Refocusing Engineering Curricula in Developing Countries for Endogenous Technology Development and Entrepreneurship

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A fundamental cause of the economic backwardness of developing nations is their low level of technological development, resulting from low application of science and technology for the purposes of development. Accelerated technological and industrial development in these countries, therefore, require some urgent and drastic measures. The application of science and technology to the creation of endogenous technologies is a veritable means of achieving rapid industrialization. This, however, requires skilled technical manpower which is motivated to create endogenous technologies and also develop it into small-scale industries by being willing to take entrepreneurial risks. The paper, therefore, considers ways and means of incorporating endogenous technology development and entrepreneurship into the engineering curricula of developing countries. It also advocates adoption of Problem Based Learning methodology as a suitable instructional approach for imparting the knowledge, skills and attitudes (KSAs) required for successful creation of endogenous technologies and developing them into small-scale industries.

Keywords: Engineering curricula, developing countries, endogenous technology development, entrepreneurship.

1. Introduction

It is well-established that a fundamental cause of the economic backwardness of developing nations is their low level of technological development. Consequently, the application of science and technology, particularly to the creation of endogenous technologies in developing countries constitutes an important and essential means of fostering technological and economic development, leading to an improvement in the standard of living of the citizens of developing countries.

The low level of technological development in developing countries is manifested in the low quality of available technical manpower and low level of employment and poor distribution of skills in the industrial sector. This situation has arisen principally, as a result of inappropriate modes of educating and training engineers, technicians and skilled workers in developing countries.

The present corps of technical manpower generally available in developing countries has been educated and trained on the basis of models and curricula of technical manpower formation in advanced countries. Consequently, these cadres of technical manpower are attuned to advanced and foreign technologies and are usually not motivated to create endogenous technologies. These observations are aptly exemplified in the comments [1] attributed to a former Vice-Chancellor of the University of Science and Technology, Kumasi Ghana thus:

"It is true that most universities in Africa were initially inspired by, and developed as carbon copies

[1] Central Industrial Liaison & Placement Unit (CILPU), Faculty of Engineering, University of Lagos, Akoka, Lagos, Africa.

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of universities in Europe; course content, standards, methods of assessment and other aspects of the educational programme were copied from the model and any departures from the European practice were looked on as anathema both inside and outside the African country. In the science and technology disciplines, and especially in engineering, the result has been devastating.

The products have been academically equal to the best in the world but they have not brought any significant progress in endogenous technologies........ The main criticism that has been persistently levelled against technological professions is that their products are too theoretical and, in some cases, too specialised".

These observations are generally applicable to developing countries, particularly in Africa. If the economic backwardness of developing countries is not to persist, it is vital to encourage and promote the kinds of science and technology that can be used for rapid industrialisation and development. This would require changes in the existing engineering curricula in developing nations in order to enhance the supply of technical manpower with skills that are relevant to the developmental needs of the local environment of these countries.

2. Role of Science, Engineering and Technology in Development

Although economic indicators, such as gross national product (GNP) per capita, are not directly proportional to the "standards of living" in different nations, a disparity of over 400:1 between two nations (e.g., Switzerland's GNP/capita of US$40,630 compared with Ethiopia's GNP/capita of US$100 in 1995) clearly indicates and implies a great deal of difference in nearly all "aspects of living" between the peoples of both nations. In fact, comparative data in **Table 1** demonstrates the extent of such disparities in GNP/capita amongst selected countries in different regions of the world [2,3,4,5]. These disparities, rather than lessening, had in fact grown wider between 1980 and 1995, e.g., between the countries in Sub-Saharan Africa on the one hand and the G7 Group of Industrialised Nations on the other. Generally, while the most industrialised countries recorded substantial increases in their GNP/capita between 1980 and 1995, nearly all the least industrialised countries recorded significant drops in their GNP/capita over the same period.

