A CHEMICAL ENGINEERING CURRICULUM-MEETING THE NIGERIAN NEED

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ABSTRACT

This paper is about the development of a Nigerian Chemical Engineering Curriculum of world class standards to train indigenous Chemical Engineers that will be instrumental to meeting the Chemical Engineering related needs of Nigeria. A brief history of the Nigerian Chemical Engineering undergraduate program is presented. The present state of the Curriculum was examined and compared with the Chemical Engineering Curricula of Universities with well-established Chemical Engineering Programs outside Nigeria. It was observed that about seventy-five (75) required courses are in the Nigerian Chemical Engineering Curriculum as against thirty-three (33) required courses in the foreign Curricula. Several needs of Nigeria that require the input of Chemical Engineers such as energy, job creation, agriculture etc. are discussed. Gaps in the Chemical Engineering Curriculum are succinctly presented and recommendations on how these gaps can be filled, such as; provision of options in Chemical Engineering, need for more focus on core areas, emphasis on entrepreneurship etc. are presented with a view of meeting the needs of Nigeria. The very needs for the Chemical Engineering Curriculum to not only be well developed but also well implemented is highlighted.

Keywords: *Curriculum, Chemical Engineering, entrepreneurship, Gaps, Needs*

1.0 INTRODUCTION

Chemical Engineering is a discipline that deals with the application of the basic sciences and technology in the design, operation and maintenance of equipment and processes for the large scale production, transformation and transportation of materials and energy to provide valuable goods and services. Such processes are the fundamental core of the Chemical, petroleum, iron and steel, pharmaceutical, and electronics industries. Along these lines, Chemical Engineering emphasizes fundamentals required to design, optimize, and operate Chemical processes as safely and efficiently as possible.

The role of Chemical Engineering in the development of any nation in this 21st century cannot be overemphasized. Chemical Engineering cuts across a wide spectrum of interconnected fields and disciplines needed for the industrialization and advancement of any 21st century civilization. These enormous responsibilities are within the capabilities of Chemical Engineers in meeting the Nigerian Needs if the Chemical Engineering Curriculum that seeks to expose the undergraduates of this noble discipline to the deep understanding of Engineering fundamentals, to enable them apply this knowledge to the management of complex systems with particular attention to the Chemical process and product industries, is updated to meet world-class standard. However, engineering education Curricula in Nigeria are not updated making them obsolete. The inadequacy in the Curriculum has made the nation to be weak in new technologies. Graduates of such obsolete Curricula can no longer handle new technologies and they often find it difficult to compete with their overseas counterparts.

Considering the present state of our beloved nation viz-a-viz the practice of the Chemical Engineering discipline for several decades in Nigeria, it is certainly not far-fetched to opine that the practice of Chemical Engineering in Nigeria is yet to deliver satisfactory dividends to the Nigerian state. Could this be, to an extent, attributable to gaps/defects in the present Chemical Engineering Curriculum in Nigeria as measured against world-class standards? If there are gaps, can they be filled and how do we go about remedying the situation? Thus this paper takes a look at the adequacy of the Nigerian Chemical Engineering Curriculum viz-a-viz the current and emerging expected needs of Nigeria.

2.0 THE NIGERIAN CHEMICAL ENGINEERING & ITS CURRICULUM

In order to have an accurate assessment of our present situation, we must understand where we are coming from, where we are going to and then we can attempt to assess our present location and possibly how to move onwards from our present location to the destination that we have envisioned.

2.1 Nigerian Chemical Engineering Undergraduate Program – An Historical Survey

In Nigeria, Chemical Engineering is a relatively young

profession, dating back only to about the 1960s, when the first wave of Nigerian students graduated from Chemical Engineering schools in the United States and the United Kingdom. Even so, the profession was virtually unknown in Nigeria until the late 1960s, when several overseas-trained graduates returned to their home country (Dada et al 2013).

Nigeria started its domestic training of Chemical Engineers when the University of Ife (now Obafemi Awolowo University), introduced a course in Chemical technology in 1969. By 1972, the school had upgraded to a full Chemical Engineering program and consequently, graduated the first Nigeria - trained Chemical Engineers in 1973. Around that time, the University of Lagos and Ahmadu Bello University, in Zaria, also developed Chemical Engineering programs, producing their first graduates in 1976 and 1977, respectively (Dada et al, 2013).

The Student Industrial Work-Experience Scheme (SIWES) which started officially in 1974 was imbued in the Chemical Engineering Curriculum and now constitutes a requirement for the completion of the Chemical Engineering undergraduate program as specified by the National University Commission (NUC) and the Council for the Regulation of Engineering in Nigeria (COREN) (Mafe, 2018; NUC, 2014; COREN 2013).

2.2 The Present state of the Nigerian Chemical Engineering Curriculum

The Nigerian Chemical Engineering program has evolved over the years and presently is a five (5) years course at the University level comprising of nine (9) semesters of classroom learning and laboratory work. A period of six to nine months (6 - 9 months) distributed between the long sessional breaks and the entire 400L second semester is provided for Student Industrial Work-Experience Scheme (SIWES) as required by the NUC and COREN. (Mafe, 2018; NUC, 2014; COREN 2013; EUI, 2016; UNIBEN, 2015).

