World Transactions on Engineering and Technology Education
Vol.2, No.1, 2003

A framework for the delivery of a competitive undergraduate training programme in mechanical engineering: a JKUAT case study

Paul W. Magoha & Alfayo A. Alugongo

Jomo Kenyatta University of Agriculture and Technology
Nairobi, Kenya

ABSTRACT: With increased sophistication in a global trade pattern, both industries and universities worldwide cannot afford to ignore exploring strategies and opportunities for sustained competitiveness. For industry to be competitive, it has to efficiently exploit the resources at its disposal. Human resource is one of the major inputs that any industry requires for a successful operation. Suitable human labour required by industry are graduates well grounded in both theoretical and practical work, and able to adapt to continually changing industrial needs. For a university to be competitive it has to offer training that will attract prospective students and meet industry's requirements. Conducting engineering training programmes, relevant to industry's needs, poses a big challenge to institutions of higher learning in developing countries. This paper appraises the entire mechanical engineering undergraduate programme offered at *Jomo Kenyatta* University of Agriculture and Technology (JKUAT), Nairobi, Kenya, in terms of industry needs. It shows why the prospective employers prefer to hire graduates of this programme. Finally, it serves as a case-study on how a university in a developing nation, despite many problems, has organised itself to provide quality education in mechanical engineering.

INTRODUCTION

Shortages of human labour with suitable skills and knowledge have been, and remain, a significant problem for industries in developing countries. Therefore, the development of human resources with appropriate skills and knowledge is crucial. This task can only be efficiently accomplished by institutions of higher learning like universities. To attempt to accomplish this, higher learning technical institutions have to continuously develop innovative programmes of education delivery and training. One core activity is to continue to serve society by transferring intellectual products to meet the changing needs of society.

Collaboration with industry in academic and professional fields to search for solutions and strategies to improve society is fundamental to this process. Training and other capacity-building measures in engineering education should be built into action plans for strategic directions that deal with each respective engineering discipline. However, in addition to these measures, a strategic plan should aim at promoting engineering education and training and more general organisational development and planning at the university level.

The Department of Mechanical Engineering at *Jomo Kenyatta* University of Agriculture and Technology (JKUAT), Nairobi, Kenya, has achieved these goals by developing a programme outlined in this article. In order to abide by standards shared throughout engineering professions worldwide, the Department has positioned itself at the cutting edge of knowledge creation and dissemination. Modern equipment for teaching and research has been acquired through generous donations made by the Governments of Kenya and Japan. The Department is emerging as a centre for excellence in the region, serving to underwrite effective teaching, training and research programmes in mechanical engineering in accordance with the University's mission.

HISTORY OF THE DEPARTMENT

The Department of Mechanical Engineering was founded in 1981 at the inception of *Jomo Kenyatta* College of Agriculture and Technology (JKCAT). It initially offered technician certificate and diploma courses in three areas: automotive, construction plant and agricultural machinery. Since then, it has grown and developed tremendously over the years, both in terms of facilities and programmes. The certificate and diploma programmes have since been discontinued. Today, the Department offers two programmes: Bachelor of Science (BSc) and Master of Science (MSc) degrees in mechanical engineering. The first intake for the BSc degree in mechanical engineering was admitted in 1990. The programme takes five years and admits students in the 8-4-4 system of education.

Problems and Challenges Encountered during Initial Phases of the Programme's Implementation

In the past two decades, all sectors of the Kenyan economy, including higher learning institutions, experienced various kinds of problems, including political interference in the running of the institutions. During the same period, the universities' limited resources were mismanaged due to high-handedness of the administration, which never embraced democratic principles in the management of the institutions.

The Structural Adjustment Programmes (SAPs), which negatively affected social services in sub-Saharan Africa, were introduced in Kenya under the influence of the World Bank in the 1980s and 1990s. The cost-cutting measures brought about by the SAPs led to a reduction of spending by the government on higher education. [1]. This resulted not only in deteriorating educational facilities, but also in an acute shortage of learning and teaching resources in the universities. However, most universities, including JKUAT, underwent major transformations

in terms of infrastructure growth. It was during this period that the mechanical engineering degree programme began at JKUAT.

