometres from the most populous city Dar es Salaam. I was born, raised, and attained my primary and ordinary level education in the same region, thinking that, perhaps, this was where I would spend my entire life.

I guess I was wrong. After my ordinary level, I was selected by the national Ministry of Education to join one of the best public schools in Tanzania, Msalato secondary school in Dodoma region (the capital city of Tanzania) for my advanced level education. This education level was designed for two years to establish a preliminary background for university bachelor degrees. Therefore, I pursued physics, chemistry, and mathematics subjects for engineering programs.

For two years, I did not return home as Dodoma is about 900 km from Kagera region and the travel fare was expensive. My parents afforded only my tuition fee and subsistence allowance but not the holiday travel tariffs. Hence, I spent almost all of my holidays at school and, sometimes, at my relatives' homes near Dodoma region.

Throughout my school education, I was forced to believe that the use of phones and computers were not good for students, especially not for girls. I was told in vivid examples of my elder relatives and neighbours' children who dropped out of school due to drug addiction and early age pregnancy or died due to AIDS, that using these devices might lead me to a similar direction.

In 2011, when I joined the University of Dar es Salaam as a first-year undergraduate student of Civil engineering, I was a free individual without any restriction towards the devices I own and use. I was shocked when I realised that having a personal computer was compulsory, especially for doing assignments, learning different designing software for civil engineering, and taking notes during lectures.

I was introduced to different types of devices that would assist me in my studies. My preferred choice was a tablet that could perform as a smartphone and computer. I knew my parents could not afford to buy me the tablet. Thus, I spent the first lump sum that I received as a study loan from the government to buy the tablet. I was astonished how efficient, effective, simply marvellous the portable device was.

Despite that, it was my first smart device at the age of 19, and it merely took a month to master its applications. Then, it assisted me in understanding lectures, practical training, and group discussions that I attended through the audio and video recordings. Besides this, it simplified communication with my classmates in arranging discussions, sharing notes, and instantaneous problem solving when we could not meet physically. Regardless of the environment, I could study anywhere without carrying heavy books or going to the library. Indeed, I was studying smartly and enjoyable.

Nonetheless, smart devices opened multiple doors beyond what was provided in class. Through media channels, scientific and social forums, I experienced civil engineering and other fields in a broader view and nurtured my personal development. Eventually, it enhanced my connection and networking with highly influential individuals and potential organisations that helped to build the foundation of my career.

Therefore, the integration of smart devices with social forums should be emphasised to be used professionally to advance knowledge transfer from ordinary to tertiary education. In implementing this, various techniques and innovations may be designed and applied to motivate the erudition of young generations. I know, that this costs money and cannot be afforded by everyone, particularly not in developing economies. Therefore, governments and educational institutions need to find ways to support this better, since there is no better investment than in contemporary learning and teaching methods.

Affordability of electronic equipment for digital education and communication

There has been great excitement on the possibility of using digital communication systems to close the gap on education and vocational skills between the developed and developing countries by using the internet uptake use trend. In Tanzania for instance, there is a 43% penetration level. Although this is very promising, it should be noted that this surge is mainly attributed to internet access through mobile phones which accounts for over 96%. The problem with this media is that the speed is not reliable and getting online for video conferences for example becomes very difficult, especially in high traffic hours. The problem of power shortages in Sub-Sahara Africa is another issue that additionally hinders efficient individual online communications.

As a group though, academic institutions have a major role to play in understanding the advantages of integrating these digital communication systems in their syllabuses. It is essential for universities to set a bigger budget dedicated to setting and improving computer labs and giving access to wireless network with reasonable speed. This in turn will bring out greater opportunities to individual students as well as the universities to link with other international institutions to exchange knowledge and skills.