A semester in a typical Nigerian University comprises of 14 weeks of learning and 2 – 3 weeks of exams. The Chemical Engineering student is saddled with the task of learning and assimilating an average of about 8 - 9 usually voluminous courses in a semester and for the 400L first semester, they would need to offer about 10 to 12 courses comprising of about 9 heavy weight Chemical Engineering courses within 3 months in preparation for the SIWES programme.

The Curriculum comprises of about seventy-five (75) courses on the average comprising of about ten (10) practical courses.

The Curriculum covers the major core areas of Chemical Engineering such as Chemical reaction Engineering, Chemical Engineering design, transport phenomena, Biochemical Engineering, environmental Engineering, Engineering economics, software application in Chemical Engineering etc. (NUC, 2014; COREN 2013; EUI, 2016; UNIBEN, 2015) as well as the requisite foundational courses such General Chemistry, Mathematics, Physics etc. There are about twenty-five (25) general Engineering courses such as Engineer and society, Engineering mathematics I-IV, Engineering mechanics I & II, Engineering drawing I & II etc., in addition to seven (7) General studies courses (NUC, 2014).

The Chemical Engineering laboratory courses are available as from 300 Level and a total of 3 Chemical Engineering laboratory courses are provided for throughout the Chemical Engineering program and these laboratory courses are usually not linked with any specific area of Chemical Engineering but are designed to cut across all the various subject areas covered in each level.

As a requirement for obtaining a Bachelor's degree in Chemical Engineering, the student is expected to undertake a Chemical Engineering research project and in some institutions, an additional Chemical Engineering design project.

2.3 A Comparison of Chemical Engineering Curricula

The Nigerian Chemical Engineering Curriculum as presented in the Benchmark Minimum Academic Standards (BMAS) of the National Universities Commission (NUC) is compared here with the Chemical Engineering Curriculum of YALE University, Manchester University and the University of Illinois; Universities in the United States of America (U.S.A) and the United Kingdom (U.K) with highly reputed Chemical Engineering programs.

2.3.1 Curricula of Foreign Universities

The Curricula of three foreign Universities namely; YALE University, Illinois University and Manchester University are compared with the Nigerian Chemical Engineering Curriculum.

The Chemical Engineering Curriculum of YALE University is presented contiguously with the Nigerian Chemical Engineering Curriculum in the Benchmark Minimum Academic Standards (BMAS) of the National Universities Commission (NUC) in Table 1 of the Appendix.

The Chemical Engineering program at YALE University requires 18 technical credits in addition to 9 prerequisite courses listed and 3 Engineering electives to a total of 30 courses for the undergraduate degree program (https://seas.yale.edu/departments/Chemical-and-environmental-Engineering/undergraduate-study-Chemical/undergraduate-curric 11/19/2018; http://catalog.yale.edu/ycps/subjects-of-instruction/Chemical-Engineering/Chemical-Engineering.pdf 2018). A typical schedule of required courses for the Chemical Engineering program of YALE University is presented in table 1 of the Appendix

The Chemical Engineering Curricula of Illinois University and Manchester University are also presented in Tables 2 and 3 of the Appendix.

2.3.2 Let Us Compare & Contrast

Comparing the Chemical Engineering Curricula of Yale University, Manchester University and the University of Illinois with the typical Nigerian Curriculum for Chemical Engineering as present in the NUC BMAS document, we find the following;

- The Nigerian Chemical Engineering Curriculum comprises about 75 courses which is more than double the number of courses, required (which is about 33 courses) in the foreign universities considered above. This may be clear indicators that there may be an assortment of borrowed and general courses that are not needed which have been infused into the Nigerian Chemical Engineering Curriculum. The effect of this large number of courses required to complete the Nigerian Chemical Engineering program is that there would be insufficient attention and emphasis paid on the specific course components of Chemical Engineering discipline.
- The courses taken in the foreign programs are core Chemical Engineering courses with necessary background courses in the physical sciences and only a few other general courses
- There is good emphasis on practical/laboratory work in both Curricula; however, the foreign Curricula have their laboratory courses tailor made to fit specific aspects of the various Chemical Engineering areas.

3.0 THE NIGERIAN NEEDS

The Refineries & Petrochemical Industry: There is need for functional refineries that are designed, built, operated and maintained by indigenous Chemical Engineers. It is indeed highly bewildering to find that a nation such as Nigeria exports her raw crude products in very large amounts only to import the refined products for use at relatively high costs. Our crude oil reserves are rapidly depleting with production at about 2 million bpd and our national purse is not growing commensurately with the amount of black gold that leaves our ground. This anomaly is one that needs urgent rectification and although, this problem is hydra-headed with the root being corruption at all levels of government and society, the Nigerian Chemical Engineers has a great role to play in remedying the situation.

Natural gas flaring has to be curbed and our natural gas reserves need to be harnessed to provide better economic value. About 30% of the total natural gas production of 6.5 billion scf/d is currently flared in the oilfields, primarily because there is insufficient manufacturing infrastructure to use it, as well as the sluggishness of the IOCs to comply with the Nigerian government's gas utilization and monetization policy. Of the 4.5 billion scf/d gainfully utilized, about 3.0 billion scf/d (67%) is liquefied for export in an integrated LNG plant. Another 0.5 billion scf/d is exported as pipeline gas to the neighboring countries of Benin, Togo, and Ghana. Only 1.0 billion scf/d (22%) is used domestically, out of which about 0.8 billion scf/d goes to power generation (Dada, 2013; Oniwon, 2010).