In highlighting the role of science, engineering and technology in development, the Council for the Regulation of Engineering in Nigeria (COREN) in a report [6] to the Federal Government of Nigeria observed that:

"The difference between a developed, rich and prosperous country and an undeveloped, poor and wretched country is the difference in their levels of scientific, engineering and technological advancement. It is not progress in sports; it is not refinement in culture; neither the colour of skin; nor rhetoric or erudition in debate on the floor or the United Nations. It is simply Science, Engineering and Technology (SET) advancement. The G7 countries achieved their enviable status because they are the greatest SET nations in the world. They do not need to win medals in the Olympics or Arts Festivals. In the comité of nations, honour and respect go only to great Science, Engineering and Technology (SET) countries. That is the only parameter that classifies, distinguishes, honours or degrades. A nation neglects Science, Engineering and Technology at its own peril!"

Using data from the 1994 UNESCO Statistical Yearbook, the 1995 World Educational Report and other sources, **Okigbo** [7] showed that the more commitment a nation gives to science and technology, particularly with respect to funding and formation of technical manpower, the more industrialised that nation becomes. Similarly, **Mordell** and **Coales** [1] have demonstrated the linkage between the stock (quality and quantity) of technical manpower available and the level of development of a nation; whereby the larger the number of people (technical manpower) employed in the industrial sector, the more technologically and economically advanced the nation becomes.

Data in **Table 2** shows industry's contribution to GDP and employment for selected countries in different regions of the world from 1980 to 1995. It further demonstrates the role of science, engineering and technology in economic growth and development [8,9]. Generally, the higher the percentage share of the workforce engaged in industry, the higher the level of economic growth and development of the nation. Similarly, the higher the percentage contribution of industrial output to the gross domestic product (GDP), the higher the level of development of the country. In fact, the greater the share of manufacturing as a component of the total industrial output, the higher the level of development, which in turn reflects a higher

TABLE 1: *Comparative Data on GNPs/Capita (US Dollars) for Selected Countries in Different Regions of the World, 1980 - 1995*

Countries	1980	1985	1990	1995
A. Sub-Saharan Africa				
Benin	310	260	360	370
Cameroon	670	810	960	650
Cote d'Ivoire	1,150	660	750	660
Ethiopia	140	110	120	100
Ghana	420	380	390	390
Kenya	420	290	370	280
Nigeria	1,010	800	290	260
S. Africa	2,300	2,010	2,530	3,160
Togo	410	230	410	310
Zimbabwe	630	680	640	540
B. Maghreb Africa				
Algeria	1,870	2,550	2,060	1,600
Egypt	580	610	600	790
Morocco	900	560	950	1,110
Tunisia	1,310	1,190	1,440	1,820
C. Latin America & Caribbean				
Argentina	2,390	2,130	2,370	8,030
Bolivia	570	470	630	800
Brazil	2,050	1,640	2,680	3,640
Colombia	1,180	1,320	1,260	1,910
Costa Rica	1,730	1,300	1,900	2,610
Jamaica	1,040	940	1,500	1,510
Paraguay	1,300	860	1,110	1,690
Peru	930	1,010	1,160	2,310
Trinidad & Tobago	4,370	6,020	3,610	3,770
D. Middle East				
Israel	4,500	4,990	10,920	15,920
Jordan	1,420	1,430	1,240	1,510
Syria	1,340	1,560	1,000	1,120
E. Asian Tigers				
Indonesia	430	530	570	980
Korea, S.	1,520	2,150	5,400	9,700
Malaysia	1,620	2,000	2,320	3,890
Singapore	4,430	7,420	11,160	26,730
Thailand	670	800	1,420	2,740
F. Other Dev. Countries				
China	290	310	370	620
India	240	270	350	340
Pakistan	300	380	380	460
Philippines	690	580	730	1,050
G. G7 Industr. Nations				
Canada	10,130	13,680	20,470	19,380
France	11,730	9,540	19,490	24,990
Germany	13,590	10,940	22,320	27,510
Italy	6,480	6,520	16,830	19,020
Japan	9,890	11,300	25,430	39,640
UK	7,920	8,460	16,100	18,700
USA	11,360	16,690	21,790	26,980
H. Other Industr. Nations				
Australia	9,820	10,830	17,000	18,720
Spain	5,400	4,290	11,020	13,580
Sweden	13,520	11,890	23,660	23,750
Switzerland	16,440	16,370	32,680	40,630
I. East European				
Bulgaria	4,150	-	2,250	1,330
Hungary	4,180	1,950	2,780	4,120
Poland	3,900	2,050	1,690	2,790
Russia	-	-	-	2,240

Source: Compiled from "Basic Indicators" World Development Indicators, World Development Report, World Bank, 1982, 1987, 1992 and 1997.

