A NEW MODEL FOR ENGINEERING EDUCATION AT THE Ph.D. LEVEL

Kofi Nyamekye, Ph.D.

Nyamekye Research & Consulting
Rolla, MO 65401
USA
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Yildirim Omurtag, Ph.D., P.E.

Dean
School of Engineering,
Mathematics and Science
Moon Township, PA 15108
USA

Abstract

This paper presents a new model for designing a Doctor of Philosophy (Ph.D.) program in engineering. The paper recognizes that changes in the global economy require a new approach for producing Ph.D. graduates in engineering. Today, some major U.S. companies are beginning to realize that they can get top-flight research scientists offshore to solve their research problems at substantially low costs. Compounding such problems is the lack of state budgets for funding new engineering programs in the emerging disciplines. Consequently, a critical need exists to address these critical issues facing the U.S. Ph.D. programs in engineering. The paper first gives an overview of the critical problems facing the U.S. engineering education, and then uses the design loop, as a generic approach to reflect the fact that when the societal need changes the Ph.D. program in engineering must adapt to it. An example of a newly established, innovative Ph.D. program in Engineering at Robert Morris University (RMU) in Pennsylvania that attempts to address some of these issues has been illustrated.

1.0 Introduction

In recent years, the U.S. has lost its manufacturing base to the emerging countries, such as China and other Asian-Pacific countries. For example, China has now become the "factory floor capital of the world." The economic consequence of the loss of our manufacturing base is enormous. Today, U.S. engineering graduates must not only compete for the fewer engineering jobs in the U.S., but they must also compete for the same high-skill jobs with engineers from the low-wage countries. Why should a U.S. company pay an engineering graduate fresh from college an annual salary of $60,000 if it can pay an annual salary of $10,000 to an engineer with the same skills from China or India to do the same job?

The statistics for this trend is alarming. According to Gartner Inc.[1], about 10 percent of computer engineering related jobs would be outsourced offshore by the end of 2004. A survey conducted by Deloitte Research[1]showed that about 2 million jobs and $356 billion in operations would be moved to overseas within the next five years. Forrester Research[1] study concurs with the previous studies. They forecast that by 2015 about 3.3 million high-tech and service-industry jobs would be outsourced offshore. Forrester Research points out that such jobs amount to about $136 billion in wages. Meta Group Inc.[2] estimates that offshore spending in information technology by U.S. businesses will reach about $10 billion this year and that the use of offshore information technology services will grow about 20% annually through 2008. The trend in outsourcing of jobs does not stop with jobs related to computer engineering alone. A recent report by Bingham[3] indicates that some major U.S. companies have started outsourcing their research and development (R & D) efforts offshore. According to Bingham, in just two years, Procter & Gamble (P & G) has boosted the percentage of its product innovations that come from outside sources from less than 20% to 35%[3]. It wants 50% of its product innovations to come from external sources. Such external sources include offshore research scientists that can solve P & G particular research problems. Other major U.S. companies too are practicing the same business strategy[3]. Consequently, a critical need exists at our universities to redesign their Ph.D. programs to address the onslaught of U.S. R & D and other technical and scientific jobs offshore.

Despite the threat posed by offshoring the technical and scientific jobs, very little has been done by our universities to prepare our future engineers to meet this global challenge. A variety of reasons may be attributed to this challenge.

First, our engineering schools were designed based on the concept that once our students take all the basic science and engineering courses, they will be fully prepared to enter into the world as practicing engineers. Thus, they can acquire the practical experience as they work in their companies. So, why spend the extra effort to prepare them with the appropriate practical experience, before they graduate. The model served well until today's information technology and global manufacturing age.

Second, our engineering faculty members earn their Ph.D.s with dissertations that emphasize only science rather than both science and commercial applications. Consider the format of a typical Ph.D. dissertation work. The format includes the following basic steps[4]:

1. The student first defines the research problem.
2. He or she then conducts the literature survey to find the current research activities in the research area. He or she reviews the deficiencies in the current research work. He or she then justifies the need to conduct his or her research work to ensure that the work can advance knowledge in the research area.
3. The student then develops the theoretical models to solve the research problem.
4. A research plan to conduct the research then follows.
5. He or she discusses the findings from the research work.
6. Conclusions and recommendations for future work then follows.