The Petrochemical industry also needs to be revitalized as it serves to provide feedstock to a large fraction of the manufacturing industry. If the manufacturing industry in Nigeria will receive a significant boost, the Petrochemical industry has to be up and running.

Energy: The poor level of energy generation and distribution has been a major problem and hindrance to the industrial development of Nigeria. Many international companies such as Michelin and Dunlop have packed out of Nigeria as a result of this (Ogedegbe, 2008). This again calls for the Nigerian Chemical Engineer to contribute his expertise in providing and helping to implement lasting solutions to this. Presently, the trend of power generation is shifting rapidly from

use of fossil fuels in generating power to renewable energy sources such as biofuels.

Agriculture: In view of the collective attempts to diversify our economy and reduce our oil-dependency, we must of necessity look to develop other sectors of our economy. One of these key sectors of the economy that we must pay keen attention to is the agricultural sector. Chemical Engineering has a role to play in the provision of readily available and affordable locally manufactured fertilizers, pesticides, herbicides etc. as well as in the design and operation of equipment and processes for the long-term preservation of our perishable goods. Furthermore, our farm produce have to be further processed to produce value added products of high quality which can serve the local market and can also be exported to generate revenue.

Iron and Steel: Nigeria needs her iron and steel industry to come alive again if it is to experience the sort of industrialization that we desire. Also, there has to be much more emphasis on special steels and alloy steels so as to enable the Nigerian iron and steel products compete favourably with those from anywhere else in the world.

Unemployment: The establishment of small and medium enterprises (SME) is highly recommended to curb the menace of unemployment especially amongst the Nigerian youths. The Nigerian Chemical Engineering Curriculum has to be designed in such a way that the average graduate is armed with the requisite knowledge to set up an SME in his own area of interest in the Chemical Engineering discipline.

These challenges are indeed enormous, multi-faceted and intricately laden with below the surface dynamics and complexities, with corruption at all levels of government and societies being the bane of Nigeria, the solutions to these problems do not lie solely or even majorly with the Nigerian Chemical Engineer or the Chemical Engineering Curriculum.

However, we cannot deny that we have a great role to play in ameliorating these ailments. One sure way to play our part is to design a Chemical Engineering Curriculum that is discipline concentrate rather than Faculty based to produce graduates that can compete favourably with their counterparts from all over the world and at the same time, a Curriculum that is tailor-made to equip the average Chemical Engineer with the requisite skills and knowledge that will enable him contribute his quota towards addressing the Nigerian needs.

4.0 IDENTIFYING & BRIDGING THE GAPS – MEETING THE NEEDS

4.1 The gaps in the Chemical Engineering Curriculum

The Biology Deficiency

Chemical Engineering is a unique discipline amongst other Engineering disciplines for a number of reasons one of which is the way Chemical Engineering draws from a very wide spectrum of science subjects in a way that other Engineering disciplines do not. One of such very pivotal science subjects is Biology. Biology has however not been given the necessary attention in the Chemical Engineering Curriculum. Presently, Biology is not a compulsory entry requirement for admission into the Chemical Engineering Program in our Universities. Furthermore, there is no first year course on biology in the present Chemical Engineering Curriculum. How are our students expected to fair excellently in courses on Biochemical Engineering, Bio-molecular Engineering, Bio-technology, Chemical Reaction Engineering etc. without a sound and verified proficiency in biology?

Insufficient Industry Application Focused Courses: The Curriculum that guides Chemical Engineering programmes in Nigeria consists of the fundamental knowledge of mathematics, natural sciences, technology, a large assortment of general Engineering courses, core Chemical Engineering courses and only a few application courses. This fundamental knowledge, which forms the basis for understanding and solving Engineering problems, are good and very necessary, but we should not stop there. There appears to be too much focus on the fundamentals and generics. There should be provision in the Curriculum to accommodate some aspects of application of Chemical Engineering that are prevalent in today's world.

Feedbacks received from employers of Chemical Engineering graduates (indicated by high rate of retraining) are evidence that the application part is either lacking in the Curriculum or inadequate. Since socio-economic and other factors that define an environment change with time, this aspect of the Engineering Curriculum should also vary to accommodate these changes. There are many examples of developed nations who still modify and continue to study and discover areas of modification in their Chemical Engineering Curriculum according to the changes and challenges of

time. For instance, when the United States of America had the September 11th, 2001 problem in their country, one of the things they did in response was to adjust the school Curriculum to accommodate the study of homeland security.

Inadequate Attention & Depth of Coverage for Key Chemical Engineering Courses: It is opined that the overall amount of attention and depth of coverage given to some of the most vital aspects of Chemical Engineering such as Chemical reaction Engineering, unit operations, transport phenomena, Plant and process design etc. is less than commensurate because some other courses which are not so needed are given more than commensurate attention thereby greatly reducing the amount of resources (human resources and time) that are devoted to the most important and defining aspects of the Chemical Engineering Curriculum.