TABLE 2: *Comparative Data on Industry's Contribution (Percent) to GDP and Employment for Selected Countries in Different Regions of the World, 1980 - 1995*

	+Contribution to GDP (%)		Contribution to Employment (%)	
Countries	1980	1995	1980	1995
A. Sub-Saharan Africa				
Benin	12 (8)	12 (7)	7	8
Cameroon	23 (9)	23 (10)	8	9
Cote d'Ivoire	20 (13)	20 (18)	8	10
Ethiopia	12 (6)	10 (3)	2	2
Ghana	12 (8)	16 (6)	13	13
Kenya	21 (13)	17 (11)	6	7
Nigeria	40 (8)	53 (5)	8	7
S. Africa	50 (23)	31 (24)	35	32
Togo	25 (8)	21 (9)	10	10
Zimbabwe	34 (25)	36 (30)	12	8
B. Maghreb Africa				
Algeria	54 (9)	47 (9)	27	31
Egypt	37 (12)	21 (15)	17	23
Morocco	31 (17)	33 (19)	20	25
Tunisia	31 (12)	29 (19)	30	32
C. Latin America & Caribbean				
Argentina	41 (29)	31 (20)	34	32
Bolivia	35 (15)	- -	18	18
Brazil	44 (33)	37 (24)	24	23
Colombia	32 (23)	32 (18)	20	22
Costa Rica	27 (19)	24 (19)	29	31
Jamaica	38 (17)	38 (18)	16	23
Paraguay	27 (16)	22 (16)	20	23
Peru	42 (20)	38 (24)	18	18
Trinidad & Tobago	60 (9)	42 (9)	39	31
D. Middle East				
Israel	- (-)	- (-)	32	29
Jordan	- (-)	27 (14)	32	32
Syria	23 (-)	- (-)	28	24
E. Asian Tigers				
Indonesia	42 (13)	42 (24)	12	14
Korea S.	40 (29)	43 (27)	27	35
Malaysia	38 (21)	43 (33)	19	23
Singapore	38 (29)	36 (27)	44	36
Thailand	29 (22)	40 (29)	10	14
F. Other Dev. Countries				
China	49 (41)	48 (38)	14	15
India	26 (18)	29 (19)	13	16
Pakistan	25 (16)	24 (17)	15	20
Philipines	39 (26)	32 (23)	15	15
G. G7 Industr. Nations				
Canada	40 (22)	- -	33	25
France	34 (24)	27 (19)	35	29
Germany	- -	- -	45	38
Italy	39 (28)	31 (21)	38	32
Japan	42 (29)	38 (24)	35	34
UK	43 (27)	32 (21)	38	29
USA	34 (22)	26 (18)	31	28
H. Other Industr. Nations				
Australia	36 (19)	28 (15)	32	26
Spain	- -	- -	37	33
Sweden	37 (25)	32 (23)	-	-
Switzerland	- -	- -	39	35
I. East European				
Bulgaria	54 (-)	34 (-)	45	50
Hungary	- (-)	33 (24)	43	38
Poland	- (-)	39 (26)	38	36
Russia	- (-)	38 (31)	44	42

+Figures in parentheses represent manufacturing share of the contribution by industry.

Source: Compiled from "Population and Labour Force" and "Structure of the Economy: Production", World Development Indicators, World Development Report, World Bank, 1997.

level of technological development since technology is the intervening variable in the transformation of inputs to outputs in manufacturing.