Fatma Mohamed, University of Dar es Salaam

The necessity of physical meetings – or why real life still beats virtual reality

Mareike Thiedeitz | Chadlia Ounissi


The digital globalization has increased the efficiency of international and crossing borders research a lot. These days, research can be shared within seconds. We have the possibility not only to share our investigated knowledge in conferences and symposiums but also to form international research groups to investigate striking research topics together. This enhances the research output and can prevent redundant research programs in different places. This makes research much more economic. Nowadays, we really have plenty of possibilities for virtual meetings to make international team work as effective and real as possible. Attending a conference on innovation in building materials with the striking issue of sustainability spending thousands of dollars for highly carbon emitting flights, therefore, might not only seem old-fashioned but simply dumb. We could ask ourselves why we did not use the spent money on real building projects in our countries and save at least some emissions.

Well, in times of social media, virtual reality and artificial intelligence people tend to forget that we are actually still human beings. Human beings are equipped with more senses than just seeing and listening. The power of feelings is too often unhesitatingly underestimated. A direct talk, where both partners are physically present, sharing the same ideas, a great experience together and a rising connection increases empathy, sympathy and appreciation for people and therefore might end up not only in creative and powerful solutions in research and innovation, but helps building enduring friendships. For us, ISEE Africa did not end after the conference but has actually just started. As PhD students in Building Material Sciences, we expected experienced people in our research, interesting talks and most important ideas on how to deal with building and construction in a sustainable way all around the world. What we got has been all of that but even more - most importantly - we got connected to people who think in the same way, share the same ideas and values and are willing to make a change. We found new partners for our aims, but in them we found great friends as well.

ISEE was not one of the conferences where you collect some new business cards for your drawer, but a conference where we found true associates for our personal and professional aims. This perfectly shows what really matters in the world. It is humanity: the cooperation and communication with respect, cordiality and impartiality. During these days, we felt that we talked to people with the same humanity principles which facilitated a deep and long lasting connection. Just imagine a digital conference with short web meetings. Normally – if the internet connection does not break up, no participant has a problem with the sound and even the time shift is no hindrance, there still is the obstacle of the sound of the voice, the real facial expression, gesture and atmosphere.

We did not know each other before we started preparing for the conference. We are from Tunisia and Germany. But since the telephonic preparations for the workshops, which we were supposed to chair during the conference, we established a connection that strengthened during the conference and now will be continued. We are thrilled that it is possible to get such deep connections to people, who are from completely different places in the world, different backgrounds, histories and cultures just within a few days of conference. The picture stands for the wonderful friendship we got during ISEE: together with Luca from Italy and Faudhia from Tanzania we explored some places in Nairobi for one day after the conference. We went to see the nature and the normal street life as well. We hiked through Karura forest, went up the Kenyatta International Convention Centre

One day after the conference with Faudhia Zando, Luca Valentini, Mareike Thiedeitz and Chadlia Ounissi

to have a great look all over Nairobi and walked across the Masaai market. During the whole day, it felt like we knew each other for ages.

With this enduring friendship, we will share our prospective ideas, work together across the borders and keep on fighting for the aims we have in sustainable engineering and education. Due to that - besides all these wonderful inspiring talks of incredible persons during the conference - we really would like to reflect on this humanity issue which is one of the most valuable things you can have in the world. We all should keep in mind that working together is the only way to solve global issues, either in building and construction or human and societal challenges.

International background, amicable atmosphere: the perfect ground for global solutions

In the very beginning of the conference Namata Musisi talked about our built environment as utopia: "Whose utopia is it, anyway?". So to conclude and to say it with her words: thank you for this opportunity to keep on fighting for our utopia. It is probably a utopia, but who says it is not possible? Societies have built everything we see around us right now. Why shouldn't there be a possibility for change? There just have to be enough people all around the world willing a change. Someone just has to start. Even a tiny sparkle can ignite a flame within the crowd. And we think, these crossing borders connections that were made during ISEE are a great start for this. Physical meetings are the only possibility to set a vibe and feel the power. They are the only possibility to overcome prejudices, misunderstandings, cultural pitfalls and other obstacles.