What is critically missing in the above format is the economic impact of the research study on the society. Does the Ph.D. dissertation work have any competitive advantage? That is, does the research work have any technical and scientific breakthroughs that a U.S. company can adopt to sustain superior performance within its industry? Today, many Ph.D. dissertations lack such a competitive advantage in the marketplace. Because the next generation of engineering jobs in U.S. will come from technical and scientific innovations, this issue becomes critically important to the competitiveness of the U.S. economy.

Consider another implication of the competitive advantage of a Ph.D. program in manufacturing engineering. A well-designed Ph.D. program in manufacturing engineering should produce Ph.D. graduates whose dissertations should enhance the competitiveness of U.S. manufacturing base. Today few Ph.D. graduates from such a program assume faculty positions with hardly any experience in a real manufacturing production facility. How do you expect such graduates to educate the manufacturing engineering students who in turn will work in the U.S. manufacturing companies that must compete in the new economy if the faculty members themselves do not have clear idea about the needs of such companies to compete? Not only must our faculty members be educators and researchers, but they must also be innovators in conducting fundamental and applied research, and converting that research into commercial applications. Through such efforts, the faculty themselves will become industrial practitioners who understand the actual needs of the society and how they in turn can prepare the students for the new global economy before they graduate. Recent emphasis by all the federal funding agencies, including the newly established Department of Homeland Security, for strongly encouraging university faculty members to actively participate in the SBIR/STTR (Small Business Innovation Research/Small Business Technology Transfer) programs, attests to this issue[5]. President George Bush's new executive order, which authorizes the SBIR/STTR programs as the major sources of technical and scientific innovations in U.S. manufacturing, strongly emphasizes the importance of such an issue[6].

We should emphasize that the SBIR program emphasizes on applied research, and the STTR program on basic research[5]. For the SBIR program, the small business must be the lead investigator, but be it can sub-contract one-third of the research work to a faculty member in Phase I. Phase II permits the small business to subcontract half of the research work to a faculty member. In contrast, the STTR program permits a faculty member to be the lead investigator for Phase I and Phase II, respectively[5].

Third, the current engineering curricula used by most universities are not sufficiently flexible for meeting the challenges of the new information and global manufacturing. Consider a typical industrial engineering (IE) program with manufacturing engineering option. Most IE curricula with this option still emphasize cellular manufacturing as the cornerstone of their manufacturing engineering programs, with few courses here and there in designing and operating global logistics system. Lacking in such programs are the comprehensive integration of information-science courses into the manufacturing engineering courses that will help students to understand the design and operation of distributed enterprise systems such as manufacturing and retail supply chains. More importantly, the students should also understand how the operations at the retail outlets could help improve the design of global logistics systems as single systems. Note that the final stage of logistics system is the retail outlet. Thus, we must have a feedback loop from the retail systems to the suppliers for improving the design and operation of global logistics systems.

This article will discuss a new model that will serve as a possible model for engineering education at the Ph.D. level. In the subsequent sections, we will first discuss the current structure of Ph.D. engineering programs. Then a discussion of emerging engineering disciplines, such as linguistics engineering, forensic engineering that may require new theoretical and applied research work, will follow. A generic model, based on Axiomatic Design principle[7] for constructing a Ph.D. program in engineering, will be discussed. An example of a newly established, innovative Ph.D. degree in Engineering at Robert Morris University (RMU) in Pennsylvania that attempts to address some of these issues will be described.

2.0 Traditional Ph.D. Engineering Programs

The traditional Ph.D. programs are narrowly focused and discipline-defined dissertation research. A typical discipline normally requires a graduate student to take certain number of courses beyond those already taken to fulfill the Master of Science (MS) degree within the same discipline. The idea here is to ensure that when the student completes the Ph.D. program he or she will be prepared to teach graduate level courses in that discipline at a university. This idea assumes that upon completion of his or her Ph.D. dissertation, those courses will be sufficient to prepare the students to teach courses in new emerging areas that do not have any theoretical and scientific concepts established. More importantly, textbooks may not even be available for teaching courses in the new scientific areas. After certain number of quarters or semesters within the program, the student takes a Ph.D. qualifying examination. If successful, the student forms his or her dissertation committee, defines his or her research topic, and presents the topic to the committee for approval. The research work then follows. The student later defends the thesis work. Upon successful defense, he or she makes the appropriate refinements to the dissertation per the committee's suggestions. The student then graduates after the committee endorses the final dissertation.

