

# Potential of Theory of Innovative Problem Solution (TRIZ) in Engineering Curricula

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## Abstract

Currently there is an escalating worldwide rivalry for advanced product and process functionality, lower costs, superior quality, and other concerns together with environmental challenges and energy considerations. Everything needs to be done not only fast, but also accurately, effectively, and efficiently. Solving problems facing the 21<sup>st</sup> Century society demands creativity and innovation. Creativity is a fundamental skill that Engineers must develop in order to be competitive. However there is a generalized concern amongst industry and academic leaders about the effects of traditional engineering education on students' creativity (for example: lacking design capability or creativity, as well as an appreciation for considering alternatives). The traditional approach to creativity (using methods such as brainstorming, C-sketch, morphological charts, and scamper among others) calls upon the designer to look inward for inspiration. The Theory of innovative problem solution TRIZ, on other hand, invites the Engineer/Designer to use a readily available pool of knowledge for inspiration. The main objective of this research is to comprehensively illustrate the rationale for introducing TRIZ in engineering curricula with particular emphasis on developing countries (exemplar Kenya). The study justified that numerous countries have already in full swing benefiting from such methods as TRIZ; on the other hand many of us in the developing nations are either completely unaware, or in a very comfortable state of hibernation with the warning sign "Do not disturb", or extremely resistant to any changes, even if the change is emphatically for the better.

Keywords: *Creativity, Curricular, Engineering, Innovation, TRIZ, Theory of innovative Problem Solution*

## 1. Introduction

Solving problems facing 21<sup>st</sup> Century society demands creativity and innovation. Thus, community and government leaders are asking the question: "How can we teach children to be creative, innovative, and better thinkers so that they can become productive members of society?" Creativity and innovation have also become strategic issues as business organizations strive to remain competitive [1].

Developing students' creativity is an important issue in education in the 21st Century of knowledge-based society. So, what is creativity? Creativity is often defined "*as the ability to produce work that is both novel (original, unexpected, imaginative) and appropriate (useful, adaptive regarding task constraints)*" [2].

In response to various factors including particularly a demand by the business and engineering communities for enhanced design competencies in graduating Engineers, there is a tendency in engineering accreditation in the direction of "outcomes-based" assessments and the integrated engineering design curriculum. Under outcomes-based criteria, engineering programs must exhibit that their graduates have the capability to *apply* knowledge of mathematics, sciences and engineering in solving engineering problems. In engineering, design competencies such as the ability to design and conduct experiments, and the ability to design a system, component, or process to meet desired needs are emphasized. Above all other skill-level considerations, Design Engineers require some level of hands-on proficiency in the use of tools or processes relevant to their field [3, 4]. These skills are lacking among engineering graduates, based on the frequency with which this issue appears in the literature [5, 6, 7, 8, and 9].

Professional attitude is commonly cited as a key competency for Engineers and Technologists in general along with the ability to adapt to changes in circumstances [3, 10]. Design engineering practice suffers from varying attitudinal pathologies. "Not-Invented-Here" attitudes [10] confusion of creativity with innovation (creativity is coming up with new ideas while innovation is putting those ideas to work and creating a benefit)[11], notions of design as an individual activity [11], and reluctance to leverage the knowledge of technicians or tradesmen [4] are recurring problems amongst new graduates of university engineering programs.

Usually in developed countries, quality in engineering education has been realized by providing high-value instruction, excellent laboratory facilities, and relevant tutorials and assignments. In most developing countries, including Kenya the situation regrettably is not so rosy. In some countries achieving quality in engineering education is not only an uphill struggle but in fact an immense effort just to stay afloat mainly due to financial and political constraints. The problems are numerous; however these are outside the scope of this paper.