Clearly, if developing countries are not to persist in their economic backwardness, they must transform their economies from a primary, raw material exchange economy or a natural, resource-based type to a production economy or a diversified technology-based type. As observed by **Dyson** [7], technology is *"perhaps the greatest of God's gifts as it offers to the poor of the Earth, a shortcut to wealth, a way of getting rich by cleverness rather than by back-breaking labour"*. It is no surprise, therefore, that the Asian Tigers of the Confucian Belt of countries have recently treaded this path with considerable success, leading to prosperity and great improvements in the standard of living of their peoples. [7]

3. The Place of Endogenous Technology in Development

In order to foster rapid economic development, developing countries must embrace industrialisation, particularly manufacturing which is the engine of growth even in industrialised countries. "Accelerated industrialisation" needs to be well conceptualised and clarified in the context of developing countries. The process of industrialisation in developing countries need not be identical with that undertaken in industrialised countries. The industries need not be those requiring high energy consumption or high capital investment per employee since it is desirable to generate employment in developing countries where much manpower is available. Hence, the type of industry must be different from those generally found in industrialised countries and more like the types of industry found in the early days of the industrial revolution - albeit, with modern techniques being applied. This type of industry is often referred to as endogenous/appropriate/indigenous technology. [1].

3.1 What is Endogenous Technology?

There seems to be no generally accepted definition of endogenous technology but it can be taken to be a technology that makes the best use of the local resources of a particular country or region in order to improve the economy of that country or region [1]. It does not exclude the adoption of "foreign" or "international" or exogenous technology, but such technology must necessarily be adapted to suit the particular needs, conditions and resources of the developing country.

The development of endogenous technologies may not attract the attention of engineers and technicians in industrialised or advanced countries. Nevertheless, it requires highly qualified and skilled engineers or technicians since a high degree of competence is needed to see how technology can be adapted to suit different environments (technical infrastructure, climate, culture, quality of labour, raw materials, etc.) in developing countries. Moreover, the development of endogenous technology almost always requires innovation and is, therefore, as much a challenge for well-qualified personnel as in the development of some of the most sophisticated new technologies.

Endogenous technology should not be considered a second-class technology because it requires the best and most qualified talents if it is to be properly done. It may not be "glamorous" or "sophisticated" compared to space research or mobile radio communications, for exampe. However, it is no less challenging, no less demanding of the best and no less unforgiving of error or omission.

3.2 Role of Endogenous Technology in Development

Endogenous technology, although not sophisticated, constituted the foundations of the industrial revolution via the inputs of pioneers such as Newcomen, Watt, Telford, Maudslay, Stevenson, Brunei, Whitworth, Ferranti, Parsons and others [1]. Gradual improvements on the initial technologies pioneered by these men have over the years led to the technological transformation of the industrialised or advanced countries today.

Fortunately, developing countries need not tread the long and arduous path followed by the advanced countries before breaking through the walls of underdevelopment. Today, all the relevant technologies which developing countries need to adapt into endogenous technologies for their survival and development are available and have been tested in at least one application. Consequently, many experts [1,11] endorse endogenous technology as an effective vehicle for technological transformation and the primary tool for economic development in the less industrialised countries. However, the vital element required in the development of endogenous technologies remains the same as during the industrial revolution in the U.K. - the human resource, that is, the men who invented, developed, produced and operated all the technological inventions, particularly that element of which is concerned with what can be termed the productive and technical manpower.

4. Engineering Curricula in Developing Countries

The question that must be answered is: *"Do the current curricula of engineering in developing countries meet the needs of rapid industrialisation through the formation of the right calibre of technical manpower, capable of creating endogenous technologies and developing them into small-scale industries?"*. This question requires an affirmative answer otherwise, the engineering curricula in developing countries need urgent review.

The reality is that the persisting patterns of educating and training engineers in developing countries is often more relevant to a country which has had over 100 years of sustained industrial development, with all the human resources and technical infrastructure, than one which is struggling and just starting its industrial development and has a weak or non-existent technical infrastructure.