Several problems exist with such an approach. First, except for a student with a MS degree from a discipline different from the discipline within which the student enrolls the Ph.D. program, such an extra course work may be unnecessary. That is, the MS degree should sufficiently prepare the student for all the graduate level courses needed to conduct any teaching work in the discipline after obtaining his or her Ph.D. degree. For the student with a MS degree, different from the discipline within which the student has enrolled the Ph.D. degree, remedial courses may be appropriate.

Second, such a program lacks any structure that prepares the students to write proposals to seek research grants to support their dissertations. This issue is very important. If a student could write a successful proposal, the student would then have already achieved a major technical innovation even before completing his or Ph.D. dissertation. In fact, the research grant would validate the student's contribution to the advancement of knowledge within the research area.

Third, such a program lacks any student interactions among the Ph.D. students. For example, a student never learns anything about peer review, which is the requirement for publication in a refereed journal. That is, the student is not engaged in any scholarly activities that allow him or her to peer review technical papers or publications of other students in the Ph.D. program. This issue deserves attention. One of the primary goals of a Ph.D. program is to prepare a graduate student to conduct an independent research study and more importantly, to conduct research work on his her own upon graduation and publish research papers in technical journals or conference proceedings. Publications in technical journals require that the work be peered reviewed. So, why does a student have to complete his or her dissertation before he or she learns how to write a successful technical journal?

Fourth, as noted before the format for the traditional Ph.D. dissertations does not require the student's research work to have an economic impact on the society. If one of the goals for a successful Ph.D. dissertation is to advance knowledge, then how can the society benefit from advancement in knowledge if the research work lacks any economic benefit to the society? Consider the medical sciences. Breakthroughs in the innovative research activities have successfully saved humanity from life threatening diseases. The pharmaceutical companies have gained substantial competitive advantage from such research activities. Thus, the current Ph.D. programs in engineering should attempt to follow the graduate research programs in the medical sciences[8].

The issue of economic impact of Ph.D. dissertations on the society deserves attention. A new book, entitled "Reinventing the Research University," which is a collection of essays from 13 contributors on the condition of a modern university and the challenges facing it, reinforces this issue[9]. Herbert neatly rephrases an essay, which attests to this issue, from the book as follows[10]:

- *Industry-university cooperation. In his essay "Globalization of Research and Development in a Federated World," Hewlett Packard's Wayne C. Johnson describes a new model for innovation – which he dubs "open innovation" – in which corporate labs and university labs no longer exist as separate entities. Instead, he argues, industry and academia need to break down the traditional boundaries between them to generate the kind of knowledge in our global economy.*

In essence, academic institutions must redesign their Ph.D. research programs to ensure they have direct economic impact on the society. As noted before, recent emphasis by all the federal funding agencies, for strongly encouraging university faculty members to actively participate in the SBIR/STTR (Small Business Innovative Research/Small Business Technology Transfer) programs, strengthens such a critical need[5].

3.0 Emerging Disciplines and Their Impact on Traditional Ph.D. Programs

Many new scientific disciplines have merged as the result of 9/11. They range from linguistic engineering to biometrics engineering. Since such disciplines require new scientific and theoretical models to be established, the traditional Ph.D. programs lack the flexibility to fulfill the needs of such emerging research areas. The issue then becomes how to redesign the current Ph.D. programs so that they can adapt to new technical and scientific disciplines. Establishing a new Ph.D. program each time for a new discipline is not economically feasible because substantial resources will be required to establish each new program. In addition, the state budgets, for many academic institutions in U.S., are shrinking. Consequently, a critical need exists for U.S. universities to be innovative in creating agile Ph.D. programs in engineering. We will address a new model that addresses such a need in the subsequent sections.

4.0 A Generic New Model For Designing A Ph.D. Program In Engineering

Because constructing a new Ph.D. program or improving an existing program is a design issue, we will first discuss the design loop proposed by Wilson[11] as the framework for discussing the new model. Suh, in Axiomatic Design, has adopted the proposed concept [7]. To simplify the discussion, we will omit the theoretical details in Axiomatic Design and focus our attention only on the design framework as a basic model for constructing a new Ph.D. program. A discussion of a new Ph.D. program that illustrates our previous concepts will then follow.