With the election of a new government in December 2002, a curtain has been drawn on an era of the politicisation of institutions of higher learning. Far-reaching changes have been introduced in all public universities, including JKUAT. The thrust has been the introduction of a new culture: a new administrative system that embraces openness, dialogue and consultation.

In pursuit of this ideal, students and academic staff have been allowed to form unions as common platforms through which students or lecturers can share views and channel them to management for discussion and possible implementation. Currently, dialogue is used as means of resolving conflicts with the participation of all of the stakeholders involved in a universities' administration. Today, all public universities are expected to promote democratic practices and culture. That is only possible when all actors meet as partners committed to finding solutions to emerging challenges.

In response to the various challenges that JKUAT's Mechanical Engineering Department has experienced, including financial and prescriptive pressures, problems of relevance and survival, customer expectations and a desire for efficacy and efficiency, the Department initiated a number of programmatic changes and innovations to make the programme attractive.

The programme was developed with the intention of maintaining a high level of practical skills and attaining high academic standards that would give graduates a competitive edge over their contemporaries. Steps have been taken to transform the Department into a versatile centre of knowledge creation and dissemination and also as an entrepreneurial department that seeks to manage itself like a business enterprise without losing sight of its mission and intellectual agenda. The democratic space created by the new Government will further create a conducive environment for the improvement of this programme – and Kenyan engineering education generally.

THE UNDERGRADUATE DEGREE PROGRAMME IN MECHANICAL ENGINEERING AT JKUAT

Objectives of the Programme

In a depressed job market, graduate training offered to any individual in any institution should be geared towards helping those individuals create opportunities for themselves and for others and also exploit the few that are available. In an attempt to realise the dream of offering quality education in mechanical engineering, the programme has been drawn with the following specific objectives:

- To impart to students the skills, knowledge (scientific, managerial) and technical discipline necessary to make a career working as an engineer.
- To train specialists who are equipped with the basic tools for industrial business innovations in mechanical engineering.
- To produce graduates who can, first and foremost, create jobs for themselves and also for others by starting and operating new business and/or diversifying existing ones.
- To prepare practical-orientated graduates who will be actively involved in the community on matters pertaining to development.

Admission into the Programme

The minimum university entry requirement for the BSc degree in mechanical engineering is grade B+ (plus) in Kenya Certificate of Secondary Education (KCSE) or its equivalent qualification. Besides the normal university degree entry requirement, the programme has its subject cluster requirement. The candidate must pass KCSE or equivalent examination at the minimum grades set out as follows: either alternative A: Mathematics – B, Physics – B, Chemistry – B, Geography – B, and Biology – B, or alternative B: Mathematics – B, Physical Science – B+, Geography – B, and Biology Science – B. The holders of a JKUAT diploma in mechanical engineering with a distinction or a credit pass with two years working experience can also join the programme in the second year. All JKUAT programmes are taught and assessed in English. Therefore, good command of the English language is also a prerequisite.

Academic Calendar

Since the introduction of the undergraduate courses in the 1989/90 academic year, JKUAT has consistently followed a well-determined academic calendar. The academic year has two semesters, each comprising 16 weeks: 14 for teaching and two for examinations. Semester one normally commences in April and ends in August; the second semester runs from August/September to December. The period from January to March of the subsequent year is utilised as a third semester: the industrial attachment period.

Teaching Staff

The programme has attracted highly qualified and experienced staff. The yardstick for high standards is the availability of qualified and highly motivated staff, adequate facilities and well-managed and relevant academic programmes. Besides teaching, lecturers conduct research and assist with administrative duties in the Department as directed by the Head of the Department.

The Curriculum and its Mode of Delivery

The programme places great emphasis on the application of the mechanical engineering sciences, particularly in design and manufacturing. Lecturers are assigned to teach two units per week. This translates to 12 contact hours per week of which four are for lectures, six for practical work and two for tutorials.