In any case, whether in the developed or developing countries, the engineering design competency cannot be developed in the traditional classroom setting. Formal education overloads students with information (which alone does not make a person creative). Engineering programs teach key capabilities such as problem solving and analytical skills, but the process of creation and generation of solutions and alternatives remains an extremely challenging task. In response to this, some universities have increased the quantity and quality of design practices to give students the opportunity to experience open-ended design [12]. With this, students apply design strategies and tools (i.e. design theories and methodologies). Through the design process, students learn mostly about peripheral representations of artefacts and how to design them but students are seldom taught how to improve their creativity levels; and this is a critical step in the innovation process.

Various approaches are currently being adopted by universities in engineering education including innovative strategies for engineering design content within individual degrees, employing interdisciplinary approaches, and project-based learning. One of the noble approaches is through the application of systematic methods for innovative thinking and problem-solving, such as TRIZ- the Theory of Inventive Problem Solving. The main focus of this paper is to propose a paradigm shift in engineering education-by introducing TRIZ in engineering curricula.

## 2. Materials and methods

To address the problem highlighted above the authors thrived to make the most of literature surveys to present critical analysis on the subject matter. Holistic approach was used to assess the applicability of TRIZ in Kenya. The findings recorded below do not claim to be fully comprehensive account of every instance of TRIZ encounter, but they do give a fairly good picture of the order of magnitude of activities and achievements, and probably include the most significant ones identified for

which information was available at the time this study was carried out.

### 2.1. Description of the tool to address the problem: *TRIZ-short introduction*

The Theory of Innovative Problem Solving (TRIZ), developed by the brilliant Soviet Engineer-inventor Genrich Altshuller, is cherished as national “Golden Touch” of the Soviet Union. It was derived from an exhaustive patent study of about 2.0 million high-level inventions in the global patent literature after the 20th Century. The following are some interesting concepts on TRIZ: [13] 99.7% of inventions utilize already known solution principle and considered to be mere improvements to existing systems; only less than 0.3% is truly pioneering groundbreaking inventions- scientific discoveries.

1. Most of the problems have been solved again and again at different times in different context in different sectors. In a diverse sense, most of our problems are not faced by us for the first time, rather faced by many other people and probably been solved by them.
2. The stronger solutions find and solve the conflicts or contradictions in the system. The best solutions transform harmful elements of the system to useful resources.
3. All innovations emerge from the application of a very small number of inventive principles and strategies.
4. Technology evolution trends are highly predictable.
5. Everyone can learn to be creative! (The most crucial and unforeseen principle of TRIZ).

Following the end of the cold war in the 1990s, TRIZ was brought overseas and began to be popularized in Europe and the United States of America. Currently, it has been widely recognized as an authoritative, effective and powerful problem-solving method. TRIZ provides a methodology by which people can systematically solve problems and enhance decision-making. Innovation by trial and error is replaced with a systematic approach that allows people to mimic the way gifted inventors solve problems [14]. TRIZ does not discount the use of traditional approaches. On the contrary, TRIZ ensures that Engineers use these traditional methods in a systematically directed manner by carrying out intelligent idea generation in areas where other people have solved a similar general engineering problem. Probably, the very essence of TRIZ is that its use formulates a fundamentally new way of thinking when solving engineering problems, one which is more logical, purposeful, and creative. Fundamental

concept of TRIZ is that innovation is not a random process, but is a function of a very small set of parameters, principles and patterns; in particular: 39 engineering parameters, needed for characterizing problems; 40 inventive principles for solving technical contradictions, 4 separation principles for solving physical contradictions, 76 standard solutions for solving relatively common optimisation problems and 8 conventional evolutionary patterns (today up to 35 have been identified) that make possible to forecast the technology trends. Although many inventive problems can be solved with the use of relatively simple TRIZ tools (e.g. Contradiction Matrix and 40 Inventive Principles), a broad class of more difficult, non-typical problems requires a deeper understanding of the driving forces and mechanisms of innovation that were revealed by TRIZ research.