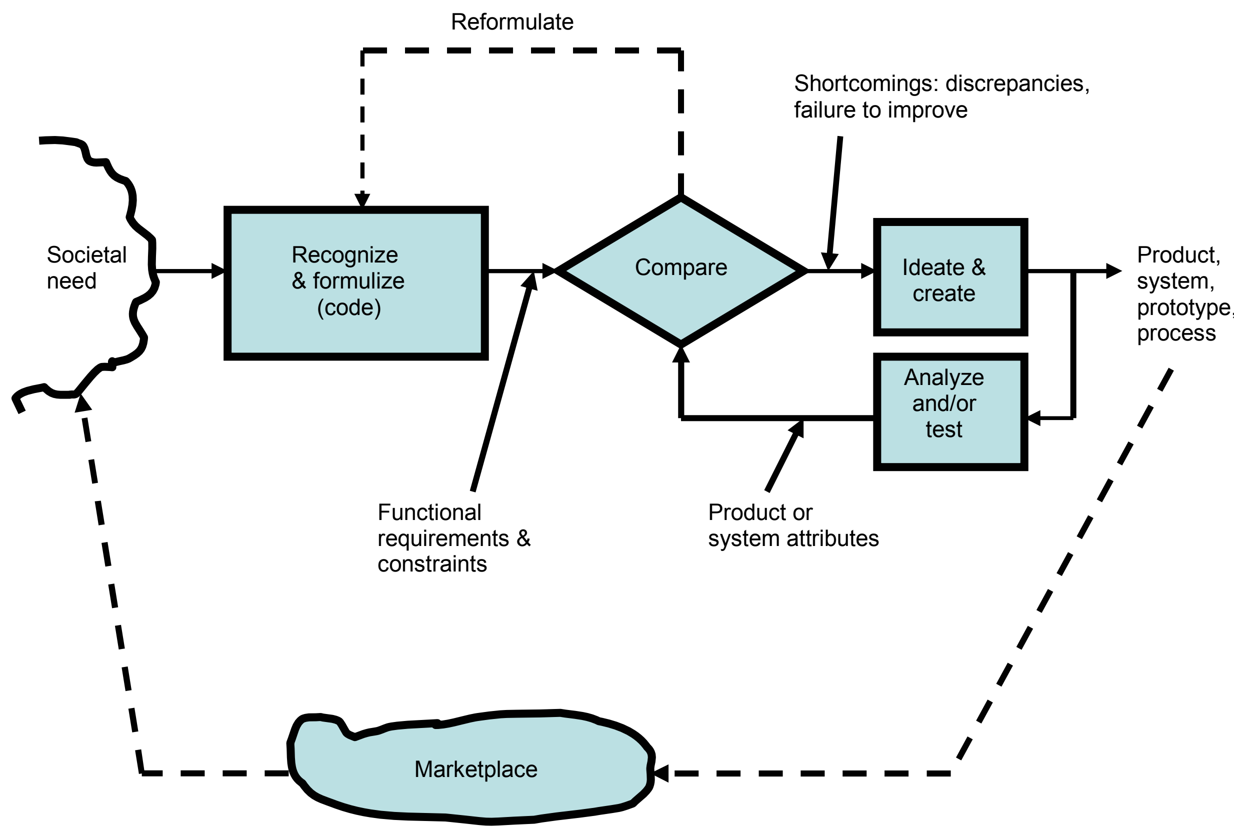

Figure 1. The Design Loop-As the Architecture for a Product or System Design[11].

