

Proposed changes in Engineering Students' Final Project & Attachment Management in JKUAT to Enhance University – Jua Kali Collaboration to bridge existing technological

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Abstract—Apart from being a major employer, Kenya's informal sector which is commonly referred to as *Jua Kali* has produced a lot of useful inventions and improved products that have changed Kenyan lives. Some of these products include airplane prototypes, improved charcoal stoves, wheelbarrows and *money maker* water pumps just to mention a few. However most of these products have failed to attain optimal mass production and improvements due to insufficient technical expertise in carrying out design and optimization, poor research and logistical support, financial constraints and ineffective marketing strategies. For this sector to fully contribute to industrialization of our country, deliberate efforts must be made to support and nurture it. This provides an entry opportunity for institutions of higher learning, like JKUAT, to collaborate and convert the raw indigenous ideas to workable and technological systems for mass production.

Keywords—Industrial collaboration, academia and industry, formal and informal sectors, Jua Kali.

I. INTRODUCTION

THIS paper reviews and proposes changes in project management for engineering students in JKUAT. We explore the benefits to be earned if student projects are done outside university premises in collaboration with Jua Kali artisans. Students will be exposed to apprenticeship in the informal sector and get a shot at production using only the equipment available to artisans in the Jua Kali sector. Students may come up with new/ improved designs or fabricate more efficient tools but will work under the supervision of the artisan since the latter is more experienced in the field. An alternative approach is where the artisan does the casting or fabrication as may be required under the guidance of the student who will design, provide intellectual support, pay and write a report on the experience with suggestions for process/ equipment improvement. Ideas and inventions generated at this level can be branded and exposed to the market. This will ensure that the products generated attract funding and raise the much needed income for the sector.

Currently JKUAT has 10 BSc engineering programs under College of Engineering and Technology (COETEC) [3]. These include; Civil Engineering, Electrical and Electronic

Engineering, Electronic and Computer Engineering, Telecommunication & Information Engineering, Geomatics Engineering and Geospatial Information Systems (GEGIS), Mechanical Engineering, Mechatronic Engineering, Mining & Mineral Processing Engineering, Marine Engineering, Agricultural & Bio-systems Engineering. Each year the university produces hundreds of graduates in electronics/ electrical engineering, agricultural, mechanical engineering, mining and mineral processing among others [3].

The college of engineering trains undergraduate and postgraduate students as well as carrying out relevant research. The following are the main objectives:

1. To provide manpower for the development of industry both the public and private sector;
2. To provide relevant manpower for various sectors involved in research in manufacturing, infrastructural development, mining, etc.

The mission of JKUAT is to offer accessible quality training, research and innovation in order to produce leaders in fields of engineering and enterprise development among others to suit the needs of a dynamic world [10]. While the vision of the University is to be a University of Global Excellence in Training, Research and Innovation for Development



Figure 1: Mining engineering students carrying out magnetic survey

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Figure 2: JKUAT engineering laboratories



Figure 3: JKUAT Electrical engineering laboratories

The training offered in engineering courses lasts for periods of 5 years for undergraduate. In the first three years of the programs, all the students cover common units mainly in mathematics, applied science, fundamental engineering and principles relating to their area of specialization [3]. Each student undergoes mandatory eight-week industry-based practical attachment at the end of the second, third and fourth years of study [3]. The student is usually tasked to write a report of the experience and draw sketches of equipment used [4].

During industrial attachment, the engaging institution/company is expected to assign a supervisor to the student. This supervisor will instruct and follow up on the activities of the attaché then give recommendation and signature on a daily basis in forms provided by the university. A student is not allowed to graduate until he/she has been to three industrial attachments and spent the required hours.

Target groups for JKUAT's engineering programs include qualified form four graduates, 'A' Level graduates, Diploma holders and holders of other qualifications recognized by the University Senate. Form four graduates are admitted through the Kenya University and College Central Placement Service KUCCPS.

The Engineers Board of Kenya (EBK) is the body mandated to register, regulate and maintains a roll of qualified engineers

in Kenya. The EBK was established under Section 3(1) of the Engineers Act 2011. EBK boasts a cumulative registered membership of over 1800 certified engineers. Most of the Engineering courses offered at JKUAT are accredited by the EBK and a good number of JKUAT staff are registered members.