A unit is defined as the equivalent of 35 one-hour lectures spread over one semester. Therefore, two hours of tutorial or three hours of practicals are equivalent to a one-hour lecture. Also, a one-hour lecture is equal to an equivalent amount of other assigned study or practical experience, or any combination of these that may be approved by the Board of the Faculty of Engineering. A unit taught jointly between departments is counted as a single unit. In the first year of study, a candidate is required to take a minimum of 16 units distributed as follows: two university units, Communication skills HRD 2101 and Development studies HRD 2102, and nine

from the Faculty of Science. The remaining five are core units from the department of mechanical engineering. Students studying for the programme in their second, third, fourth or fifth years of study take a minimum of 16 units in any one year of study, as shown in Table 1. All units taken in the first, second and third years are common. In the fourth and fifth years of study, students take units from their chosen area of specialisation. The areas of specialisation in the BSc degree in mechanical engineering focus on either automotive or production engineering.

The development of the syllabus and teaching is based on a close working relationship with the industry. Industry managers were consulted at the inception of the curriculum and are a part of the personnel who run the programme. Industry managers are encouraged to take up part-time teaching assignments on a

Table 1: The syllabus for the BSc degree in mechanical engineering at JKUAT [2].

Year of study	Semester I		Semester II	
	Unit code	Unit title	Unit code	Unit title
First	HRD 2101	Communication Skills	HRD 2102	Development Studies
	SMA 2170	Algebra	SMA 2173	Calculus II
	SMA 2171	Geometry	SMA 2174	Introduction to Computer Science
	SMA 2172	Calculus I	SMA 2108	Chemistry II
	SCH 2101	Chemistry I	SCH 2109	Physics II
	SPH 2102	Physics I	SPH 2103	Introduction to Material Science
	EME 2101	Engineering Drawing and Design I	EME 2104	Engineering Drawing and Design II
	EME 2102	Workshop Processes and Practice I	EME 2105	Workshop Processes and Practice II
Second	SMA 2270	Calculus III	SMA 2271	Ordinary Differential Equations
	SMA 2175	Computer Programming I	SMA 2276	Computer Programming II
	EME 2201	Engineering Mechanics I	EME 2206	Engineering Mechanics II
	EME 2202	Machine Elements I	EME 2207	Machine Elements II
	EME 2203	Engineering Drawing and Design III	EME 2208	Engineering Thermodynamics I
	EME 2204	Engineering Materials	EME 2209	Fluid Mechanics I
	EME 2105	Workshop Processes and Practice III	EME 2210	Workshop Processes and Practice IV
	EEE 2208	Electrical Engineering I	EEE 2313	Electrical Engineering II
	EME 2211	PRACTICAL ATTACHMENT I (Eight weeks)		
Third	SMA 2370	Calculus IV	SMA 2371	Partial Differential Equations
	EEE 2316	Electronics	EME 2307	Metrology
	EME 2301	Mechanics of Machines I	EME 2308	Mechanics of Machines II
	EME 2302	Solid and Structural Mechanics I	EME 2309	Solid and Structural Mechanics II
	EME 2303	Engineering Thermodynamics II	EME 2310	Engineering Thermodynamics III
	EME 2304	Fluid Mechanics II	EME 2311	Fluid Mechanics III
	EME 2305	Material Processes I	EME 2312	Material Processes II
	EME 2306	Engineering Design I	EME 2313	Engineering Design II
	EME 2314	PRACTICAL ATTACHMENT II (Eight weeks)		
Fourth	SMA 2272	Statistics	EME 2409	Hydraulic Power and Control
	EME 2401	Mechanics of Machines III	EME 2410	Mechanics of Machines IV
	EME 2402	Solid and Structural Mechanics III	EME 2411	Solid and Structural Mechanics IV
	EME 2403	Engineering Thermodynamics IV	EME 2412	Computational Analysis
	EME 2404	Fluid Mechanics IV	EME 2413	Machine Design II
	EME 2405	Machine Design I	EME 2414	Industrial Management II
	EME 2406	Industrial Management I	EME 2415	Systems and Control Engineering
	Electives: Either Production Engineering:		*Electives*: Either Production Engineering:	
	EME 2407	Production Technology I	EME 2416	Production Technology II
	or Automotive Engineering:		or Automotive Engineering:	
	EME 2408	Engine Technology	EME 2417	Vehicle Technology I
	EME 2418	PRACTICAL ATTACHMENT III (Eight weeks)		
Fifth	*EME 2501	Projects I	*EME 2509	Projects II
	EME 2502	Vibrations I	EME 2510	Vibrations II
	EME 2503	Industrial Management III	EME 2511	Experimental Stress Analysis
	EME 2504	Heat Transfer	EME 2512	Industrial Law
	EME 2505	Fluid Mechanics V	EME 2513	Power Plant
	EME 2506	CAD/CAM	EME 2514	Systems Reliability Engineering and Plant Maintenance
	Electives: Either Production Engineering:		*Electives*: Either Production Engineering:	
	EME 2507	Jig and Tool Design	EME 2515	Theory of Production Processes
	or Automotive Engineering:		or Automotive Engineering:	
	EME 2508	Vehicle Technology II	EME 2516	Theory of Internal Combustion Engines