Obviously, it is neither dumb nor unsustainable to accept costs and emissions to bring people together from all around the world. It is a good investment and indispensable for global solutions in sustainable engineering.

ISEE Reflections

The puzzle of education in SSA: an entrepreneur's perspective in the 4th industrial revolution

Apollo Buregyeya

The ISEE-Africa conference advanced narratives that are central to positive transformation of human life. Innovation, Science, Engineering and Education well represent the core elements of human progress that societies must understand and direct to deliver sustainable solutions to their needs. Most important of the 4 core elements is education, a frame through which access to knowledge and opportunities are democratized. The success of education must be measured against its ability to equip learners with competences to develop solutions that deliver the changing needs of the world in a sustainable manner. The right education must also be available to all because it forms the basis through which innovation, science and engineering can be applied by all and for the benefit of all. Moreover, inclusiveness is an important factor of sustainability. ISEE-Africa conference opened the debate and we hope to see a transformation in the education industry, particularly its appropriateness in the context of the people and their location specific approaches in meeting their needs.

1. The opportunity window

From South Africa to Uganda, most Sub-Saharan Africa heads of states recently established national taskforces on the 4th industrial revolution as reported in different media available online. The taskforces of all these nations have a primary objective of guiding their governments on optimal infrastructure, training and policy interventions for positive transformation of human life in the new age of artificial intelligence (AI) and the internet of things where the digital will augment the physical and biological functionalities in a manner that will deliver great opportunities for wealth and sustainability but also massive ethical dilemmas. Indeed, for technological revolutions to benefit a society, they must be guided through social-political choices that target to leverage new tools and direct resources towards innovation that have higher chances of impacting the majority of the citizenry. The move by the different heads of states of Sub Saharan Africa nations is a plausible one and an opportunity for Africa to address some of the gaps that have kept it trailing others in the recent past. The national taskforces offer platforms for renovations on the current education, infrastructure and policy establishments and an opportunity for the African entrepreneur to advocate for appropriate local reforms.

2. The industrial African trajectory

The history of technological revolutions shows us that, at the merging of innovation peaks in transport, communication, energy and political philosophy, we experience a new technological revolution and a rapid change in the way wealth is created and shared. As new technological revolutions replace old ones, the old ways of living, working, moving and communicating are edged out in favour of new ones that come cheaper, more accessible, more profitable and with more liberty for everyone. The world is at the peak of a digital technological revolution that some still consider as a continuation of the 3rd industrial revolution while others have classified it as the 4th industrial revolution. Notwithstanding the policies adopted by the 1860-1960 colonial governments that limited the spread of the previous industrial revolutions (Alam, 1998), it is still dicey whether Africa will ride on the current wave of technological revolution and catch up with the rest. In any case, Africa is adopting at a plausible rate in consuming and applying imported technologies, tools and standards, and the rest of the world is excited at the lucrative market. The fast rate of adoption in consumption of technologies is driven by mostly young and educated entrepreneurs. These early adaptors operate in environments with weak or no regulation, scarce skills and knowledge, and absence of infrastructure and supporting policies. Therefore, correctly defining the training, infrastructure and policy needs and the initial and boundary conditions is fundamental to achieving

transformative industrial success in Africa. For the African entrepreneur to make sense of the modern tools of work that are already accessible to the alien competitor, they must overcome the challenges established in the education, infrastructure and social-political dispensations obtaining in their spaces of innovativeness. They must also look beyond the opportunity for consumption of new technologies and seek to establish skills and knowledge necessary for production of own technologies, tools and standards.