Too Many Irrelevant Courses: There appears to be excessive meddling of the Chemical Engineering Curriculum with several courses that are not so important in producing the crop of Chemical Engineers that we desire.

There are so many generalized courses infused into the present Chemical Engineering Curriculum leading to a situation whereby the average Chemical Engineering graduate is more like a jack-of-all-trade and a master of none.

In fact, most of our present day Chemical Engineering graduates do not find Chemical Engineering focused jobs, meanwhile, the few Chemical processing and manufacturing companies continually decry the inadequacy of highly trained, young indigenous Chemical Engineers needed to provide the Chemical Engineering expertise that they need.

The few ones who eventually manage to get employed have to be taken through the rigor of training and re-training in order to make them fit to handle the tasks required of them to perform as Chemical Engineers.

Too Much Focus On Producing Good Employees Rather Than Good Entrepreneurs: It is also opined that the focus of the Curriculum is geared towards making employees of our graduates rather than making employers of labor out of them. There is an insufficient emphasis on Chemical Engineering entrepreneurship in the present Chemical Engineering Curriculum adopted in most of our institutions adopted nationwide.

Deficient Training on Computer and ICT applications in Chemical Engineering: In addition to all of the above, there appears to be insufficient attention being paid to the use of computer & ICT tools and software in training of Chemical Engineers in our institutions of higher learning.

Engineering practice of yesteryears was man-machine relationship. However, in today's world, it is man-computer-machine relationship. In the history of Chemical Process Industries (CPI), no single development has affected in a more positive way the practice of Chemical Engineering than computers. The operation of plants has been transformed by distributed control systems. Perhaps even more profoundly, though, the personal computer and software like simulation and mathematical programs have changed the very way that Chemical Engineering is performed.

For a student to go through four/five years of a Chemical Engineering undergraduate program and not know and understand the workings of a process simulator is a tragedy. Now performing a multicomponent flash calculation or drawing a McCabe-Thiele diagram by hand definitely is not a good exercise. The application of computer-based methods in solving Chemical Engineering problems should be an integral part of the Chemical Engineering Curriculum.

Laboratory Courses Are Not Aptly Linked With the Theory Courses: It is also observed that practical courses are more or less generic and are not adequately tailor-made to match and provide practical understanding of the things taught by the lecturers in class. There seem to be a gap between what the students are taught in class and the practical work they are exposed to in the laboratories.

4.2 Bridging The Gaps – Meeting the needs

More Attention for Biology

Biology is an essential part of the study of modern day Chemical Engineering. Words like bio-sorption, bioreactors, bio-separation, Biochemical, bioremediation, bio-analysis, biomass, biotechnology, bio this bio that are no longer strange terms in the Chemical Engineers lexicon. The entry requirement for all Engineering courses is 5 credits, which must include credit passes, English, Mathematics, Physics, Chemistry and any other science or social science subject. It is worrisome therefore that today, a student who has not even done biology as a subject can be admitted to read

Chemical Engineering. This is an anomaly that must be addressed and corrected as soon as possible. Unlike other Engineering courses where this may be acceptable, the same cannot be said of Chemical Engineering. This should not be the case as biology ought to be a compulsory subject. It is therefore recommended that biology should be incorporated as a compulsory credit pass requirement for admission to Chemical Engineering programmes (Aluyor, 2016).
Biology should be part of the basic entry requirement for admission into the Chemical Engineering Program and there should be first and second semester first year courses in aspects of biology relevant to the Chemical Engineering Discipline.

Options in Chemical Engineering: Considering the very broad nature of Chemical Engineering and the need to produce Chemical Engineering graduates that have industry applicable knowledge in their various area(s) of interest, it is posited that it is high time that we make provision for options in the Chemical Engineering Curriculum at the undergraduate level. Taking a cue from sister departments, Electrical Engineering, with a Curriculum that provides for the electrical Engineering student to opt for either the power option or telecommunication option at the undergraduate level; Mechanical Engineering with options in Production and Manufacturing. Non-faculty based like Surveying with options in Land and Quantity Survey, Medicine with specialties in Gynaecology & Surgery, it is of necessity that there be about five options in the Chemical Engineering Curriculum at the undergraduate level namely Biochemical Engineering, Biotechnology, Polymer Engineering, Petrochemical Engineering and Refinery technology.

Focus on Core Areas: The Chemical Engineering Curriculum should be better stream-lined to give more focus to the core areas of the Chemical Engineering discipline so that the Chemical Engineering graduate has sufficient expertise in his field. The Pareto principle should be brought to bear on this matter in a sense. We should allocate a much greater fraction of the human resource requirement, course hours and course units in our Chemical Engineering Curriculum to the relatively small fraction of really important courses in our Chemical Engineering Curriculum. Also, courses that are not so relevant to the training of the crop of Chemical Engineers that we desire should be completely expunged from the Curriculum or at least presented as electives with zero credit units.

Entrepreneurship: Entrepreneurship should be thoroughly imbued into the Chemical Engineering Curriculum. The courses on entrepreneurship should also be further tailor-made to suit the Chemical Engineer who intends to use his training to start up an enterprise. It should not just be general entrepreneurship but entrepreneurship for Chemical Engineers. We may start with a general entrepreneurship course to be taken by the various Centre for Entrepreneurship Development (CED) Departments in our schools at the lower levels, we should go beyond this to provide a tailor-made course on entrepreneurship for Chemical Engineers at the higher levels.