*Projects I, II: EME 2501 and EME 2509 are examined as four units at the end of the second semester.

regular basis, particularly on management related courses. Excellence in teaching and learning outcomes is achieved through nationally recognised quality improvement procedures and professional development programmes that support change and encourage innovative approaches to teaching and learning. The Department periodically revises the curriculum to ensure it is in line with the fast-changing demands of the economy. In this part of the world, the University is a recognised leader in creating a student-centred and technology mediated learning environment for all students.

Departmental Teaching and Research Facilities

The Department has a physical environment conducive to the realisation of the educational objectives of the programme. Planning has been cognisant of the rapid developments taking place in the engineering educational arena and caters for the delivery of quality education well into the future.

The mechanical engineering facilities are spread over a large area and include mechanical engineering workshops, which consist of fitting and welding shops, a construction plant room, a machine shop, an automotive shop and laboratory, a plumbing shop and several laboratories, namely: thermodynamics, fluids mechanics and hydraulics, metrology, materials, production engineering, vibrations and control laboratories. Examples of these are shown in Figures 1-4. In addition, there is a drawing room, which is equipped with modern drafting machines and a small departmental library for teaching staff only. It should be noted that the Departmental facilities are used for both teaching and research activities.

Figure 1: Students working on assignments in a computer laboratory.

The Department recently acquired a computer laboratory equipped with software and facilities for special mechanical engineering training in Computer Aided Design (CAD). A robot, model 5100, was purchased from Lab-Volt Company for the demonstration of Flexible Manufacturing Systems (FMS). This robot provides a complete training in the programming and operation of industrial-style robots. Through the curriculum and hands-on experience gained in working with the robot, students learn to create automated work cells that are ideal for FMS and Computer Integrated Manufacturing (CIM) [3].

Industrial Attachment

The Department places a lot of emphasis on practicals and students spend long periods on an attachment assignment in industry to give them hands-on experience in their fields of study. To facilitate the process of industrial attachment, the Department and industry have established a linkage-Departmental/industry liaison committee. A full-time member of staff, whose duty is to identify those industries where students can be attached, handles industrial attachments. He/she is also charged with conducting market needs assessment surveys and the findings are used for curriculum review and to improve teaching approaches.

Figure 2: CAD/CAM training at JKUAT.

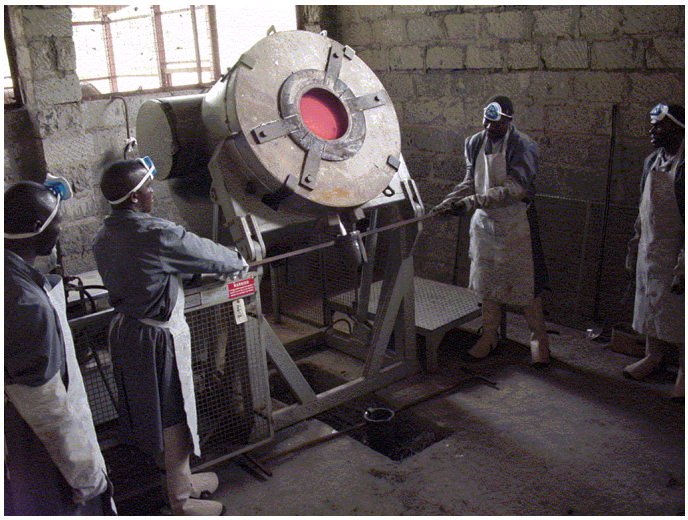

Figure 3: Students conducting practical assignments in a foundry workshop.

Figure 4: Students working on practical assignments in a machine shop.