3. The education conundrum

On education, this is the medium through which innovation, science and engineering are scaled for the benefit of many. Driven by an ethics frame, education democratizes access to knowledge, skills and opportunities for wealth. We can therefore trust education to establish a culture of excellence in the citizenry, a culture that society can leverage on to build a strong commerce construct with results that guarantee dignity and a prosperous life. Education must then be assessed by its ability to produce graduates that accurately define and address obtaining problems of their societies using locally generated appropriate tools and technologies. What we now have across sub-Saharan Africa are graduates who lead at consuming technologies and not at producing it. We have scaled the world in consuming mobile phone technologies, for example. We did American and Asian technologies like Ericsson, blackberry, Nokia, Samsung and Apple as China adapted fast and established Huawei, OnePlus, Xiaomi, Vivo Nex, Opo, Honor and other many companies that are now global players in technology development and production. Certainly, there is a flaw in our education structure and how we direct our knowledge. I tasked Civil Engineering students of a leading university in Uganda, each, to produce a sketch of a house in 60 seconds and that of the sun in 30 seconds. As I had predicted, all 80 students in my class produced similar images, the house being a two equal sided triangle (isosceles triangle) seated on a box with a door opening in the center of the box and two side windows. The sun was a circle surrounded by dashes. Of course, these are images common in our kindergarten and lower primary school and are not sophisticated enough to accurately represent the actual objects that I had asked my students to sketch. That University students pursuing a Bachelor's degree in Civil Engineering, the students that had emerged the best in the country at their university entry examinations, are still consciously running on kindergarten mental models shows the disconnect in our education system. We teach innovation, design thinking, product development, technology management and other key skills of technology development to old, mentally roughened and rigid minds at postgraduate level yet these skills would benefit our society better if they were introduced at kindergarten level when the minds are still very creative and free of horror experiences. We have graduates who shine at consuming European standards in their practice but have very low faith in their own original thoughts. And all this is rooted in the fact that we run an education curriculum of the European 2nd industrial revolution that was established to produce factory workers. Apparently, where there is any conflict in knowledge in the process of curriculum review, the European is given priority over our traditional knowledge. While Europe has evolved its education to adapt to the complex learning curve of human development and their boundary conditions, our education remains inflexible to Africa's boundary conditions. The 4th industrial revolution presents a challenge to our education system on how we can prepare the African masses to apply its tools for a social and economic transformation that we need. Our education system has a responsibility to move us from consumers to producers of own technology, tools and standards.