Engineering and technical education in the universities and polytechnics of developing countries suffer from peculiar problems [1]. First, they usually have inherited a curriculum based on a foreign model (in most cases, European) which has evolved under conditions (staff, equipment, laboratory, technical infrastructure, industrial training opportunities, etc.) that are not easily duplicated in developing countries. Secondly, there is usually a shortage of highly competent, indigenous teaching and support staff with sufficiently wide practical experience of engineering. Thirdly, most of the available textbooks which are usually expensive are often illustrated with examples of practices from outside the local environment and which are irrelevant to the particular developing country.

Further contributing to the inadequacy of the engineering curricula in developing countries in fostering or engendering rapid industrialisation are the following observations: [10]

- A tendency for the curricula to be too academic and overloaded with intellectual content while being unrelated to practical realities existing in the particular developing country;
- Use of engineering curricula that are overloaded with pure science and mathematics at the expense of basic engineering and technology;
- Inadequate provision in the curricula for industrial exposure/industrial training of students;
- Obsolete, broken-down or non-functioning equipment and ill-equipped laboratories;
- Uniformity in the curricula of various engineering courses run by different institutions in the same country or region, leading to a somewhat generalised training of engineers;
- Inadequate provision for the humanities, social sciences, business management concepts and entrepreneurial skills development in the curricula;
- Lack of balance between depth and breadth in the curricula; and
- Lack of emphasis on engineering technologies in the curricula.

It is obvious from the foregoing observations that the current corps of engineering and technical graduates from universities and polytechnics in developing countries, however well-qualified in the academic sense, are not well-equipped or motivated to participate in their countries' development through the creation of endogenous technologies and their subsequent development into small-scale industries.

5. Need to Refocus Engineering Curricula in Developing Countries

Developing countries must realise that their destinies are in their hands and that nobody else would assume the role and responsibility of industrialising their countries for them. These countries must also realise that endowment with natural resources and a large population do not necessarily make a country rich. A country can remain potentially rich on a permanent basis while a country that is not generously endowed with natural resources can become very rich, e.g., Japan. Ultimately, it is the quality of the human resources, particularly the stock and growth of relevant technical skills that determines the prosperity of a nation [7].

Consequently, developing countries ought to refocus their engineering curricula to produce technical manpower, which can create a culture-relevant, people-oriented array of technologies that promote the acquisition of skills for entrepreneurial self-reliance rather than mere accumulation of facts or knowledge. In other words, developing countries must embrace the endogenous industrialisation process to ensure sustainable, socio-economic growth and development [12], which can only take place with the availability of an adequate stock of technical manpower having the requisite skills for the development of endogenous technologies and entrepreneurship.

Other reasons which make it imperative to include Endogenous Technology Development (ETD) and Entrepreneurial Skills Development (ESD) in the engineering curricula of developing countries [1, 10] are:

- The role of endogenous technology in facilitating technology diffusion and internalisation by being easy to identify with and being an effective vehicle for transformation of the rural areas as a carrier of development and the engine of socio-economic growth;

- Development of the entrepreneurial spirit through the formation of a new cadre of technical manpower which can be self-reliant and self-employed while creating employment for others;

- Inculcating the right attitude towards national development in the products of the new curricula, thereby making them patriotic and conscious of their enormous ethical and professional responsibilities to society;

- Formation of a cadre of engineers who are resourceful, creative, innovative, practical and self-motivated;

- Proliferation and establishment of science - and technology-based and science - and technology-driven, small-scale industries;

- Formation of well-rounded, engineering graduates equipped to contribute to their countries' development via the integration of business management and entrepreneurial skills with engineering and technical skills;

- Opportunity of using real-world problems of relevance to the local environment to stimulate the engineering-thinking and ingenuity of students;

- Development of innovative and non-traditional curricula but with strong engineering underpinnings that specifically serve the purposes of the individual developing country;

- Formation of a cadre of engineers with relevant productive skills who can identify and solve the technological and developmental problems of the local environments of their countries; and

- Prevention of the loss of indigenous technological capabilities without thorough acquisition and mastery of the modern skills intended to replace them.