Basically, TRIZ is just a way of thinking, a design approach, an algorithmic methodology which helps break psychological inertia in problem solving, a family of tools, judgment processes, and software. “Simply” TRIZ is a matter of finding the previously well-solved problem analogous to the problem at hand. The TRIZ approach is fundamentally different from other approaches to creativity and problem solving in the following ways (extracted from [15]):

- i. It is a rule based rational approach to creativity and not revelation based random approach. It is a repeatable problem solving process, based on fixed algorithm and not on intuition.
- ii. Our experience is not enough; use other people's experiences to solve problems. Allows deriving knowledge from other fields, as creative problem solving patterns are universal across different areas.
- iii. The contradiction (a contradiction arises when mutually exclusive demands are placed on the same system. Improvement or resolution of one of the demands then leads to deterioration of other(s). Examples: reliability vs. complexity, strength vs. flexibility and so on) is explored and eliminated and not avoided-other processes try to avoid contradiction. TRIZ tries to solve contradictions. A breakthrough solution is a result of overcoming a contradiction.
- iv. All TRIZ techniques are derived from real life solutions and patented inventions from past. The rules of past can be applied to solve future problems.

- v. The goal is Ideal Final Result and not a perfect compromise.
- vi. TRIZ attempts to avoid the many mediocre solutions to problems and get directly to the best solution faster. Better and more innovative solutions (as the difficulty increases, the number of solution increases). Reduces the number of trial and error solutions (saves time, money and reduces risks).

TRIZ problem solving can be illustrated by the following steps of DMASI methodology shown in Fig.1: [16]

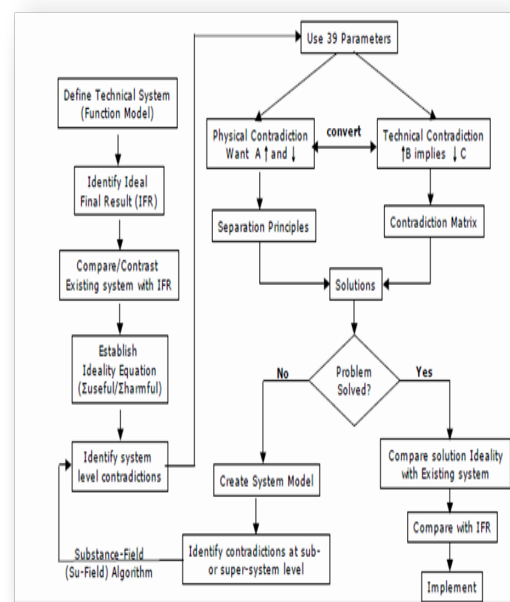


Fig. 1: TRIZ DMASI methodology [16].

1. *Define* the innovation problem/system (requirements, constraints ...), the Ideal Final Result.
2. *Model* the system (how its elements interact; how its elements create contradictions; how to resolve contradictions).
3. *Abstract* the specific problem into a generic problem (Express the contradictions in terms of the 39 engineering parameters).
4. *Solve* for the specific solution using TRIZ tools (separation principles, inventive principles, standard solutions ...).
5. *Implement* solutions (that eliminate problems or generate new revenues).

The power of TRIZ is no longer questioned. Many well known U.S.A., European and Asian companies have and are continuing to make significant investments in learning and applying the methodology. Among the most prominent companies are: Boeing Corporation, Daimler Chrysler, IBM, Intel, Johnson&Jonson, Motorola, Kodak, NASA, Nestlé, Panasonic, Procter&Gamble, Samsung, Shell, Siemens, BTicino and many others [17]. TRIZ is credibly applied in technical industries such as machinery, electronics, biology, chemistry and military engineering, and then extended to a broader application in non-technical areas such as management, marketing, education and psychology.

## 2.2. TRIZ and the role of computers in engineering education

"Creative Thinking" is one of the most important issues requiring attention in engineering education. Today, however, the emphasis of many engineering curricula is moving steadily toward increasing the role of computers. There is overabundance of computers and the unwritten belief that they can solve ANY problem! While computers and computer based techniques such as CAD, CAD/CAM, and FEA are powerful tools that significantly improve the productivity of Practicing Engineers, they do not offer Engineers much help in developing novel concepts for solving design and manufacturing problems.