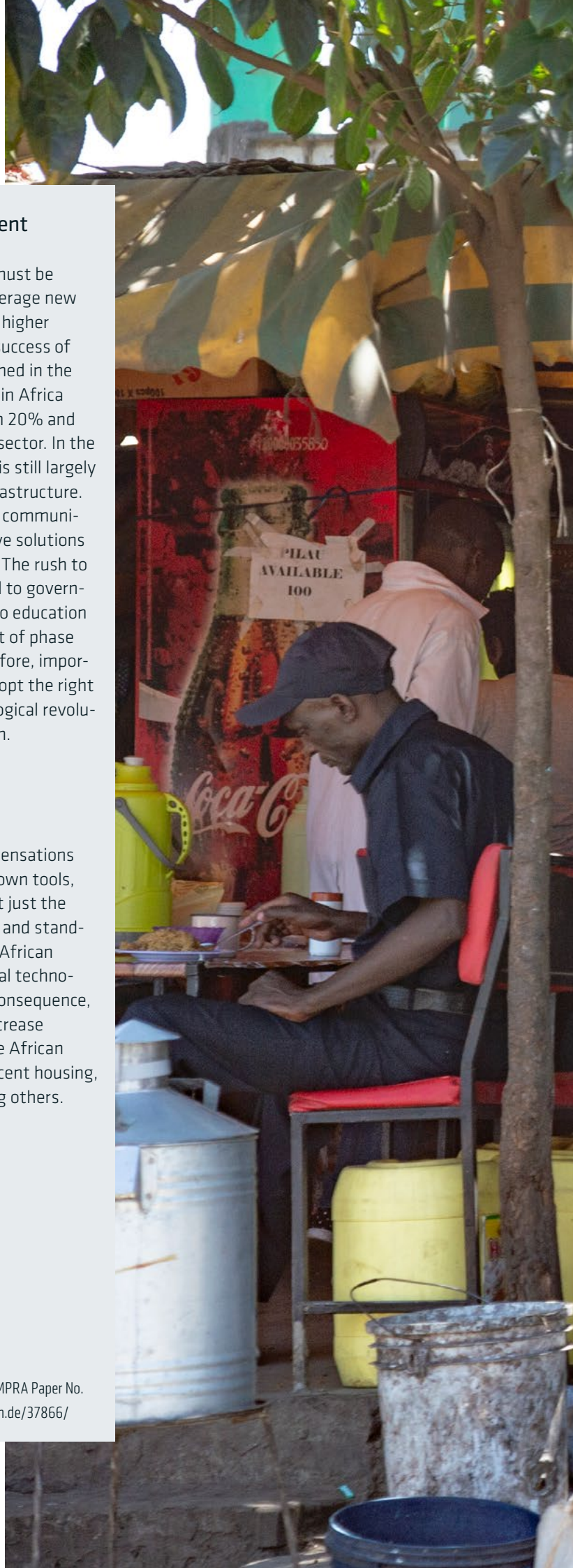
Besides, for every 100 children that start school in sub Saharan Africa, over 95 do not make it through University education. This, therefore, further emphasizes the flaws in the way the education system is structured and an urgent need to make it work for the 95% share of the human resource that drops out of school. Indeed, a society cannot transform sustainably without the over 95% of the population that is incidentally isolated by the main stream education system. The entrepreneur on the African continent has a big part to play in addressing this challenge. He/she must develop means to deploy the unschooled and unskilled majority of the population in Africa to turn it both into valuable labour and a market. The African entrepreneur currently embraces the role of skilling their workers, mostly starting at the basic level of training.

4. The role of the social-political establishment

For technological revolutions to benefit a society, they must be guided through social-political choices that target to leverage new tools and direct resources towards innovation that have higher chances of impacting the majority of the citizenry. The success of a society in applying technological innovation is established in the political decisions of the season. This is more important in Africa where expenditure of governments account for between 20% and 30% of GDP and drives economic activity of the private sector. In the midst of the present digital industrial revolution, Africa is still largely in a race to catch up on the 2nd industrial revolution infrastructure. The obtaining deficit in housing, health services, energy, communication and transport infrastructure is met with expensive solutions that are typical of Europe's second industrial revolution. The rush to establish these old forms of infrastructure is not limited to government institutions, entrepreneurs and developers but also education programs that produce graduates with skills that are out of phase with the demands of modern industrial tools. It is, therefore, important that the social-political establishments in Africa adopt the right policies to shape the deployment of the current technological revolution in both infrastructure development and in education.

5. Conclusion

Knowledge, skills, infrastructure and social-political dispensations necessary to transform Africans into producers of their own tools, technologies and standards must be established and not just the opportunity for consumption of new technologies, tools and standards that are alien to the African continent. The current African entrepreneur must appreciate the opportunities of digital technological revolutions in reducing marginal costs and, as a consequence, addressing the need for low-cost products in order to increase sustainable access to the basic human necessities on the African continent. The biggest gap in this area is in access to decent housing, health services, sustainable energy and transport among others.



References

Alam M. Shahid, 1998, "Colonialism and Industrialization: Empirical Results", MPRA Paper No. 37866, posted 7. April 2012 12:32 UTC, Online at http://mpra.ub.uni-muenchen.de/37866/

Summary

This book was created in conjunction with the first ISEE conference in Nairobi, January 30 to February 1 in 2019. ISEE stands for Innovation, Science, Engineering and Education. The book provides statements and opinions of strong individuals on sustainable architectural, structural and materials solutions for environmental challenges of today and in the future. Since the challenges are getting more complex, their solutions require new ways of thinking, which in return require new educational approaches.