According to Wilson, a design process begins with the establishment of the *functional requirements* to fulfill a given set of needs. The design then ends with the creation of an entity (a product, a system, or a process) that fulfils the *functional requirements*. Figure 1 shows the design process. The design process begins with the recognition of the *societal need*. For an academic institution, such a need may originate from the society or from within the institution. Typically, the *societal need* is usually unclear. For example, today the federal government wants to protect its cyber space against terrorism, but is not sure what scientific research program (*societal need*) is required. The need is then coded into a concrete *set of functional requirements*. In the cyber space example, a *specific functional requirement* in the *set of functional requirements* may be -- "use multi-agent systems" -- to find and destroy harmful messages through the cyber space. After the need is coded, ideas are generated to create the product or system. In the cyber space example, the final system may be -- "a cyber-ecosystem." For an academic institution, the system may be a new Ph.D. program. The product or system is analyzed and the performance measures compared with the original *set of functional requirements* through a feedback loop. For a new Ph.D. program, we may not have the luxury to see immediate results for comparison with the original *set of functional requirements*. We may need to wait for several years to do so. When the product or system does not fully satisfy the original *set of functional requirements*, then we must reformulate new ideas or change the *functional requirements* to be accurately consistent with the *societal need*. We continue this iteration until we create an acceptable system.

We should emphasize that when the *societal need* changes, the system may not be adequate to meet the new need. Consequently, we must go through the design loop again to redesign the existing system. For a typical Ph.D. program, the budget constraints may not permit it to build a new Ph.D. program if the existing program cannot be improved to meet the new *societal need*. Thus, we must be creative when we design a new Ph.D. program so that it can be agile to meet future *societal need*. We will use a new innovative Ph.D. degree in Engineering at Robert Morris University in Pennsylvania as an example to address some of the issues noted previously.

4.1 Robert Morris University Ph.D. Program in Engineering

A brief review of existing Ph.D. degree in engineering is essential before discussing the details of RMU program. Several Ph.D. programs in Engineering exist[12]. Similar to the traditional programs such as Civil, Electrical, Mechanical and Electrical Engineering, the traditional Ph.D. programs in Engineering are discipline-focused. That is, the students follow some rigid coursework in the same discipline even after completing advanced graduate level courses in the MS degree program. For a student with a thesis option, the MS degree usually takes about two years to complete. Thus, when the student enters the Ph.D. program, he or she would have had the appropriate coursework to teach after graduation. We should note that for students without the appropriate coursework, remedial coursework is quiet appropriate. More importantly, little interaction exists among the graduate students in exchanging scholarly ideas in such programs. Because the emerging research disciplines require strong collaboration among different research scientists, it is important that the Ph.D. programs in engineering prepare students to meet such a need.

In contrast, the RMU program, with a cohort of classmates pursuing the Ph.D. degree and with research in possibly different discipline areas of engineering, will provide many opportunities for interaction and consequent cross-fertilization among the graduate students[4]. Consequently, the primary goal (*societal need*, Figure 1) of the RMU's Ph.D. program in Engineering is to provide a terminal degree to engineers and other technical professionals with degrees in following areas[4]:

- engineering

- technology
- mathematics/statistics
- hard natural sciences
- computer science
- operations research and other similar fields.

Designing a Ph.D. program in engineering that meets all the above needs, requires the program be discipline-focused independent and be agile to respond to changes in future needs. Thus, the Ph.D. program prepares the students for career advancement in technical and engineering enterprises, and career options in academe and in government services, as well in emerging disciplines. Consequently, the emphasis of the program is to educate students to develop research and proposal writing skills and depth in analytical, technical, and engineering areas of expertise while enhancing their leadership skills and potentials[4].

4.1.1 Academic Requirements - General

The *functional requirements* (Figure 1) of the RMU Ph.D. program are:

- Design non-disciplined focused courses.
- Produce scholarly dissertation.
- Publish one conference paper.
- Publish two refereed journals.

The students must take 54 credits hours after a successful completion of an MS degree in a technical field. Unlike of the traditional programs, the courses consist of the following sets:

- **core courses** that prepare students to develop research and proposal writing skills
- **process seminar courses** that prepare students to interact extensively with their advisors and fellow students
- **dissertation research courses** that prepare the students to independently conduct research work.