More Strategic Laboratory Courses: Additional attention should be accorded to practical/laboratory work. Laboratory courses should be designed specifically for the various aspects of the Chemical Engineering discipline.

Industry relevant & local problem oriented research projects: There are a lot of problems in our environment that require Engineering solutions, yet, graduate students grope about in search of topics for research projects. Also, most of the research projects undertaken by our undergraduate and graduate students are neither relevant to the local industries that we have in the country nor do they really solve any local or national Chemical Engineering problem. A much greater emphasis should be laid on the need to carry out industry relevant/ local problem solving research projects. Industry and academia should partner to design research projects which will then be co-sponsored by both parties and the fruits of such work will be to the benefit of all. Part of the criteria for evaluating and scoring research projects should be the industrial relevance or ability of the work to solve a local or national Chemical Engineering problem, this should be well specified and highlighted in the Curriculum.

Industrial Visits/ Field Trips: The Student Industrial Work Experience Scheme (SIWES) is quite a good avenue for our students to gain relevant industrial experience, however, as a result of the considerably low number of functional manufacturing and processing companies/industries in Nigeria and also, the present state of our economy, most of our students are not able to secure placements in relevant companies and industries. It is therefore recommended that industrial visits /field trips be built into the Curriculum as a requirement for completing certain courses, reports of this industrial visit by the students should serve as a part

of the continuous assessment for these courses. This will enable our students who are not so opportune to find relevant industrial placements, to have some form of vital industrial experience, also, other students who were able to secure placement in a relevant industry will also be able to visit other plants and industries thus providing them with a much more robust industrial experience.
Companies who are not willing to receive more than one or two students for the SIWES program lasting six months will likely not mind hosting a number of students for one or two days industrial visit.

A Course on Refinery Design and Operation: A course on refinery design and operation should be developed and included in the Curriculum. This would help to bolster the case for licenses to be given to Chemical Engineers or Chemical Engineering firms to run modular refineries with the long-term end effect of putting a stop to importation of refined crude products.

Introduction of Industry Specific/Applicable Courses: Certain Industry applicable courses should be built into the Chemical Engineering Curriculum to make it richer and also reduce the need and extent of retraining that our graduates have to go through when they finally get a job in an industry. Examples of such courses are: Process Safety in the Oil & Gas Industry, Process Safety in the Pharmaceutical, Food & Consumer Product Industries, Applied Hazard and Operability Studies (Applied HAZOP), Process Plant Reliability and Maintainability, Process Engineering for Control etc. These courses should be designed in collaboration with industry and possibly taught in partnership with industry.

Computer & Software Applications in Chemical Engineering:
Process simulation software such as ChemCAD HI, ASPEN PLUS, PRO II, HYSYS, PD Plus etc. should be given much more emphasis in the Chemical Engineering Curriculum. This will make the students to appreciate how it improves Engineering efficiency. Chemical process simulators are used by Chemical Engineers for a range of important applications such as mass and energy balances calculations, performance evaluation of process alternatives, equipment sizing, optimization and so on. A Chemical Engineer can now very quickly define a complex flow sheet and all the process conditions.
It is suggested that the computer & software application component of a course should be built into the course and taught together.

5.0 CONCLUSION

It is one thing to develop a Curriculum; it is another thing for it to be rightly implemented to achieve the desired results. In order to impart the right standard of training to the Chemical Engineering student, the academia must be equipped with adequate, up-to-date knowledge and skills and must have and demonstrate the right attitudes in the conduct of their duties.

Having a decent training is a pre-requisite for landing a fine Chemical Engineering job or establishing a company that will thrive in an equitable society. Having a decent training is hinged on the quality of the Curriculum with which one is trained and hence, the need for a wholesome Chemical Engineering Curriculum must not be down played.

Government, Industry and also the academia must be willing to demonstrate more commitment and synergy towards the actualization of our set targets of producing Chemical Engineers of world class standards that are fit in all respects to utilize the expertise and skills garnered in making significant contribution towards meeting the Nigerian needs for the collective good of us all.

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APPENDIX

Table 1: A comparison between a typical schedule of required courses in the Yale University Chemical Engineering Program and the schedule of required courses in the Nigerian Chemical Engineering Curriculum [3, 4, 7, 8]