6. Proposed Changes in Engineering Curricula

Although engineering curricula cannot be exactly the same throughout the developing world, it is presumed, for the purposes of this discourse, that the extant engineering curriculum in Nigeria is representative and typical of what obtains in developing countries, as confirmed by a perusal of engineering curricula in some other English-speaking African countries [10].

This curriculum (i.e., the range of subjects to be studied or the entire range of activities to be undertaken in order to qualify) is modelled on the system that obtains in advanced countries. However, an engineering curriculum fashioned after what obtains in advanced countries may not produce the same results in a developing country because of limitations that are not easily surmounted, e.g., limited technological infrastructure and places of industrial attachment for students. Therefore, developing countries need to fashion out their own engineering education systems or curricula, with due attention being paid to existing technological, social, economic, political and other limitations. Such curricula should be in consonance with national objectives so that competent technical manpower capable of transforming their societies through accelerated industrialisation are produced. Since curriculum development is an ongoing exercise, it is suggested that changes be incorporated in the engineering curricula of developing countries to reflect their needs for technical manpower capable of creating endogenous technologies and developing same into small-scale industries.

In a paper of this nature and length, it suffices to provide outlines for the courses - Endogenous Technology Development (ETD) and Entrepreneurial Skills Development (ESD) - being proposed for inclusion in the engineering curricula of developing countries. Moreover, the detailed content of an engineering course can only be determined or specified by the Department and Faculty of Engineering concerned and approved by the senate of the respective university. It is, therefore, recommended that the outline of the course(s) on ETD should include topics such as History of Engineering and Technology dating back to prehistoric times, History of Technological Innovations and Inventions detailing the socio-economic and political factors and motivations of the inventors that influenced their creation, Identification of Problems of Relevance to the Local Environment that require creation and development of endogenous technologies for their solutions, Adaptation of Exogenous Technologies, Copy Technology, etc. Exercises and projects predicated on creating endogenous technologies that are of relevance to the immediate local environment should be used to challenge students to solve real, significant and meaningful problems in order to give them a feeling or sense of self-confidence, accomplishment and pride.

If engineering graduates are to nurture endogenous technologies created by them into small-scale industries, they must be assisted in the acquisition of the skills required to achieve success. In fact, small businesses need to learn and master many managerial techniques; they need to learn to be as competent, as well-managed and as purposeful as the large business - and in many ways, the managerial demands on small businesses may be greater than on large businesses [13]. Consequently, the proposed course(s) on ESD should cover areas such as economics, business management, resource management, time management, cost management, management of innovations, project management, risk management, patents, copyrights, licensing, trademarks, contract law, equipment financing, equipment leasing, venture capital, capital market operations, joint venture, human resource management, marketing, etc.

The inclusion of the two proposed courses in the engineering curricula should not in anyway compromise the level of technical competence required of engineering graduates, particularly with respect to advances of knowledge in science and technology. Rather than delete existing courses from the curriculum in order to accommodate the two courses being proposed, it is suggested that the duration of the engineering programmes in developing countries be increased by one year instead.

7. Instructional Method

The acquisition of knowledge, skills and attitudes (KSAs) essential to the creation of endogenous technologies and entrepreneurship requires certain personal skills or attributes on the part of engineering students. These attributes and skills include problem-solving, analysis-synthesis, creativity, resourcefulness, initiative, innovation, visualisation, visioning, decision-making, leadership, discipline and critical thinking. However, these skills and attributes cannot directly or easily be imparted to students via the usual lecture-based method of instruction, which is pedagogic, whereby they are served a menu comprising bits and pieces of facts and information. Rather, the development of these personal skills or attributes is fostered by an approach to instruction whereby students/learners are challenged to solve real, significant and meaningful problems.

Consequently, it is recommended that Problem Based Learning (PBL) methodology be adopted as an appropriate instructional approach for the two courses (ETD and ESD) since it can foster the application of fundamental knowledge acquired in the core disciplinary courses (engineering) and their linkage to non-engineering disciplines. Whereas students are accustomed to a lecture-based, teacher-centred, discipline-based and subject-based learning environment, PBL requires students to be active, self-motivated, self-directed and inter-disciplinary problem-solving learners [14].