It is absolutely essential that students are empowered with a set of guidelines for creative thinking, and provided with some experience in formulating and conceptually solving design and manufacturing problems. Success in this effort will certainly lead to the added advantage of enhancing the usefulness of computer-aided applications.

While enterprises are adapting themselves to this new environment, the educational system is yet rather slow, still referring to traditional industrial systems and its outdated requirements. Engineering education is a complex, adaptive system which must evolve in response to feedback coming from its challenging and ever changing environment. Like any other system, higher education changes in response to internal and external conditions. In the past, standardization was the keyword, now customization and creativity are the leading principles.

## 2.3. Illustrative implementation of TRIZ in selected universities

Many countries have introduced TRIZ into the curriculum and encouraged teachers to innovate teaching methods, inspire students' inventive thinking and develop students'

creativity. According to European TRIZ association (ETRIA), more than 140 universities included TRIZ in their engineering curricular. A worldwide survey of TRIZ perception and usage conducted in 2009 [18] indicated that the vast majority of college and university education of TRIZ is based on programs ranging up to 40 hours. The leading countries include Russia, USA, Germany, Japan, UK, South Korea and China. In African continent, TRIZ, so far, has been introduced only at the Institute for Technological Innovation University of Pretoria, South Africa and in University of Gezira, Sudan. The list, titles and contacts of all the universities which introduced TRIZ can be found via reference [19].

The universities worldwide offer some form of TRIZ education at various levels. The majority of them focus either on several awareness-level lectures on TRIZ (2-4 hours, e.g. the University of Groningen, The Netherlands) or they offer introductory TRIZ learning with two or three classical TRIZ tools (up to 30 hours, e.g. the Technical University of Liberec, Czech Republic). The most extensive program reported, outside Russia, is available at the National Institute of Applied Sciences (NIAS) in Strasbourg, France. It covers 175 hours of TRIZ training [20]. However, as NISA's TRIZ program is part of a specific master programme, it is not accessible to other students.

Russia, rationally, is one of the most advanced in TRIZ education, research and application. There are several different types of TRIZ education programs in Russia starting from the introduction 40-hour course and up to 240-hour training for TRIZ consultants and trainers. There are also TRIZ programs for school children of different age [21].

Engineering schools in North America are beginning to embrace TRIZ given its ability to provide innovative solutions to technical problems in design, research and development, manufacturing, safety, reliability, and quality control. In the foreseeable future, each engineering program in the West will incorporate TRIZ into its curriculum. A study of Ogot [22] results from the formal assessments between students introduced to TRIZ and those not, clearly indicate that TRIZ makes it easier for students to generate feasible concepts to design problems.

According to a case study, Busov [23] regarded TRIZ as a good mode in engineering education and innovative education in 21<sup>st</sup> Century. Wits [24] found that students who used TRIZ showed a lot of interest and were capable of finding inventive solutions for both small parts and big

project design throughout the course. Students in Pennsylvania State University increased their creative output by using TRIZ methods to design ice dispenser. Ogot [25] recommended TRIZ as a systematic creativity methods and innovative learning styles in engineering education. As mentioned by Belski [26], 97% of students who completed the TRIZ course at the Melbourne University in Australia reported that their confidence in the ability to solve any problem had grown after the course (versus only 9% of the students that were confident in their problem solving capabilities before the course).

Training in TRIZ and the introduction of TRIZ principles into a capstone design course, results in highly beneficial changes to the participants' mindsets. It is important to make TRIZ methodology available for masses of students (and Engineers), enabling them to become more open, more creative, and more mentally flexible [27]. Nakagawa [28] in Osaka Gakuin University, Japan launched a Six-Box Scheme of TRIZ training seminars for graduate students. The study showed that TRIZ methodology encouraged students' structured inventive thinking to derive creative engineering works.

In 2009, Ministry of Science and Technology in China carried out TRIZ theory training nationwide. TRIZ methodology was applied in engineering education as a new way to explore innovative higher engineering education, to develop students' creativity and train excellent Engineers in the future. Changzhou engineering vocational and technical college [29] ran TRIZ courses and originality competition to push through education reform and promote students' creativity. Tsinghua University, Sichuan University and Southwest Jiaotong University [30] have placed TRIZ on the curriculum for the graduate students to improve their creativity and innovative abilities.