The last two functional requirements, “Publish one conference paper,” and “Publish two refereed journals”, deserve attention. For many refereed journals, the cycle time – the time from submission until the journal paper is finally accepted for publication – may take anywhere from six months to two years. This obviously could delay students’ progress through the program and eventual graduation. Robert Morris University recognizes this problem. For the first students in the new Ph.D. program, RMU will carefully monitor the number of successful scholarly publications of each student as they progress through the program. For students that do not meet the minimum requirements for publications at any critical point of their progress, a request for a waiver from the Ph.D. committee will be required. As part of this process, the Ph.D. committee will submit a formal request that will include evidence such as the dates the papers were submitted and letters from the journals’ editors, to the Dean of Engineering for approval. At least one journal article and a conference paper must be in print with strong evidence that the second paper has been submitted in a quality format with positive initial feedback from the reviewers for the waiver request to be approved and the final defense can be scheduled. To ensure that the new Ph.D. program has consistent requirements for each student, the RMU will reevaluate the requirements for publications and new consistent requirements for scholarly publications established, before the next batch of students graduate from the program.

The **core courses** consist of 18 credit hours, the **process seminar courses** 21 credit hours, and the **dissertation research courses** 15 credit hours. Also, the program prepares students to write proposals to seek grants for their research work. More importantly, competitive advantage of the Ph.D. dissertation is strongly encouraged. That is, the student Ph.D. dissertation should attempt to include a section that clearly demonstrates the competitive advantage of the research work. To strengthen such as an effort, the program has been designed to attract small-and medium sized scientific-based companies to locate near the campus. With such a model, the program can attract top quality graduate students who may be interested to pursue Ph.D. programs from such companies. As noted previously, the federal research funding agencies now strongly encourage such type of strong academic-industrial research programs[5]. Only through such an innovative Ph.D. program can the U.S. achieve competitive advantage through technical and scientific innovations.

We should emphasize that as the *societal need* (Figure 1) changes new courses could be added to the program. Also, the program can be easily redesigned to meet the new *societal need* without having to build a new Ph.D. program in engineering. Thus, the program is low cost and agile. For students whose research interest and background indicate a need for more preparation, the program has appropriate courses to prepare the students. The subsequent sections discuss the courses in details to fulfill such needs.

4.1.1.1 Core Courses

The core courses are:

1. ENGR 8100: Engineering Communication (3 credit hours)
2. ENGR 8300: Engineering Leadership for Innovation (3 credit hours)
3. ENGR 8500: Research Methods in Engineering I (3 credit hours)
4. ENGR 8550: Research Methods in Engineering II (3 credit hours)
5. ENGR 8700: Engineering Research Project Development I (3 credit hours)
6. ENGR 8750: Engineering Research Project Development II (3 credit hours)

As part of the final requirements for **Engineering Research Project Development II**, students take rigorous written and oral examinations. When a student successfully completes this course and passes the oral and written examinations, he or she can then start the research for dissertation. Thus, the **Engineering Research Project Development II** acts as a Ph.D. "qualifying" stage for the students[4].

A brief description of each course follows.

- **ENGR 8100: Engineering Communication**: This course includes the description of technical mechanisms and processes; designing, using tables, graphs and figures; producing progress reports, feasibility reports, and formal reports; and doing technical briefings. The course prepares the students for conference presentation and journal article publication based on their dissertation work[4].

- **ENGR 8300: Engineering Leadership for Innovation**: Today, engineers and scientists create and implement technologies in their organizations, including educational institutions. Examples include Nanoscience Technologies at universities and private research laboratories. This course focuses on the strategic use of innovation in engineering, science and technology with a view towards developing effective technical leaders. It covers the integration of technology and strategy with innovation in modern organizations, thereby achieving competitive advantage[4].

- **ENGR 8500: Research Methods in Engineering I**: The course provides strong background for developing research methodologies and problem definitions, formulating research methodology, statistical concepts, such as descriptive statistics, relationship between variables, differences between groups and multivariate techniques[4].

- **ENGR 8550: Research Methods in Engineering II**: This course provides an in-depth survey of experimental research techniques including design of experiments, validity and reliability of experimental results and Taguchi techniques. It builds on the foundation from ENGR 8500[4].

- **ENGR 8700: Engineering Research Project Development I**: Using literature in developing research problems, the course will provide the students knowledge and skills to formulate their research problems in the form of dissertation proposals[4]. The course also provides an in-depth coverage of industrial/commercial proposals and proposals to government funding agencies, such as NSF, DOE, NIST, etc. More importantly, after completing this course, the student can develop a wining proposal[4]. Particularly for the Ph.D. students from small scientific-based research companies, the course provides the solid foundation for the students to write successful SBIR/STTR proposals.