JKUAT was started as a technical college in 1981. It was a cooperative project between the Government of Japan and the Government of Kenya. Since then, this institution has grown tremendously. It is now the leading and most prestigious, most preferred institution of higher learning for engineering enthusiasts in the region, offering training at undergraduate, Masters and Doctor of Philosophy levels [3]. According to [3], the University consists of the College of Engineering and Technology, Faculty of Science, Faculty of Agriculture, the School of Architecture and Technology, School of Human Resource Development and Institute of Computer Science and Information Technology. There are several research institutes that focus on extension activities and scientific inquiry.

Programs in the College of Engineering and Technology fall under three Schools: School of Civil, Environmental and Geospatial Engineering; School of Electrical, Electronic and Information Engineering; School of Mechanical, Manufacturing, Mining, Materials and Petroleum Engineering [3].

I. JUA KALI

Jua Kali is a Swahili word which can be interpreted as 'hot sun'. This refers to Kenya's informal sector where in many cases business is carried out under open air environments exposed to the heat of the sun throughout the day [6]. Jua Kali artisans and traders form the majority of the human capital which powers the economy in urban areas countrywide. According to a research done by J. O. Marwanga [1] there is enough evidence indicating that the majority of the population derives their livelihood from the informal economy. They procure or extract, raw materials, manufacture essential products and distribute various commodities through shops, open-air stalls and hawking. Most Jua Kali activities are concentrated in urban areas though a good number of artisans operate in the rural setting. In Nairobi, Jua Kali artisans are located at Gikomba, Kamukunji, Ziwani, Kawangware, Kariobangi Githurai and Roysambu to mention just a few.

Artisanal apprenticeship may be a result of traditional African craftsmanship which has been around as long as our communities have been handed down from generation to generation. However the artisanal informal sector (Jua Kali) as is known today may have started as early as 1899 at the advent of colonialism. After the completion of the Uganda railway Nairobi and other towns started to mushroom. This also came with the alienation of land and this forced many Africans to migrate to the White settler farms, Nairobi and other urban centres, in search of wage labour. Those who failed to secure wage labour in Nairobi turned to hawking and other marginal activities such as the brewing of traditional liquor and craftsmanship. It is further argued that although a number of Africans acquired artisanal skills from the government departments and mission schools by the inter war period, very

few of them practiced artisanal businesses in Nairobi. Rather, most of them acquired jobs in the formal sector. Therefore, the African pioneer Jua kali artisans were those who acquired their skills informally from the Asian artisans. The Second World War marked the increased exploitation of the Kenyan economy. Most of the Africans who migrated to urban centers, demobilized soldiers after the Second World War and those evicted from white settlement farms after farm mechanization turned to the informal sector to make a living. They engaged in carpentry, metal work, woodwork, bicycle and motor vehicle repair, as well as shoe repair. Evidently, these Jua kali trades, were a direct consequence of the inadequate job opportunities in the waged sector of the economy. At independence in 1963, the influx control measures against African movement into Nairobi were lifted. This in turn accelerated the influx of thousands of the ex-detainees and other Africans who had been repatriated from Nairobi during the Emergency, educated and semi-educated job seekers. It is against this background that many Kenyans were pushed into the Jua kali sector after independence into the 1980s and 1990s.

The Jua Kali industry constitutes shop owners, engineers, craftsmen, apprentices and road-side traders etc. Their activities include repair or production oriented activities in motor vehicle repair, carpentry and woodwork. Areas of specialization have broadened since M. Walsh's [2] publication and has incorporated very many additional areas ranging from electronics to beauty and cosmetics. The products include amplifiers, inverters, wheelbarrows, furniture, kitchenware, metal suitcases for students (*sanduku*) and clothes, which are sold locally and regionally in the various market centers. Main means of distribution is through the traditional commercial supply chain and infrastructure.



Figure 4: Wheelbarrows & Metallic Boxes made by Jua Kali



Figure 5: Improved Charcoal stove by Jua Kali artisans



Figure 6: An assortment of Jua Kali products

The potential of the informal sector and the Jua Kali sector in particular as a vehicle for job creation and a tool for wealth generation was first recognized by ILO in 1971 [5]. More attention was focused on the movement in 1986 triggering the creation of the Ministry of Technical Training and Technology by the Government of Kenya. In more recent years, the definition of Jua Kali has evolved to mean small scale operators who are more limited by resources than by choice.