The TRIZ practices in graduation design (final year project on engineering design) of hydraulics in Heilongjiang institute of science and technology indicated that the number of design proposals increased by 25%, and the effective high-level scheme accounted for 12%, which improved the quality of graduation design [31].

#### 2.4. KENYA: Background, University education and Accreditation of engineering programs

##### *Background*

Kenya is an East African country with a population of 41.8 million people. GDP per capita (US\$) 832.5, with sectoral value-added (% GDP), 2011 being Agriculture 23.1, Industry 19.2 and Services 57.7 [32]. The World Bank

Global Competitiveness report presents the ranking of the Global Competitiveness Index (GCI), developed by Professor Xavler Sala-I-Martin and introduced in 2005. The index based on 12 pillars of competitiveness. Fig.2 shows the pillars and the stage of Kenya's development.

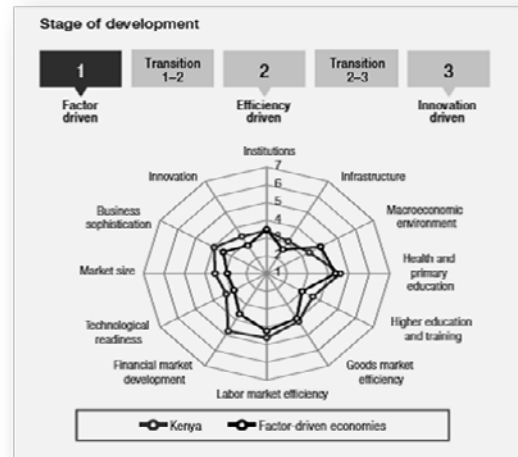


Fig.2: Kenya's 12 pillars of competitiveness and stage of development [32].

The Kenya GCI for 2012-2013 is 106/144 [32]. Table 1 illustrates only 2 out of 12 pillars of competitiveness; which is relevant to the research (Innovation and Higher education & training).

The Kenya Vision 2030 is to become a nation that harnesses science, technology and innovation to foster global competitiveness for wealth creation, national prosperity and a high quality of life for its people. Within this vision the goal of Education and Training sector is to promote appropriate science, engineering and technology (SET) skills, creativity and learning by discovery at all levels of education and training [33].

To facilitate the achievement of goals of Kenya Vision 2030, in January 2013, the Kenyan parliament passed the Science Technology and Innovation Act 2013 or ST&I Act 2013 [34]. This is the first Act of Parliament that has created the governance structure for the Kenyan Innovation System. The ST&I Act 2013 created the following three key institutions:

1. The National Commission for Science, Technology and Innovation, the successor to the National Council for Science and Technology. This is mainly the regulator of the science technology, research and innovations sector.

2. The Kenya National Innovation Agency (KENIA), a new body whose mandate is to develop and manage the Kenya National Innovation System.
3. The National Research Fund (NRF) that will manage a fund amounting to 2% of the national GDP for the purpose of funding research and innovations in Kenya. This is a new foundation.

*University education*

The Quality of Education system of Kenya is ranked 37 out of 144 (see Table 1). University education in Kenya can be traced back to 1951 when the Royal Technical College of East Africa was established in Nairobi. The college opened its doors to the first students in April 1956. In 1961, the Royal Technical College was transformed into a university under the name University College of Nairobi giving University of London degrees. In 1970, the University of Nairobi was established through an Act of Parliament (University of Nairobi Act 1970). The high demand for university education in the 1980s and 1990s led to the increase in the number of universities from one public university college in 1970 to seven public universities in 2007[35]. At the time of this study, there are 22 Public universities, 14 Chartered Private universities and 12 universities with Letter of Interim Authority (LIA). These Universities are established through institutional Acts of Parliament under the Universities Act, 2012 which provides for the development of university education, the establishment, accreditation and governance of universities. Out of these universities, 6 public and several private universities offer diverse engineering degree programs [36].