PBL uses a problem situation to drive the learning and is, therefore, suitable in acquiring skills that are essential in the development of endogenous technologies and entrepreneurship. Unlike subject-based learning which assumes that the student knows very little and proceeds to lay out the information in a pre-selected or pre-determined sequence, PBL challenges the student to discover what he needs to solve the problem that is posed. Having a problem at the onset or beginning provides a challenge and motivation for concrete application of knowledge and skills, resulting in a feeling of pride, self-confidence and accomplishment.

For the course on ETD, variants of PBL including design projects, practical assignments, research projects, problem-solving exercises, equipment design and fabrication, case studies, guided design, etc. can be employed to impart the required skills. Simulations, business games, case studies, role plays, experiential exercises, etc. can be used as variants of PBL for the course on ESD. In both courses, the problems posed or solved should have technological, social, economic, legal and other non-technical dimensions of relevance to the local environment of the developing country.

8. Implementation: Implications and Constraints

In implementing the foregoing proposal, certain problems and limitations are likely to arise. Some of these implications and constraints are addressed as follows:

- Because people are usually comfortable with routines, there may be an initial resistance change in the curriculum on the part of Faculty members due to lack of interest, motivation and/or appropriate qualifications. However, the only thing that is constant in life is change. Moreover, curriculum development in any discipline is dynamic and, in the case of engineering, it should constantly evolve to reflect the needs of society and the national aspirations of the country under consideration.

- Since ETD and ESD are not included in the traditional or extant engineering curricula, it will be necessary to develop outlines and detailed contents for these courses.

- Educational materials on ETD are scarce and/or unavailable and, therefore, it may require the development of texts by Faculty members.

- Educational materials on ESD, although available, may be scattered among several different texts, thereby requiring integration of the diverse sources of information and knowledge.

- Starting from scratch to put materials together for the two courses may demand significant extra effort on the part of Faculty members, since one must identify topics and prepare necessary instructional materials. However, the extra effort should be worthwhile since it is a contribution to national development.

- Engineering Faculty members may lack qualifications, experience, and/or expertise to teach the courses, particularly Entrepreneurial Skills Development. This shortcoming can be overcome by networking and partnering with the Faculty of relevant disciplines, as well as practitioners in industry.

- Time is an important consideration, since there is never enough time for Faculty members to get through all the material they intend imparting to students. Hence, including two additional courses in the curriculum would put pressure on the available time. Consequently, it is recommended that the duration of the engineering programme in developing countries be extended to five years to properly accommodate the proposed courses. After all, there is an on-going clamour in advanced countries, notably the USA, to increase the duration of engineering courses from four to five or six years in order to accommodate the "soft" skills required by engineering graduates, leading to simultaneous award of both an MBA and the normal BSc Degree in Engineering [15,16,17,18].

- The inclusion of the two proposed courses in the engineering curriculum of developing countries should not lead to deletion of other courses that are normally components of the traditional or extant curriculum. This would ensure that the engineering curricula in developing countries meet the globally acceptable minimum standards while allowing variations that would take care of their special needs and aspirations. Surely, engineering curricula of developing countries need not be exactly the same as those in advanced countries.

- Attention would need to be paid to the provision of adequate supporting resources, both hardware and software, that would be required in running the courses properly and successfully.

- The formation and composition of multidisciplinary teaching teams to handle the courses should be given adequate consideration since the problems to be solved by the students would be essentially interdisciplinary and would, therefore, require integration.

9. Profile of the Engineer-Entrepreneur

The adoption of the proposed changes in the engineering curricula of developing countries should lead to the formation of well-rounded, engineering graduates who are patriotic and conscious of their enormous ethical and professional responsibilities to society and who are well-equipped to contribute to the technological and economic growth and development of their countries.