Industrial attachments are practical training sessions where students are attached in industry each time at the end of their second, third and fourth years to spend eight weeks undergoing industrial practical training. Industrial training is an integral part of a five-year engineering educational programme and is sandwiched with a theoretical programme. These are designed to impart practical skills and enable students to appreciate the theoretical lessons covered in class. The minimum duration of the attachment for the entire programme is 24 weeks. The second years' attachments are undertaken in the faculty workshop under strict conditions and the supervision of members of staff, whereas the third and fourth years' attachments are conducted in industry.

EVALUATION OF THE PROGRAMME

Students periodically undergo tests and examinations, which they have to pass before being promoted to the next level. The various courses that make up the programme are assessed by Continuous Assessment Tests (CATs), assignments, practicals and examinations. External examiners, who are appointed by a departmental board of examiners and approved by the Senate, moderate the examinations that are taken at the end of every semester.

All units are examined during the semester in which they are taken, except for projects, which are normally examined at the end of second semester. Candidates are not allowed to sit for an examination without attending at least two thirds of the lectures and practicals. No candidate is deemed to have passed an examination unless the candidate has passed practical work. Continuous assessments contribute 30% and written University examinations contribute 70% of the total marks, excepting where a course consists solely of practical work, where it is assessed 100% by continuous assessment. This consists of CATs, coursework and/or laboratory assignments. The structure for continuous assessment is as follows: 15% – practicals/laboratory work; 5% – assignments; and 10% – tests [4].

The examinations consist of papers that each cover one unit completed during the semester. The time allowed for each written paper in a course unit is two hours, except in drawing papers, which are three hours. In order to proceed to the subsequent year of study, a candidate must pass all the required units. Each unit is graded out of 100 marks and the pass mark for each unit is 40% of the total marks. The marks are translated into literal grades as follows: 70-100% A; 60-69% B; 50-59% C; 40-49% D; and 39 and below E (fail) [4].

A candidate is allowed to sit for supplementary examinations in failed units up to a maximum of five units in any one academic year. A candidate who fails, even after sitting supplementary examinations, may be allowed to repeat the year upon recommendation of the departmental and faculty board of examiners and with approval from the Senate. No candidate is allowed to repeat any given year of study more than once. The semester system is convenient to both the administration and students, as it enables students to work hard to clear their course knowing that supplementary examinations await them if they fail.

All students taking the programme must also undertake, in their final year of study, a suitable engineering project under supervision of a member of the teaching staff.

The assessment of practical industrial attachments is done through student's reports, an industry-based supervisor's report and reports from the University lecturer, who must visit the student at least once during the attachment period. The industrial attachment is graded and assessed as either pass or fail. The grades form a part of conditions for the award of the degree. It is a part of the curriculum followed by all students in the Faculty of Engineering, and no candidate can be awarded the degree certificate without fulfilling the attachment requirements.

Award and Classification of the Degree

The award and classification of the degree of mechanical engineering is guided by the regulations of the Faculty of Engineering. A candidate who qualifies for the award of the degree is placed in one of three classes namely: First Class, Second Class (Upper and Lower Division) and Pass. The First and Second Class degrees are awarded with honours, with the provision that any student who has repeated any year of study shall not be awarded with an honours degree [4].

The final classification of the degree in the Faculty of Engineering is based on the 80 required units taken during the five years of study for the BSc degree. The total marks for the degree, as specified with the Faculty of Engineering, are averaged to arrive at the final classification. The degree is graded as indicated in Table 2.

Table 2: Grade and final classification.

Grade	Honours Classification
70-100%	First Class Honours
60-69%	Upper Division Second Class Honours
50-59%	Lower Division Second Class Honours
40-49%	Pass
39 and below	Fail

Recognition of the Programme by Professional Bodies, Associations and Employers

The Engineers Registration Board of Kenya (ERB (K)) is the professional body that is responsible for ensuring the accreditation and quality assurance of engineering education and practice. The ERB (K) has accredited this programme at the JKUAT. Therefore, after graduation, the graduate may be registered as a graduate engineer. Thereafter, upon completion of three years of relevant practical experience, a graduate engineer can register with the ERB (K) as a professional engineer and qualify for membership of the Institution of Engineers of Kenya (IEK).