About 89.72 per cent of the 832,900 new jobs created in 2016 were from the informal sector. The 2017 Economic Survey by the Kenya National Bureau of Statistics showed that the informal sector, commonly referred to as Jua Kali, generated 747,300 jobs while the remainder 85,600 were created by the formal sector.

II. LITERATURE REVIEW

A. Kenyan Academia's Current Project Management and Apprenticeship/ Industrial Attachment

A lot of studies have been carried out regarding the Jua Kali sector by many academicians and researchers from various Kenyan universities. These include JKUAT, UoN, KU, Moi, etc. Most of these studies have focused on various thematic areas of the sector including government policy, marketing, value addition, technological improvements, organization, training, intellectual property etc. The authors referenced in this paper have demonstrated understanding of the sector's challenges. Kathuru Joseph Gitari (UoN) studied The Emergence and Development of the Informal Sector 1908-2009 in Eldoret. J. O. Marwanga, did a study on "The impact of informal economy on employment creation," the Case of

Kamukunji Jua Kali artisans in Nairobi, Kenya [1], Berlin, J. Sullivan ed., cried out a study titled “Under the sun or in the shade? Jua Kali in African countries and S. M. Maina, R. W. Rukwaro, [2] M. Walsh, on “Education, training and the informal sector in Kenya” and W. H. Onyango, wrote a paper on “Infusing design in the Jua Kali production processes” among others.

The evidence investigated by M. Walsh [2] shows that the informal sector can absorb many more apprentices than are trained at present. According to M. Walsh the total number of trainees could be more than doubled simply by filling up the existing underutilized capacity. It is noted that the pattern of underutilization seems to have arisen because entrepreneurs are experiencing difficulty in recruiting capable apprentices, a reflection of the fact that many of them are no longer happy to take on trainees primarily for social reasons, but are beginning to put more economic considerations first. M. Walsh proposes new uses of existing training institutions acknowledging that the existing public training institutions possess the capacity, at least in theory, to service the informal sector in skill upgrading, product diversification, quality improvement, and research for appropriate technology.

B. Short-comings of Formal Education System

In Kenya, according to UNEVOC Berlin, J. Sullivan ed [5], the majority of the unemployed, characterized by people without work who are seen idling around or actively looking for work, are the young and relatively more educated. It is estimated that the informal sector will create about 100,000 jobs per year if critical training programs which are market-driven are created [5]. It is also noted that despite high demand for education and major investments in this sector by Sub-Saharan African countries, the region’s education systems are not producing the intellectual and human resources required for sustainable economic growth and political stability. It recommends that “The supply of technicians as well as of craftsmen and artisans should be augmented through ‘on-the-job’ and ‘in-service training’, a move that should involve both government department and the private sector.

III. JUSTIFICATION

The human resource produced from Kenyan universities has not been fully and effectively utilized in powering industrialization geared towards substantial economic development for the country. According to J.O. Marwanga [1] and UNEVOC Berlin, J. Sullivan [5], there is urgent need to come up with proactive radical solutions to this problem so as to create employment opportunities that match the high rate of growth of the labor force in Kenya. Long-term collaboration between JKUAT and the Jua Kali sector with regards to innovation has a number of benefits:

1. It will help link academia and researchers to the informal and indigenous sector creating the much needed synergy that will utilize the strengths of two sectors to propel industrialization.
2. The Jua Kali sector may be compared to the pre-industrial Europe cottage industry which formed the

foundation for industrialization. This sector is at its infancy and therefore provides opportunities for innovations, improvisations and research.

3. Unlike the formal sector the Jua Kali sector is not riddled with rigid bureaucracy and red tape which inhibit creativity and spontaneous thinking and therefore the Jua Kali sector may accommodate more mistakes providing the opportunity to test new ideas. This may also help improve the quality of the sector’s products and change the negative public perception about the sector.
4. Most artisans engaged in the Jua Kali industry do not have sufficient education required to document and protect their intellectual property. This has led to lose of indigenous Kenyan knowledge, innovations and ideas to other countries. So, University-Jua Kali collaboration will help seal this loophole.
5. Currently there is a critical shortage of vacancies for student attachment in the formal sector. So opening up and accepting the informal sector as an alternative provider for attachment with create limitless opportunities.