NUC BMAS	YALE UNIVERSITY
YEAR 1	**YEAR 1**
1. GST 111: Communication in English I 2. GST 112: Logic, Philosophy and Human Existence 3. GST 113: Nigerian Peoples and Culture 4. GST 121: Use of Library, Study Skills and ICT 5. GST 122: Communication in English II 6. Communication 7. GST 123: Basic Communication in French 8. GST 124: Basic Communication in Arabic 9. GST 125: Contemporary Health Issues 10. GET 111: Basic Engineering Drawing 11. CHM 101: General Chemistry I 12. CHM 102: General Chemistry II 13. CHM 107: General Practical Chemistry I 14. CHM 108: General Practical Chemistry II 15. MTH 101: Elementary Mathematics I 16. MTH 102: Elementary Mathematics II 17. PHY 101: General Physics I 18. PHY 102: General Physics II 19. PHY 107: General Practical Physics I 20. PHY 108: General Practical Physics II	1. CHEM 161 General Chemistry I 2. CHEM 134L General Chemistry I 3. MATH 112 Differential Calculus I 4. CHEM 165 General Chemistry II 5. CHEM 136L General Chemistry II Lab 6. MATH 115 Integral Calculus 7. ENAS 130 Intro Computing for Engineers/Scientists
YEAR 2	**YEAR 2**
1. GST 211: Environment and Sustainable Development 2. GST 222: Peace and Conflict Resolution 3. GST 223: Introduction to Entrepreneurship 4. GST 224: Leadership Skills 5. GET 201: Applied Electricity I 6. GET 202: Applied Electricity II 7. GET 203: Engineering Drawing I 8. GET 222: Engineering Drawing II 9. GET 204: Students Workshop Experience 10. GET 205: Fundamentals of Fluid Mechanics 11. GET 206: Fundamentals of Thermodynamics 12. GET 207: Applied Mechanics 13. GET 208: Strength of Materials 14. GET 209: Engineering Mathematics I 15. GET 210: Engineering Mathematics II 16. GET 211: Computer Programming I 17. GET 212: Engineering Materials 18. GET 213: General Engineering Laboratory Course 19. GET 299: SIWES I	1. CHEM 220 Organic Chemistry I 2. CHEM 222L Organic Chemistry I 3. PHYS 180 Physics I 4. ENAS 151 Multivariable Calculus 5. CENG 210 Principles of Chemical Engineering 6. CHEM 221 Organic Chemistry II 7. CHEM 223L Organic Chemistry II Lab 8. ENAS 194 Ordinary & Partial Differential Equations 9. PHYS 181 Physics II

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NUC BMAS	YALE UNIVERSITY
YEAR 3	**YEAR 3**
1. GET 301: Engineering Mathematics III 2. GET 302: Engineering Mathematics IV 3. GET 303 Engineer-in-Society 4. GET 304 Engineering Communication 5. GET 399 SIWES II 6. GST 311 Entrepreneurship 7. STA 305 Statistics for Physical Science and Engineering 8. TCH 300 Chemical Engineering Laboratory I 9. TCH 301 Transport Phenomena I 10. TCH 302 Chemical Engineering Thermodynamics I 11. TCH 303 Separation Processes I 12. TCH 304 Chemical Kinetics 13. TCH 305 Biochemical Engineering 14. TCH 306 Science of Materials 15. TCH 307 Polymer Process Engineering 16. TCH 308 Process Instrumentation TCH 309 Process Simulation	1. CHEM 332 Physical Chemistry I 2. CENG Thermodynamics 3. MENG 361 Fluid Mechanics 4. CHEM 333 Physical Chemistry II 5. CENG 301 Kinetics and Reactors 6. CENG 315 Transport Processes 7. Engineering Elective
YEAR 4	**YEAR 4**
1. GET 499 SIWES III 2. TCH 400 Chemical Engineering Laboratory 3. TCH 401 Transport Phenomena II 4. TCH 402 Chemical Engineering Thermodynamics II 5. TCH 403 Separation Processes II 6. TCH 404 Plant Design I 7. TCH 405 Chemical Engineering Analysis 8. TCH 406 Particle Technology 9. TCH 407 Environmental Engineering 10. TIE 402 Economics for Engineers	1. CENG 411 Separation/Purification Processes 2. CENG 480 Process Control 3. Engineering Elective 4. CENG 412 Chemical Engineering Lab 5. CENG 416 Chemical Engineering Process Design 6. Engineering Elective
YEAR 5	**YEAR 5**
1. GET 501 Engineering Management 2. GET 502 Engineering Law 3. GET 500 Chemical Engineering Laboratory 4. TCH 501 Separation Processes III 5. TCH 502 Plant Design II 6. TCH 503 Process Control 7. TCH 504 Process Optimization 8. TCH 505 Reservoir Engineering 9. TCH 506 Loss Prevention in Process Industries 10. TCH 507 Chemical Reaction Engineering 11. TCH 508 Coal Processing Technology 12. TCH 509 Sugar Technology 13. TCH 510 Detergent Technology 14. TCH 511 Fermentation Technology 15. TCH 512 Pulp and Paper Technology 16. TCH 513 Polymer Science and Technology	

NUC BMAS	YALE UNIVERSITY
17. TCH 514 Technology of Fossil Fuel Processing 18. TCH 515 Biochemical Engineering 19. TCH 555 Chemical Engineering Research Project	

Table 2: A comparison between a typical schedule of required courses in the University of Illinois Chemical Engineering Program and the schedule of required courses in the Nigerian Chemical Engineering Curriculum [3, 4, 9]