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Table 1: Kenya: competitiveness ranking in Innovation

and Higher education & training, 2012-2013

Higher education & training	Rank /144	Innovation	Rank /144
Secondary education enrolment	108	Capacity for innovation	46
Tertiary education enrolment	130	Quality of the scientific research institutions	50
Quality of the education system	37	Spending on R&D	31
Quality of Maths & Science education	76	University-industry collaboration in R&D	41
Quality of Management of school	56	Government procurement of advanced tech products	76
Internet access in schools	85	Availability of scientists and Engineers	66
Availability of research and training facilities	64	PCT patents, applications /million pop	95
Extent of staff training	70		

Source: Compiled from *The Global Competitiveness Report, 2012–2013* [32].

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*Accreditation of engineering programs*

To ensure that engineering programs offered by education institutions meet educational standards acceptable for Professional Engineer registration, and that the quality and relevance of engineering education continuously improve, engineering associations of many countries in the world have established accreditation mechanisms to evaluate and accredit the undergraduate engineering programs of education institutions.

Engineering training in Kenya is typically provided by the universities. Registration of Engineers is governed by the Engineers Act. All registrations are undertaken by the Engineers Board of Kenya (EBK)- a statutory body established through an Engineers Act of the Kenyan Parliament of 1969. A minor revision was done in 1992, to accommodate Technician Engineer grade. The bill was assented into law on 27th January, 2012 and published on 30th March, 2012 in the Kenya Gazette.

A candidate stands to qualify as a Professional Engineer, P. Eng. if he/she is a holder of a minimum four years post-secondary engineering education and a minimum of three years post graduation work experience [37]. The Board has been given the responsibility of regulating the activities and conduct of Practicing Engineers in the Republic of Kenya in accordance with the functions and powers conferred upon it by the Act. As of April 2012, the EBK had about 4,785 registered Graduate Engineers, 1,285 Professional Engineers and 260 Consulting Engineers (6,330 Engineers in total for a country with population of about 40 million). According to UNESCO guidelines for a country to be globally competitive the ratio of Engineers to total population should be 1: (500- 2000); therefore Kenya based on EBK registers (at the time of this study) has a shortage of minimum 13,670 Engineers (a -216% deficit).

According to Sec. 7 (1) of the Engineers Act, the EBK is mandated to approve and accredit all Engineering programs in Kenya. In 2011, 47 Engineering programs were denied accreditation by EBK, because of the claimed: low quality curriculum, lack of qualified lecturers, segmentation and duplication of programs, and absence of professional focus [38].

### 3. Discussion

Fig.2 illustrates Kenya being at stage 1 of development (factor-driven), GDP per capita < US\$2,000 with important areas for competitiveness and their corresponding shares (%): [32]

1. Basic requirements at 60 percent (Pillar 1- Institutions, Pillar 2- Infrastructure, Pillar 3- Macroeconomic environment, and Pillar 4- Health and primary education)
2. Efficiency enhancers at 35 percent (Pillar 5- Higher education and training, Pillar 6- Goods market efficiency, Pillar 7- Labor market efficiency, Pillar 8- Financial market development, Pillar 9- Technological readiness and Pillar 10- Market size)

3. Innovation factors at 5 percent (Pillar 11- Business sophistication and Pillar 12- Innovation).

The Global Competitiveness Report by World Bank, 2013 ranked Kenya at position 106 out 144 economies of the world that were considered. For Kenya to reach Stage 3 of development (innovation-driven) with GDP per capita > US\$17,000 (presently Germany, Republic of Korea, Norway, Spain, United Kingdom, and United States among others) there should be a major restructuring of important areas for competitiveness and their corresponding shares (%) as: Basic requirements (20 percent), efficiency enhancers (50 percent), and innovation factors (30 percent) [32]. The Key for innovation-driven economies identified by The Global Competitiveness Report, 2013 is Pillar 11- Business sophistication and Pillar 12- Innovation [32]. Therefore Innovation plays a fundamental and a catalytic role in enhancement of country's competitiveness and consequently in lifting living standards of Kenyans.