A. Optimal Utilization of the Academic Knowledge and Creativity of Students

In Kenya, engineering knowledge and expertise is diverse. There exists traditional craftsmanship passed down from parent to offspring, *Jua Kali* craftsmanship in urban areas and academically qualified engineers.

When engineering is supported with quality management, theoretical research, design, standardization, financing and government policy support, success becomes inevitable. This can be witnessed from the developments in the West and Asian countries throughout the last century and currently.

Students are usually gifted with innovative talent and JKUAT offers the convenience of having experts from a wide range of interdependent academic disciplines within the same institution. This provides an ideal place for catalyzing the creation of complete industrial systems by incubating ideas from various departments. Experts from the informal sector can provide the much needed experience in tool handling, efficient methods, no-go’s and much more.

B. Industrial attachment and students’ final project

Apart from the theoretical classes, mentioned elsewhere, engineering students at JKUAT are required to undergo practical attachment within and without the university. In addition they also undertake an individual final year project. A student will undergo a mandatory practical training attachment, each of eight weeks, on at the University at the end of the second year and the others at the end of third and fourth years of study including units of practical training in the engineering workshops during the academic semesters. A student must undertake, in their final year of study, a suitable engineering project under supervision of a member of academic staff. All this is geared towards ensuring that the student acquires the basic engineering skills and innovative attitude.

To appreciate the dynamics of attachment in JKUAT, two departments have been sampled namely Mechanical Engineering Department and Mining, Materials & Petroleum Engineering (MMPE) Department for the year 2017-2018. The table below shows the frequently visited companies for attachments by students and the activities that they are involved in.

Attachment records for 4th year MMPE Students 2017-18

Name of company	No of students	Activities
Ministry of Mining; Mines and Geology Department	2	<ul style="list-style-type: none"> • Map analysis and digitization. • Geophysical exploration methods • Explosives and drilling • Assaying • Geochemistry lab and equipment (atomic absorption and spectrometer, gold analysis). • Lapidary section(jaw crusher and pulveriser) • X-ray fluorescence
East Africa Portland Cement	3	<p>KURKUR QUARRY</p> <ul style="list-style-type: none"> • Quarry operations, Crushing operations and collection of cycle time data • Tracking and mapping quarry boundaries using GPS mapping tools • Limestone crusher inspection • Laboratory analysis samples <p>BISSEL QUARRY</p> <ul style="list-style-type: none"> • Safety and Health policy • Drilling operations • Blasting of drill holes <p>KABINI QUARRY</p> <ul style="list-style-type: none"> • Location of drill holes using GPS • Maintenance of diesel crusher • Clinker manufacturing and kiln operation • Cement milling and packaging
City stone Quarry	9	<ul style="list-style-type: none"> • Safety and Maintenance operations. • Drilling. • Stone cutting. • welding • Drilling holes for blasting, charging, stemming and blasting. • Operation of a wheel loader.
National Water Corporation	1	<ul style="list-style-type: none"> • Beams and columns. • Well design and construction. • Hydrological surveying and stratigraphy. • Drill pipes, bits and rotating equipment. • Hoisting equipment. • Rig instrumentation system • Noise control.

Wazaire Gems Company	1	<p>Study of gemstones</p> <ul style="list-style-type: none"> • Cut and rough gemstones, • Naming and measuring gems (Trade names and misnomers) • physical and chemical properties of gems • Study of magnification using loupe and gem microscope. • Grading of gems
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Mechanical Engineering Department attachment record 2017-18