NUC BMAS	UNIVERSITY OF ILLINOIS
YEAR 1	**YEAR 1**
1. GST 111: Communication in English I 2. GST 112: Logic, Philosophy and Human Existence 3. GST 113: Nigerian Peoples and Culture 4. GST 121: Use of Library, Study Skills and ICT 5. GST 122: Communication in English II 6. Communication 7. GST 123: Basic Communication in French 8. GST 124: Basic Communication in Arabic 9. GST 125: Contemporary Health Issues 10. GET 111: Basic Engineering Drawing 11. CHM 101: General Chemistry I 12. CHM 102: General Chemistry II 13. CHM 107: General Practical Chemistry I 14. CHM 108: General Practical Chemistry II 15. MTH 101: Elementary Mathematics I 16. MTH 102: Elementary Mathematics II 17. PHY 101: General Physics I 18. PHY 102: General Physics II 19. PHY 107: General Practical Physics I 20. PHY 108: General Practical Physics II	1. CHEM 202: Accelerated Chemistry I 2. CHEM 203: Accelerated Chemistry Lab I 3. ENG 100: Engineering Orientation 4. MATH 221: Calculus I 5. RHET 105: Writing and Research 6. Elective in Social Sciences or Humanities 7. CHBE 121 CHBE Profession 8. CHEM 204: Accelerated Chemistry II 9. CHEM 205: Accelerated Chemistry Lab II 10. CS 101: Introduction to computing Engineering Science 11. MTH 231: Calculus II 12. PHY 211: University Physics: Electromagnetism
YEAR 2	**YEAR 2**
1. GST 211: Environment and Sustainable Development 2. GST 222: Peace and Conflict Resolution 3. GST 223: Introduction to Entrepreneurship 4. GST 224: Leadership Skills 5. GET 201: Applied Electricity I 6. GET 202: Applied Electricity II 7. GET 203: Engineering Drawing I 8. GET 222: Engineering Drawing II 9. GET 204: Students Workshop Experience 10. GET 205: Fundamentals of Fluid Mechanics 11. GET 206: Fundamentals of Thermodynamics	1. CHBE 221 Principles of Chemical Engineering 2. CHEM 236 Fundamental Organic Chemistry I 3. CHEM 237 Structure and Synthesis 4. MATH 241 Calculus III 5. PHYS 212 University Physics: Electromagnetism 6. CHBE 321 Thermodynamics 7. CHEM 436 Fundamental Organic Chemistry II 8. MATH 285 Intro Differential Equations

NUC BMAS	UNIVERSITY OF ILLINOIS
12. GET 207: Applied Mechanics 13. GET 208: Strength of Materials 14. GET 209: Engineering Mathematics I 15. GET 210: Engineering Mathematics II 16. GET 211: Computer Programming I 17. GET 212: Engineering Materials 18. GET 213: General Engineering Laboratory Course 19. GET 299: SIWES I	9. MATH 415 Applied Linear Algebra 10. PHYS 214 University Physics: Quantum Physics Technical Elective**
YEAR 3	**YEAR 3**
1. GET 301: Engineering Mathematics III 2. GET 302: Engineering Mathematics IV 3. GET 303 Engineer-in-Society 4. GET 304 Engineering Communication 5. GET 399 SIWES II 6. GST 311 Entrepreneurship 7. STA 305 Statistics for Physical Science and Engineering 8. TCH 300 Chemical Engineering Laboratory I 9. TCH 301 Transport Phenomena I 10. TCH 302 Chemical Engineering Thermodynamics I 11. TCH 303 Separation Processes I 12. TCH 304 Chemical Kinetics 13. TCH 305 Biochemical Engineering 14. TCH 306 Science of Materials 15. TCH 307 Polymer Process Engineering 16. TCH 308 Process Instrumentation 17. TCH 309 Process Simulation	1. CHBE 421 Momentum and Heat Transfer 2. CHEM 315 Instrumental Chemical Systems Lab 3. CHEM 420 Instrumental Characterization 4. CHEM 442 Physical Chemistry I 5. Elective in Social Sciences or Humanities or Technical Elective
YEAR 4	**YEAR 4**
1. GET 499 SIWES III 2. TCH 400 Chemical Engineering Laboratory 3. TCH 401 Transport Phenomena II 4. TCH 402 Chemical Engineering Thermodynamics II 5. TCH 403 Separation Processes II 6. TCH 404 Plant Design I 7. TCH 405 Chemical Engineering Analysis 8. TCH 406 Particle Technology 9. TCH 407 Environmental Engineering 10. TIE 402 Economics for Engineers	1. CHBE 430 Unit Operations 2. Laboratory 3. CHBE 440 Process control and dynamics 4. Technical Electives** 5. CHBE 431 Process design 6. Technical Electives**
YEAR 5	**YEAR 5**
1. GET 501 Engineering Management 2. GET 502 Engineering Law 3. GET 500 Chemical Engineering Laboratory 4. TCH 501 Separation Processes III 5. TCH 502 Plant Design II 6. TCH 503 Process Control	

NUC BMAS	UNIVERSITY OF ILLINOIS
7. TCH 504 Process Optimization 8. TCH 505 Reservoir Engineering 9. TCH 506 Loss Prevention in Process Industries 10. TCH 507 Chemical Reaction Engineering 11. TCH 508 Coal Processing Technology 12. TCH 509 Sugar Technology 13. TCH 510 Detergent Technology 14. TCH 511 Fermentation Technology 15. TCH 512 Pulp and Paper Technology 16. TCH 513 Polymer Science and Technology 17. TCH 514 Technology of Fossil Fuel Processing 18. TCH 515 Biochemical Engineering 19. TCH 555 Chemical Engineering Research Project	

Table 3: A comparison between a typical schedule of required courses in the Manchester University Chemical Engineering Program and the schedule of required courses in the Nigerian Chemical Engineering Curriculum [3, 4, 10]