The Kenyan education system is ranked highly in comparison even to more developed countries like South Africa [32]. The Quality of Education system of Kenya is ranked 37 out of 144, which is one of its highest ratings elements for all competitiveness pillars and also the highest rating for quality of education among East African countries. Kenya has been ranked 50th in the area of innovation, with capacity for innovation at positions 46. Kenya is also considered to have comparatively high quality scientific research institutions at position 50 out of 144. However there is still a massive room for improvement for Kenya in the following areas of Higher education and innovation: Tertiary education enrolment - 130/144, Quality of Maths and Science education- 76/144, Internet access in schools - 85/144, Availability of research and training facilities-66/144, Availability of scientists and Engineers-66/144, and finally PCT patents, applications/million populations -95/144.

As stated previously, there is a deficit (minimum of - 216%) of Engineers in Kenya. Huge mismatch between supply and demand of Engineers in Kenya is apparent which in turn challenges Kenya's higher engineering education system. This means that there is an urgent need for developing a significant mass of Engineers and Technologists to reduce the existing deficit gap.

The Kenya Vision 2030 is the vehicle for accelerating the transformation of our country comprising of 47 counties into a rapidly industrialized middle-income nation by the year 2030. Science, technology and innovation is indeed at

the heart of Kenya's vision to become a globally competitive and prosperous nation as contained in the National Vision 2030 national blue print. Chief Executive Officer of the Commission for Higher Education, Kenya Prof E. Standa explained that Vision 2030 policies need to be integrated into the university programs as the Government relies on education for implementation of the policies. He also added that the universities should formulate courses that address the current market trends and challenges of technology.

Although the ST&I Act 2013 did not appear to address engineering issues distinctively, it is absolutely unimaginable to implement the Act without the participation of Engineers and the introduction of reforms in engineering education in Kenyan universities and technical colleges as defined in the Universities Act of 2012 [39] and the TVET Act 2013 [40]. The new ST&I Act of 2013 is a very ambitious and it generates a new organization to promote innovation, called the Kenya Innovation Agency (KENIA). The achievement of the striving goals of the ST&I Act 2013 requires radical reforms in engineering education and research. First, there is a need to build engineering research capacity of Kenya and to boost the throughput of competent graduates. All of these transformations shall necessitate innovative leadership at both the university level and in the schools of engineering in Kenyan universities. The Universities Act 2012 aims to reform university education in Kenya and is the one that created the Commission for Universities Education that will regulate all universities, both private and public. The TVET Act 2013 aims to reform and regulate the Technical and Vocational Education and Training in Kenya. Once fully implemented, the three Acts of Parliament ensure that Kenya can pursue the Vision 2030 whose foundation is Science, Technology and Innovation [41].

Rapid dissemination of TRIZ supporting the innovation process based on best practices among world-leading industrial companies has demonstrated a higher effectiveness compared to other innovation methods. Perhaps, the main advantage of TRIZ is that while other methods are limited to answering the question: "What to do?" TRIZ targets answering both questions: "What to do?" and "How to do it?" This is possible due to the knowledge-based nature of TRIZ. During the last decade, the use of TRIZ worldwide has increased manifold, especially in Asian-Pacific countries due to the heavy use of TRIZ in their hi-tech industries. Nevertheless, academic organizations and universities have been quite slow in introducing TRIZ into their curricula and tend to leave innovation to the students creative talents [42]. Learning

TRIZ within the university environment appears to be useful not only for acquiring knowledge and skills on how to deal with technical innovation, but also on improving general problem solving skills. It can be concluded that TRIZ has become one of the most important problem-solving methodologies that has a great impact in enhancing inventive problem-solving ability and skills of students in higher education [43]. Above overview provide evidence that the practice of applying TRIZ to higher engineering education indicates that TRIZ methodology significantly improves innovative abilities of engineering students.