Company/Institution	No.of Students	Activities
GIZ Westlands	2	<ul style="list-style-type: none"> • Repair and Maintenance • Installations • Design
DT Dobie, Lusaka rd	1	<ul style="list-style-type: none"> • Repair and Maintenance • Installations • Design
East African Breweries Limited, Ruaraka	2	<ul style="list-style-type: none"> • Repair and Maintenance • Installations • Design
British American Tobacco LIMITED. Likoni RD	1	<ul style="list-style-type: none"> • Repair and Maintenance • Installations • Design
Numerical Machining complex	1	<ul style="list-style-type: none"> • Repair and Maintenance • Installations • Design
Nairobi Bottlers Limited, North airport rd	1	<ul style="list-style-type: none"> • Repair and Maintenance • Installations • Design
Unga farmcare EA Ltd, Dakar RD. Ind. Area	1	<ul style="list-style-type: none"> • Repair and Maintenance • Installations • Design
East African Portland cement, Athi river	1	<ul style="list-style-type: none"> • Repair and Maintenance • Installations • Design
Air Kenya Express LTD, Wilson Airport	1	<ul style="list-style-type: none"> • Repair and Maintenance • Installations • Design
JB Motors, Industrial area	1	<ul style="list-style-type: none"> • Repair and Maintenance • Installations • Design
CMC Nairobi, Lusaka rd/ Heavy commercial vehicles	2	<ul style="list-style-type: none"> • Repair and Maintenance • Installations • Design
Kahawa Barracks	2	<ul style="list-style-type: none"> • Repair and Maintenance • Installations • Design

Kapa Oil Refineries Ltd, Mlolongo	1	<ul style="list-style-type: none"> • Repair and Maintenance • Installations • Design
Subaru Kenya, Industrial area	1	<ul style="list-style-type: none"> • Repair and Maintenance • Installations • Design
Central Glass Industries, Kasarani	1	<ul style="list-style-type: none"> • Repair and Maintenance • Installations • Design
Kenya Airports Authority, Kisumu Airport	1	<ul style="list-style-type: none"> • Repair and Maintenance • Installations • Design
JEEP Motors TATA Kericho	1	<ul style="list-style-type: none"> • Repair and Maintenance • Installations • Design
Nzoia sugar company	1	<ul style="list-style-type: none"> • Repair and Maintenance • Installations • Design
Mumias Sugar Co.	1	<ul style="list-style-type: none"> • Repair and Maintenance • Installations • Design

From the sampled information it is observed that: (1) the preferred companies are all formal establishments. There is no informal establishment in the list. (2) The students are involved in regular routine operations. (3) Operations involving systems design and innovation are not open to students on attachment. (4) The existing systems & structures are rigid and not able to accommodate any new untested innovative ideas from students.

While understanding the existing operational systems of a company is important, development of key engineering skills at the earliest opportunity is critical. This requires companies to be prepared to take risks and create room and space for innovations within their existing structures. This will involve allowing students to participate in designs of new models, piloting and implementation. It is in this regard that it's proposed in this paper that the informal Jua Kali Sector be considered as an alternative for attachments and internships.

Apart from providing more chances for attachment, the informal sector will have a number of added advantages. It's less restrictive and more flexible in accommodating new ideas. It will be possible to take risks without adverse impacts on related systems. It will be easier for the student to own intellectual property of any innovation. The outcome of any innovation will be felt immediately given the fact that in the Jua Kali industry the innovator is in direct contact with consumers. Innovations developed under these circumstances can be easily and cheaply replicated and hence will motivate entrepreneur desire in the student. There are greater growth possibilities in the Jua kali sector going forward than the formal sector.

C. STUDY HYPOTHESIS

This study asserts that the informal Jua Kali sector will

provide the most appropriate environment for identifying, developing, nurturing, and employing young innovative skilled engineers from JKUAT using the student attachment and project format than the formal sector. This will position students for the future in this most promising sector.

D. OBJECTIVE

The key objective of this study is to explore and illustrate the merits of University-informal sector collaboration and the opportunities the informal sector can provide for engineering innovations.

- To encourage student attachments in the informal sector and increase the vacancy available for attachment
- To promote the utilization of the growth potential of the informal Jua Kali sector for innovation and experimentation
- Integrate IT in the informal sector
- Help improve the quality of products and services provided by the Jua Kali informal sector and make them competitive in the local and international market.

E. METHODOLOGY

This study was carried out by doing desk review of existing secondary data and related researches and documentation. However a substantial amount of information was acquired by unstructured interviews of the Jua kali artisans and university staff as well as through observation.