- **ENGR 8750: Engineering Research Project Development II**: The course gives the students strong background in developing proposals that can be effectively investigated and concluded as appropriate in the form of technical and scientific publications. Synthesis occurs in the process of writing and presenting a formal proposal for a research project, and discussing the proposal with other colleagues on a research team. Thus, the course requires students to review other student's proposals and suggest improvements for writing a strong proposal for a Ph.D. dissertation. The course also focuses on the delineation of a field problem and the plan for conducting substantive research leading to the resolution of or recommendations on the problem[4]. To reach a resolution of or recommendation on a problem, the student must first review the theoretical bases for the problem from a scientific viewpoint, evaluate the currently related work through literature survey, and then evaluate the research[4].

After each student has completed the ENGR 8750 and passed the Ph.D. qualifying exam, the student can form his or her Ph.D. committee. The Ph.D. committee must consist of a minimum of four members with at least two members from engineering, one from outside engineering and one from an industry/government representative with appropriate technical and scientific background in the student's research topic[4]. Upon the approval of the dissertation advisor, the Ph.D. program coordinator and the Dean of School of Engineering, the student must submit an acceptable paper for publication in the proceedings of a professional conference, as a partial requirement for the successful completion of the Ph.D. qualifying examination[4]. As noted before, RMU will closely monitor and reevaluate this requirement to ensure that students can successfully graduate on time.

4.1.1.2 Process Seminar Courses

The process seminar courses are:

1. ENGR 9310: Engineering Process Seminar I: Research Initiation (6 credit hours)
2. ENGR 9320: Engineering Process Seminar II: Preliminary Solution Development (6 credit hours)
3. ENGR 9330: Engineering Process Seminar III: Synthesis of Research Outcomes (6 credit hours)
4. ENGR 9900: Viva Voce: Research Conclusion (3 credit hours)

Note that these courses provide strong interaction between the student and his or her advisor as well as other fellow students. The following section briefly describes each course:

- **ENGR 9310: Engineering Process Seminar I: Research Initiation**: This course focuses on the initiation of the student's research project. After the student gains acceptance into the doctoral candidacy and approval of his or her proposal, the course prepares the student to apply his or her engineering and scientific knowledge to start the research[4]. The student learns how to apply the knowledge gained from the previous courses on research progress, organization, argument development, format, and presentation of the progress in his or particular dissertation work. Also, throughout the course the student interacts with his or her peers in observing his or her progress[4].

ENGR 9320: Engineering Process Seminar II: Preliminary Solution Development: This course focuses on data gathering and analysis of the research work. In consultation with the thesis advisor, the student develops a viable solution to the research topic. As part of the requirement, the student must submit a problem solution to a refereed journal. As noted before, RMU will closely monitor and reevaluate this requirement to ensure that students can successfully graduate on time. Again as in ENGR 9310, the student interacts with his or her peers in observing his or her progress[4].

- **ENGR 9330: Engineering Process Seminar III: Synthesis of Research Outcomes**: The course focuses on the design, organization, writing, and presentation of the research work. Synthesizing the research investigation and research outcomes are essential requirements for the course. Again as in previous courses, the student interacts with his or her peers in observing his or her progress[4].

- **ENGR 9900: Viva Voce: Research Conclusion**: After each student completes his or her work, the student must present his or her research problem, the methodology to solving the research the problem and the solutions to his or her problem. The solution must be written in a format that meets the needs of the audience to whom the solution is addressed. The student must present the solution to both the whole class and the student's Ph.D. committee at the same time. Upon the approval of the student's advisor, the Ph.D. program coordinator and the Dean of School of Engineering, the student submits a paper to a referred journal[4].

4.1.1.3 Dissertation Research Courses

The dissertation research courses are:

1. ENGR 9810: Dissertation Research in Engineering I (3 credit hours)
2. ENGR 9820: Dissertation Research in Engineering II (3 credit hours)
3. ENGR 9830: Dissertation Research in Engineering III (3 credit hours)
4. ENGR 9840: Dissertation Research in Engineering IV (6 credit hours)

Each course is briefly discussed below:

- **ENGR 9810: Dissertation Research in Engineering I**: The course provides the background for each student to conduct the research work independently. The student interacts only with his or her thesis advisor, the Ph.D. committee members or outside experts in the field[4].