Despite its strength and potential, several difficulties exist, however, to the wider adoption of TRIZ in the engineering design curriculum. These include: [44]

1. Terminology and modelling methods unique to TRIZ and fundamentally different from those found in classical engineering design.
2. The method is absent from nearly all introductory and capstone engineering design textbooks.
3. Most engineering design faculty are unfamiliar with the method, and therefore will require extensive training on TRIZ.

Notwithstanding the above limitations, in authors' opinion, TRIZ deserves to hold its own place in the engineering curriculum. Ideally, if TRIZ is taught as a separate subject, it would be formally integrated into other areas of the curriculum. Even without formal integration, however, students instructed in TRIZ methodology will develop the ability to think completely differently (outside the box) when solving engineering problems. Integrating TRIZ into the curriculum may take time, since curriculum development is complicated, time consuming and at times even political. The greatest challenge facing TRIZ proponents is the natural resistance to change rooted in most organizational cultures. Furthermore, the cultures of educational institutions are among the most resistant to change. Organizational cultures that embrace and institutionalize change will be needed to integrate TRIZ into the curriculum successfully.

Unwritten believe, based on the overwhelming complains from the industry, is apparently that an increasing number of fresh engineering graduates lack problem solving skills. Furthermore, the number of students choosing to study engineering in university has reduced with the increasing variety of other courses and deteriorating attitude towards engineering profession. It is also apparent, that today majority of Engineers are not leaders in modern societies



because they have lost their ability to generate new inspiring ideas, the key ability of a leader. The main reason behind this is that Engineers are not trained on how to think creatively, and this has a direct impact on their ability to invent.

Our future requires that the best and brightest students become Engineers. Engineering programs at our universities must attract these students by offering meaningful, challenging and creative engineering programs leading to successful and productive careers. The engineering sciences have their roots in mathematics and basic sciences but should carry knowledge even further toward creative application. The challenge in engineering education is to find an optimal combination and balance between fundamental engineering sciences and systematic methods for innovative thinking and problem-solving. Engineering education in Kenya today is still mounting, and in order to continue its evolution in competitive manner, it must undergo a paradigm shift by including in their engineering curricula systematic methods for innovative thinking and problem-solving, such as TRIZ. Within this paradigm introducing TRIZ at engineering schools of universities, especially within the context of a specific study subject, seems to be a right direction.

Expectations: Incorporation of TRIZ into engineering curricula will equip engineering graduates with fundamentally new way of thinking and solving engineering problems, leading to the potential boost of innovations. It would also contribute to the enhancement of quality of engineering curriculum, as conceptually new proficient problem-solving methodologies is introduced and practiced. It could hopefully also advance the accreditation of engineering programs, professional registration of graduate Engineers, and on overall enhance engineering competency. Accelerated engineering competency, industrial success of engineering graduates trained with systematic methods for innovative thinking and problem-solving, and enhanced level of innovations would in turn influence the attitude of parents and students in the process on choosing engineering as a prestigious and fulfilling career, resulting in much more students pursuing engineering, consequently significantly reducing the deficit of supply and demand of Engineers in Kenya.

#### 4. Conclusions

Creativity is a skill which can – and must – be developed. A conclusion is that, paraphrased from G. Altshuller [45]: the earlier a person starts learning TRIZ and develops creative thinking skills, the higher the chance that this

person will be able to resist psychological inertia and start thinking outside the box when solving problems.

Novel thinking towards engineering education as well as research and innovation are crucial in order to advance Kenyan engineering education to a new innovative model that will produce engineering graduates who are design-ready and confident in their ability to innovate.

Numerous countries have already in full swing benefiting from such methods as TRIZ; on the other hand many of us in the developing nations are either completely unaware, or in a very comfortable state of hibernation with the warning sign "Do not disturb", or extremely resistant to any changes, even if the change is emphatically for the better.

With the continuous globalization and potential competitors emerging worldwide, being one step ahead of the competition is essential to survive; therefore the time for change is NOW!

#### 5. Acknowledgement

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