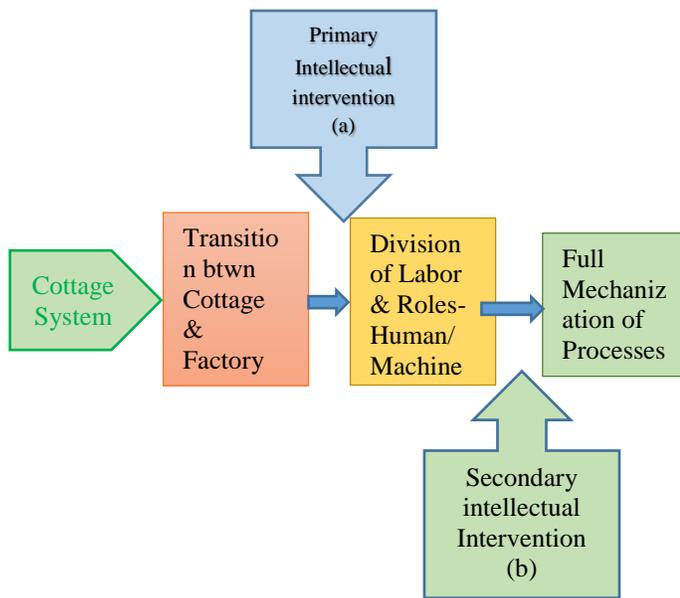
IV. INFUSION OF INTELLECTUAL KNOWLEDGE IN THE JUA KALI SECTOR: THE WAY TO THE FUTURE

Past experience from other regions such as Europe show that there are four systems leading to industrialization namely; Family System, Handicraft System (Guild System), Domestic System or Cottage System and Factory System. The Kenyan Jua Kali sector currently represents the cottage system which is at the threshold of the indigenous factory system.



Four systems leading to industrialization

Development of the Cottage industry to Manufacture



From the flow chart above and according to this paper cottage or informal sector industry develops in four stages to full industrialization. The initial cottage activities undergo a transition period in which there is both human and machine labor and some parts of the processing are done under cottage while the other parts are done by factory processes. This will then mature to a stage of division of labor in which specific processes that produce specific products are concentrated in one location to supply the rest of the production processes. The final stage is that of full mechanization where over three quarters of the production is done by machine.

Based on this Jua Kali development conceptual model there are key entry points for academic intervention. These may be referred as primary intervention (a) and secondary intervention (b). At the primary stage the key interventions will include design of factory processes, design of packaging, acquisition of intellectual property, quality assurance, marketing and health and safety among others. The secondary stage of intervention may well be similar to the first stage however at this point there will be need for advanced mechanization including digital systems, robotics and smart technology.

V. CONCLUSION

As the Jua Kali sector continues to develop there will be limitless opportunities for academic and research communities to be part of this dynamic sector. This development will provide room and space for experimentation, innovation and creativity. The earlier this opportunity is sized the better. The proposed student attachment model can and will be a stepping stone in the right direction.

Jua Kali artisans have also accumulated undocumented skills throughout their many years of innovations and improvement, which is guided mainly by market demand enforced by the need to earn a living in the modern financial system. Innovations need to be studied, catalogued and documented to facilitate

future developments.

Being an accomplished academician should not separates an individual from the larger society because of the way in which the science which drives engineering discipline strives to cope with first world trends. A desirable alternative would be studying and working to improve local industry while learning from the mistakes of developed countries.

The mistakes made by developed nations include manufacturing products with unchecked levels of carbon emission – which is the main contributor to the current problem of global warming, lead poisoning, overproduction with a focus on maximization of profits rather than continuous development targeted at fulfilling existing needs

Our education systems should have the power to return an improved individual to the society, one who not only understands the society's inner workings and technologies but is also capable of adding value by building upon the existing systems. For this feat to be achievable, local traditional and industrial products must be cataloged, their origins and developments taught to students who are expected to make improvements and other innovations with an aim of meeting existing needs with greater optimized efficiency.

Even as we encourage the education of our children, it becomes essential that we find a way of utilizing the knowledge and skills available in the communities outside the education system

It is the submission of this paper that efforts be made to adopt the current attachment and final student project requirements to suit the informal Jua Kali sector and encourage students to venture into the sector.

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