Various challenges and possible solutions on how curricula can be modernised and adapted to an ever-changing environment are presented and discussed by outstanding experts in this field. However, good education cannot be derived purely from a perspective of teachers, researchers, and professionals. It is important to give a voice to those who experience education, and those who are in demand of highly skilled offspring. Thus, the present points of view comprise of statements of individuals from different origin, provenience, gender, generation, career level, etc. It gives a diverse and colourful set of highly interesting and thought-provoking opinions.

Though many texts are of scientific origin or have an academic background, the output format is thought to address non-scientific decision makers such as administrative bodies or policy makers. The present compilation of unfiltered opinions of important players in the area of construction technology can be an important foundation for new initiatives towards enhanced and more contemporary educational initiatives that help our next generations of architects, civil engineers and materials scientists to develop the skill to make our world of the future more sustainable than it is today.

We do hope that this book and the ISEE conference can spark further activities and projects that focus on enhancing the capacities of future generations of civil engineers, architects and materials scientists to work on effective solutions to solve the greatest challenges humanity faces today and in the future.

Closure

Wolfram Schmidt | BAM | Germany

It has been a tremendously exciting experience to compile this book, and to edit and set it in order to create a tangible and vivid picture about the challenges and solution potentials for global environmental problems. The vast variety of opinions and statements helps to understand that problems and solutions can always be observed from different angles and that simple solutions do not exist, probably never existed.

Nevertheless, some realistic and manageable technological solutions were presented based on more efficient use of construction materials and their constituents. There may be controversy about the ideal solution, and different boundary frameworks may automatically demand for tailored solutions, but what is a common conclusion is that business as usual has not been an option for quite a while, and that problems and their solutions can no longer be simplified in general purpose approaches. They demand for a higher resolution lens yet in a broader context, considering various observation angles and the knowledge of multiple disciplines.

Inevitably, the necessity to look at present challenges and state of the art technologies with higher resolution comes along with the demand for new skills. These comprise of more interdisciplinarity, better communication, enhanced data processing, and much more flexible and out-of-the-box thinking. Thus, as much as technological standard solutions are not a sustainable option any more, standard education is no longer an option in an ever-accelerating world. Education has to adapt to the new context