Whereas emphasis had been placed on the acquisition of Technical Skills/Core Engineering Base Knowledge in the engineering curricula of developing countries, the present proposal will enable engineering students to acquire knowledge and skills in other areas depicted in **Figure 1**. Specifically, this new breed of engineer, or engineer-entrepreneur will possess an adequate knowledge of core engineering and demonstrable technical competence. The engineer-entrepreneur would have acquired an appropriate, intellectual foundation resulting from the development of personal attributes or skills, including engineering thinking, problem-solving, analysis-synthesis, resourcefulness, creativity, initiative, innovation, visualisation, visioning, decision-making, leadership, discipline and critical thinking. The engineer-entrepreneur would be motivated to apply his engineering knowledge and technical skills in the context of the local environment of his country, leading to the creation of culture-relevant and people-oriented technologies. Finally, the engineer-entrepreneur will be capable of integrating his engineering skills and technical competence with a sound knowledge of management and entrepreneurship in nurturing endogenous technologies into small-scale industries.

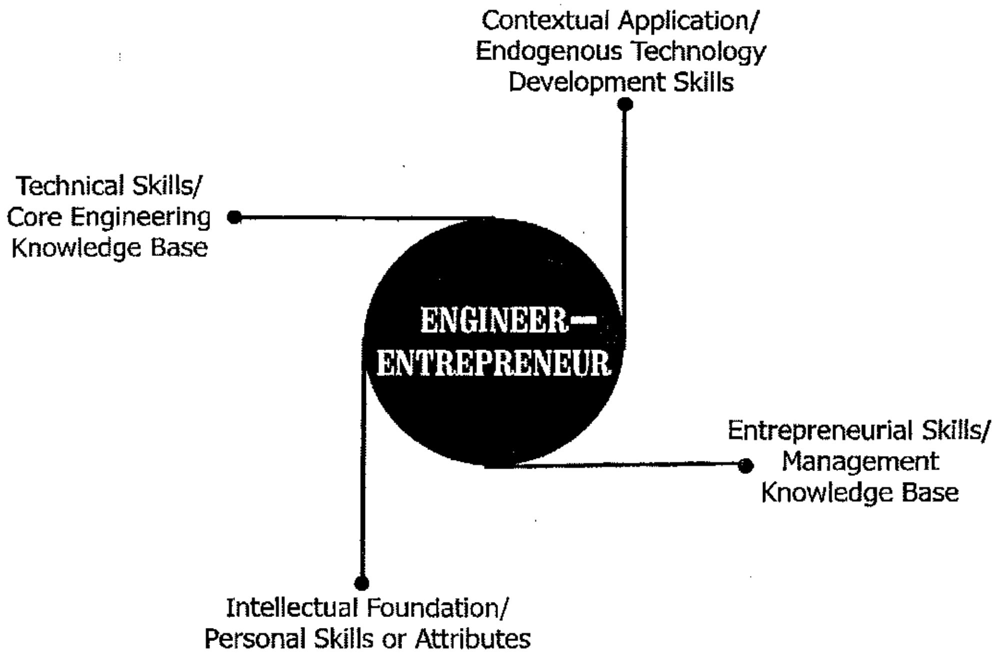

FIGURE 1: *Profile of the Ideal Engineer-Entrepreneur*

10. Conclusion

There are two possible futures for developing countries; the one they create for themselves or the one created as a result of their inaction.

If developing countries are to improve the standard of living of their peoples, they must embrace endogenous technology as an effective vehicle for technological transformation and industrialisation, leading to economic growth and development. Accordingly, developing countries must refocus their engineering curricula proactively to incorporate Endogenous Technology Development and Entrepreneurial Skills Development or reactively wobble along in the spirit of surviving by sticking to the extant curricula without modifications.

The inclusion of the two proposed courses in the curricula and their dissemination using the PBL methodology should result in the formation of a cadre of well-rounded, engineering graduates who are well-prepared and motivated to contribute to their countries' development.

Efforts in overcoming constraints that may impede the implementation of the proposal should be seen as worthwhile sacrifices, bearing in mind that engineering curricula tailored essentially after those of advanced countries will not produce technical manpower capable of transforming developing countries into industrialised nations. Afterall, curriculum development is an ongoing exercise and should evolve in response to national needs, objectives and aspirations!

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