NUC BMAS	MANCHESTER UNIVERSITY
YEAR 1	**YEAR 1**
1. GST 111: Communication in English I 2. GST 112: Logic, Philosophy and Human Existence 3. GST 113: Nigerian Peoples and Culture 4. GST 121: Use of Library, Study Skills and ICT 5. GST 122: Communication in English II 6. GST 123: Basic Communication in French 7. GST 124: Basic Communication in Arabic 8. GST 125: Contemporary Health Issues 9. GET 111: Basic Engineering Drawing 10. CHM 101: General Chemistry I 11. CHM 102: General Chemistry II 12. CHM 107: General Practical Chemistry I 13. CHM 108: General Practical Chemistry II 14. MTH 101: Elementary Mathematics I 15. MTH 102: Elementary Mathematics II 16. PHY 101: General Physics I 17. PHY 102: General Physics II 18. PHY 107: General Practical Physics I 19. PHY 108: General Practical Physics II	1. Engineering Mathematics I 2. Engineering Chemistry 3. Process Flow 4. Process Engineering Fundamentals 5. Computational Methods for Chemical Engineering 6. Laboratory Project I 7. Engineering Mathematics 2 8. Fundamentals of Thermodynamics 9. Process Heat Transfer 10. Chemical Engineering Design 2 11. Introduction to Chemical Reaction Engineering 12. Chemical Engineering Design Project 13. Engineering Biotechnology 14. Chemical Thermodynamics
YEAR 2	**YEAR 2**
1. GST 211: Environment and Sustainable Development 2. GST 222: Peace and Conflict Resolution 3. GST 223: Introduction to Entrepreneurship 4. GST 224: Leadership Skills 5. GET 201: Applied Electricity I 6. GET 202: Applied Electricity II 7. GET 203: Engineering Drawing I 8. GET 222: Engineering Drawing II 9. GET 204: Students Workshop Experience 10. GET 205: Fundamentals of Fluid Mechanics 11. GET 206: Fundamentals of Thermodynamics 12. GET 207: Applied Mechanics 13. GET 208: Strength of Materials	1. Laboratory Projects 2 2. Managing My Future 3. Mathematical Methods 2 4. Solid-Fluid Systems 5. Distillation & Absorption 6. Heat Transfer & Process Integration 7. Chemical Thermodynamics 8. Momentum, Heat & Mass Transfer 9. Chemical Reaction Engineering 10. Safety & Reliability Engineering 11. Process Design & Simulation Biotechnology & Environmental Engineering

14. GET 209: Engineering Mathematics I 15. GET 210: Engineering Mathematics II 16. GET 211: Computer Programming I 17. GET 212: Engineering Materials 18. GET 213: General Engineering Laboratory Course 19. GET 299: SIWES I	
YEAR 3	**YEAR 3**
1. GET 301: Engineering Mathematics III 2. GET 302: Engineering Mathematics IV 3. GET 303 Engineer-in-Society 4. GET 304 Engineering Communication 5. GET 399 SIWES II 6. GST 311 Entrepreneurship 7. STA 305 Statistics for Physical Science and Engineering 8. TCH 300 Chemical Engineering Laboratory I 9. TCH 301 Transport Phenomena I 10. TCH 302 Chemical Engineering Thermodynamics I 11. TCH 303 Separation Processes I 12. TCH 304 Chemical Kinetics 13. TCH 305 Biochemical Engineering 14. TCH 306 Science of Materials 15. TCH 307 Polymer Process Engineering 16. TCH 308 Process Instrumentation TCH 309 Process Simulation	1. Design Project 3 - Part 1 2. Design Project 3 - Part 2 3. Process Synthesis 4. Design Project 3 - Part 3 5. Catalytic Reaction Engineering 6. Process Fluid Dynamics 7. Advanced Engineering Separations 8. Process Control
YEAR 4	**YEAR 4**
1. GET 499 SIWES III 2. TCH 400 Chemical Engineering Laboratory 3. TCH 401 Transport Phenomena II 4. TCH 402 Chemical Engineering Thermodynamics II 5. TCH 403 Separation Processes II 6. TCH 404 Plant Design I 7. TCH 405 Chemical Engineering Analysis 8. TCH 406 Particle Technology 9. TCH 407 Environmental Engineering 10. TIE 402 Economics for Engineers	
YEAR 5	**YEAR 5**
1. GET 501 Engineering Management 2. GET 502 Engineering Law 3. GET 500 Chemical Engineering Laboratory 4. TCH 501 Separation Processes III 5. TCH 502 Plant Design II 6. TCH 503 Process Control 7. TCH 504 Process Optimization 8. TCH 505 Reservoir Engineering 9. TCH 506 Loss Prevention in Process Industries 10. TCH 507 Chemical Reaction Engineering	

11. TCH 508 Coal Processing Technology 12. TCH 509 Sugar Technology 13. TCH 510 Detergent Technology 14. TCH 511 Fermentation Technology 15. TCH 512 Pulp and Paper Technology 16. TCH 513 Polymer Science and Technology 17. TCH 514 Technology of Fossil Fuel Processing 18. TCH 515 Biochemical Engineering 19. TCH 555 Chemical Engineering Research Project	