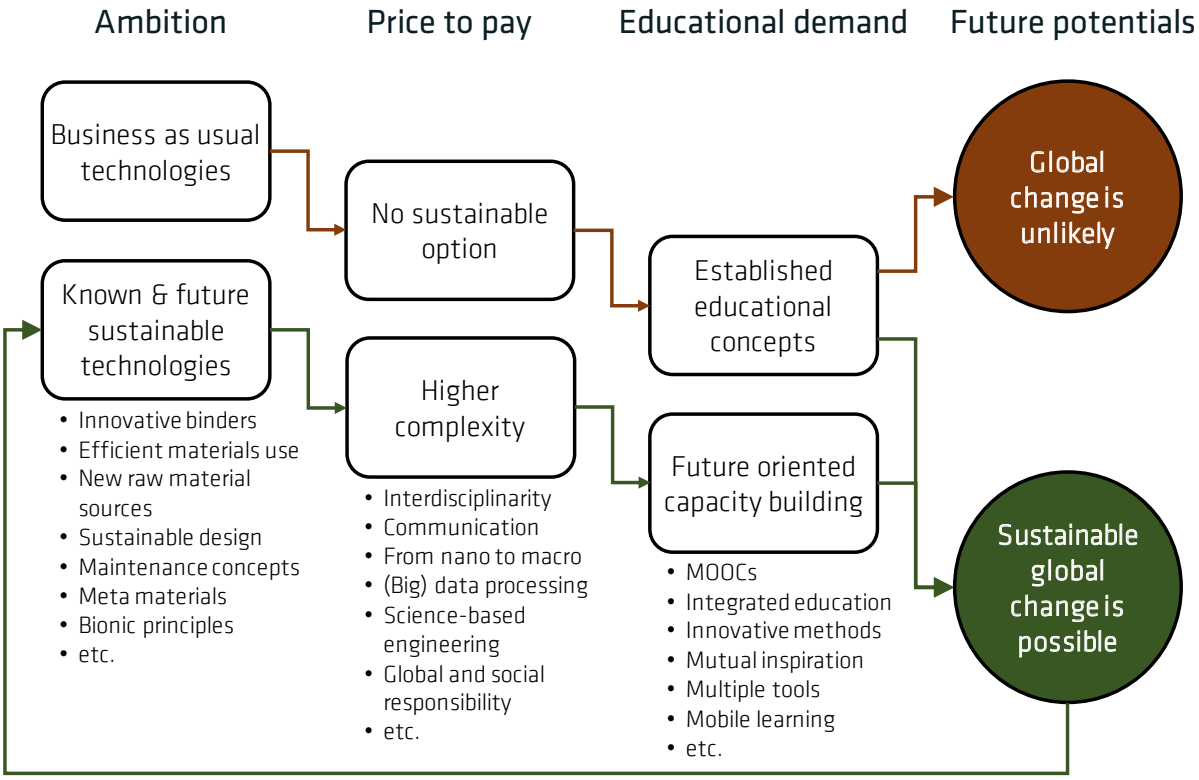


Fig. 1: Comparison of the change potential in the business of usual case and in the case of innovative technologies as the objective of innovative educational concepts.