The Department, through the Faculty of Engineering, works very closely with both the IEK and ERB (K) on professional matters. The meetings involve staff, students and the relevant professional body. Students have a chapter in the University for a professional society. The Faculty assists graduates to gain employment by approaching industry through individual employers, the Federation of Kenya Employers (FKE) and the Kenya Association of Manufacturers (KAM). In order to accomplish this task, the Faculty has proposed to establish an industrial-liaison office, which will readily provide information on employers and potential employees.

DEPARTMENTAL PARTNERSHIP WITH INDUSTRY

The Department has a number of collaborative projects with industry. These include: industrial training of undergraduate students, exchange of personnel, industry participation in departmental research committees and some teaching, consultancy, short courses, sponsorship of research activities and conferences by industrial firms, as well as the setting up of laboratories so as to meet industry special requirements.

Manufacturing industries, firms and organisations that employ most of the young engineering graduates seek to employ those with the best professional qualifications. Organisations have an uphill task when faced with the selection of suitable candidates for engineering jobs. In most cases, the selection of the best candidates is based on the grades obtained by students while at university and references from their lecturers. However, this mode of selection may not be the best way of identifying the best candidates.

In addition to grades and lecturers' references, the selection for the best candidates is accomplished much more easily and accurately when the employer/industry is familiar with the training programme that the prospective employees undergo at the university. This is why incorporating industry in the implementation of the programme at JKUAT benefits not only the Department, but also assists graduates in securing employment without much hassle. The Department also has links with mechanical engineering departments at other universities and research institutions in various parts of the world.

FUTURE PLANS FOR THE PROGRAMME

Strategies to make the mechanical engineering training programme at JKUAT remain competitive are underway. The expansion of cooperation with institutions and industries in other countries of the world has been planned. There are also plans to involve students in evaluating lecturers. This will increase the efficiency of the learning process by cultivating a close working relationship between lecturers and students. The evaluation will be done through a questionnaire that will be administered by the Office of the Deputy Vice Chancellor, Academic Affairs.

Plans are also underway to assess the success of this holistic approach to programme development by conducting tracer studies. It is expected that tracer studies will reveal graduates' success in attaining employment in various sectors of the economy – a measure of the competitiveness of the programme. Furthermore, as a requirement for globalisation, both the ERB (K) and the Department are working very closely to become a signatory to the Washington Accord for recognition of equivalency of accredited engineering education [5].

Continuing Professional Development (CPD) courses are usually designed to enable engineering graduates already employed to update themselves with the latest technological innovations taking place in the world and incorporate new knowledge in science and technology in their daily applications to engineering.

Professional mechanical engineers deserve modern high quality CPD courses. Therefore, the Department, in partnership with industry, is planning to start piloting an online resource for its former graduates in order to support their CPD needs. This will comprise setting up a Web site to help identify CPD needs, planning CPD provision and maintaining CPD records and portfolios, courses, and evaluating CPD activity. This new initiative is all about using multimedia flexibility to create exciting learning experiences. If successfully implemented, this initiative will go a long way towards meeting CPD training needs for former graduates.

CONCLUSIONS

This programme equips learners with the appropriate technical skills required in order to meet the industrial needs of society in a changing environment, both in industry and the world at large. The programme has been designed to produce highly qualified technical professionals. The development of the programme has been a major step towards enabling access to mechanical engineering education that meets the needs of both students and industry.

The delivery of the curriculum offered has enabled students to move on to higher education confident in their knowledge and with the skills to pursue their intellectual interests. Students are adequately prepared to engage in areas of entrepreneurships, advisory capacity, consultancy, production, processing, marketing and research in mechanical engineering. Students are also given engineering education as a key to unlock the potential prosperity that awaits them. The programme has been well selected and is aimed at equipping students with the necessary skills and attributes to meet the needs of a modern market.

The framework emphasises greater participation from the industrial sector in the training of undergraduate students. The strength of the programme lies in its partnership with the productive service sector: industry, which is fully involved in the training process.

The Department, through the University administration, has involved key players in the industrial sector in this training programme so that it can produce graduates who can understand the industrial dynamics and meet the needs of the labour market, ie the training is market-driven. By becoming partners in the training of human resources in mechanical engineering, both the University and industry are fulfilling their common interest to become active participants in the further development of engineering education.

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