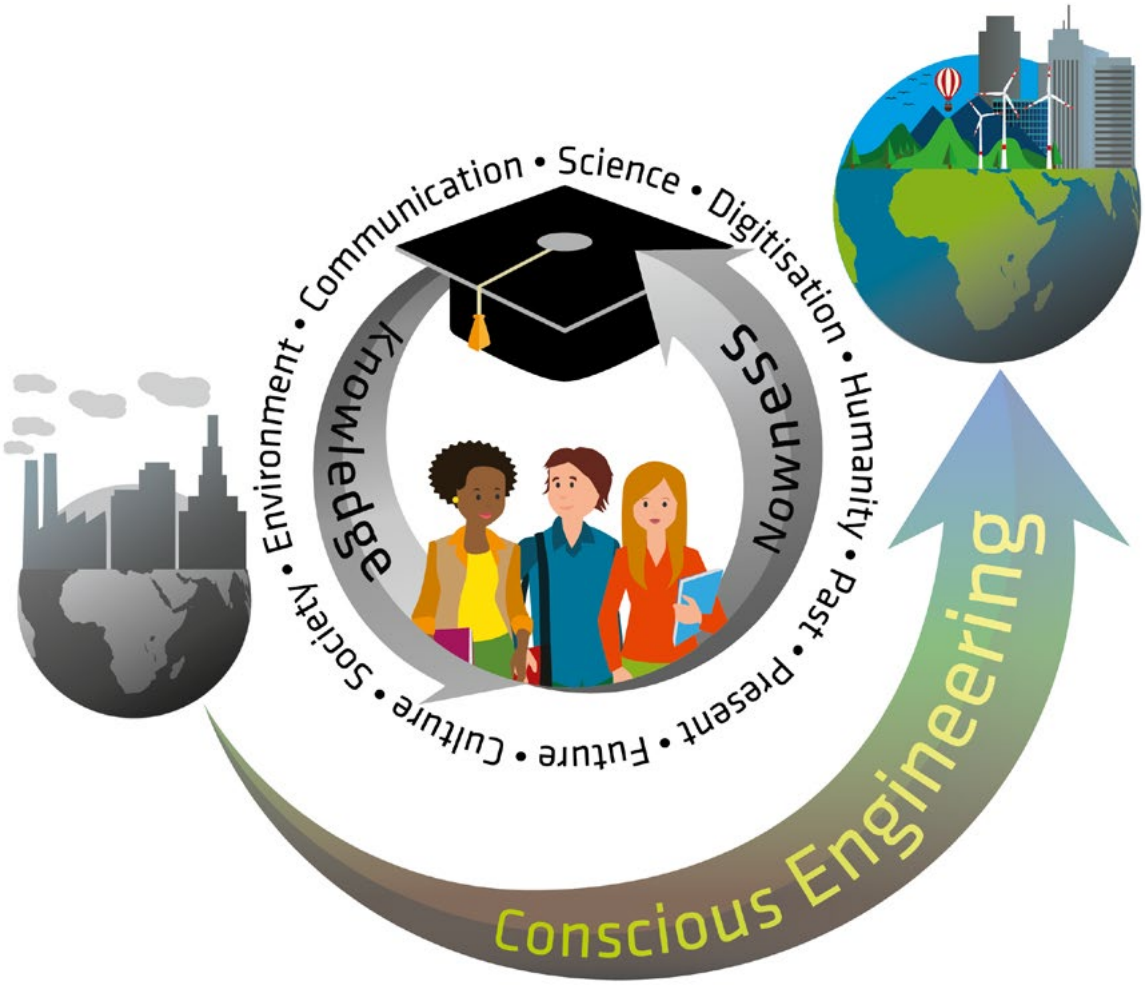


Fig. 2: How students and professors can mutually benefit towards a better global environment

and become more contemporary and flexible for the requirements of the future [Fig. 1]. In particular, engineers and architects need to develop sound awareness of their global, social and cultural responsibility, much more than before.

As the global live accelerates more and more, long-standing methods of teaching may no longer be capable to cope with the velocity. As a result, teachers have to learn permanently, since otherwise, times rapidly outdate the teaching methods and contents. Naturally, younger generations do have a better capacity to adopt and adapt to innovation and tools of modern times. Teachers, despite their higher level of knowledge and experience, thus, inevitably have to learn from their students about newness and nowness, in a way that education becomes an interactive process, where both sides, professors and students give and take for mutual benefit. This way, education tools and content can become contemporary, and capable to develop effective solutions that eventually help improving the global climate to the benefit of the entire world, its societies and a fair wealth distribution [Fig. 2].

Today's decision makers probably do not yet have the verve to implement existing more sustainable technologies and concepts. Maybe, the existing tools still lack applicability, acceptance or attractiveness. Nevertheless, today's decision makers can become a spark. A spark that enflames an innovation driven, creative, globally oriented, climate-friendly, sustainable way of thinking in the minds of future change drivers, who are most probably still learners today. Education provides the tool-kit, unbiased and adaptable creativity combined with knowledge and research capacity are the key. Then, change is possible!


OLE SERENI

Acknowledgements

The content of this book was created by many authors. It highlights a vast and marvelous variety of contents. Each contribution is highly appreciated, and we would like to thank each single author for the valuable content.

The ISEE conference, and this publication based on it, could only be implemented with the wonderful support of the VolkswagenStiftung. Without the possibility to provide for the mobility of such a high amount of inspiring people, so many different characters with so many different backgrounds from all over the world, it would have never been possible to collect such a diverse assortment of important opinions and strong statements.

ISEE operated at the intersect between multiple disciplines. An important aspect of ISEE is linking people and different opinions to create an output, which is more than the sum of the individual contents. Although addressing a technical field, the major objective of ISEE is to have impact on educational institutions, associations, policies; in short on societies, regionally and globally. Most funding bodies focus on specific areas rather than the on the link between them. Hence, it is difficult to implement interdisciplinary and unusual ideas like ISEE. Luckily, the VolkswagenStiftung fills this gap by supporting exactly these unconventional research related activities, that eventually may point out to become a game changer.

It is therefore, highly appreciated that the VolkswagenStiftung made this project, as well as many other remarkable cross-disciplinary projects of global relevance, possible. Thank you!