- **ENGR 9820: Dissertation Research in Engineering II**: The student continues his or her dissertation research, and completes the submission of the paper to a refereed journal[4].

- **ENGR 9830: Dissertation Research in Engineering III**: The student continues his or her dissertation research[4].

- **ENGR 9840: Dissertation Research in Engineering IV**: The student completes his or her dissertation and submits the second paper to a refereed journal[4].

The dissertation must be a comprehensive written document showing all the details of the work done and covering the following format as part of the body of the dissertation[13]:

1. Introduction
2. Literature Review
3. Model/Theoretical Development/ Methodology
4. Description of the Proposed Methodology
5. Findings and Analysis of Findings
6. Conclusions
7. Potential Competitive Advantage of the Dissertation Research Work

Should the *societal need* changes, additional courses in ENGR 8XXX, and ENGR 9XXX series could be easily added to meet the new need. Because the program is new, it will require sufficient time to achieve reasonable results for comparison with the original set *of functional requirements* consistent with the *societal need*, Figure 1.

5.0 RMU Research Facilities For Innovative Ph.D. Program In Global Logistics Research

As noted before, the current manufacturing engineering curricula used by most universities are not sufficiently flexible for meeting the challenges of the new information and global manufacturing or logistics. In contrast, the RMU has excellent research facilities for conducting breakthroughs in global logistics. For example, students with research interests in global manufacturing can use data fusion of RFID (Radio Frequency Identification) tags data and manufacturing process data to design an optimum configuration of global logistics system – from suppliers to the retail outlets-- and create a feedback loop to the suppliers for real-time control and operation of the global logistics. Such research opportunities currently do not exist in U.S. academic institutions with Ph.D. programs in manufacturing engineering.

6.0 Conclusions

This paper has addressed the critical issues facing the Ph.D. programs in engineering in U.S. academic institutions. Among them are the lack of responsiveness of the current programs to meet the global needs of the society and more importantly the lack of competitive nature of the traditional Ph.D. dissertations. A new model for the Ph.D. in engineering has been discussed. Using the newly established Ph.D. degree in Engineering at Robert Morris University in Pennsylvania as an example, the paper has discussed in detail the design of such a program to address some of the critical issues confronting the engineering education in the United States. With the shrinking state budgets, universities can no longer afford to build new Ph.D. programs in engineering to meet the future needs of the society. Consequently, this paper may serve as a blueprint for meeting some of the challenges facing the U.S. engineering education today and in the future.

7.0 References

1. McGraw, D., "My Job Lies Over the Ocean," ASEE PRISM, pp. 25-29, December 2003.
2 Thibodeau, P., "Offshoring Fuels IT Hiring Boom in India," COMPUTERWORLD, p. 8, October 18, 2004.
3. Bingham, A., "Innovation Inside Out," COMPUTERWORLD, pp. 49-50, September 13, 2004.
4. Robert Morris University, "Doctor of Philosophy Degree (Ph.D.) in Engineering," Program Proposal, May 11, 2004.
5. Center for Emerging Technologies, "Where Innovation Focuses Technology," Swift SBIR/STTR Tour, Sponsored by Center for Emerging Technologies, St. Louis, MO, September 13, 2004.
6. Presidential Documents, "Encouraging Innovation in Manufacturing," Executive Order

13329, February 24, 2004, Federal Register, Vol. 69, No. 38, February 26, 2004.
7. Suh, N. P., The Principles of Design, Oxford University Press, New York, 1990.
8. University of New Mexico, "The Economic Impact of the University of New Mexico Health Sciences Center, FY 2001-2002," Bureau of Business and Economic Research, March 2003.
9. Weber, E. L. and Duderstadt, J. J., "Reinventing the Research University," Economica Press, 2004.
10. Herbert, W., "A New School of Thought," ASEE PRISM, p. 45, October 2004.
11. Wilson, D. R., "An Exploratory Study of Complexity in Axiomatic Design," Ph.D. Thesis, MIT, August, 1980.
12. Profiles of Engineering Colleges, ASEE, 2002 Edition, Washington D.C.
13. Final Ph.D. Committee Report, "Doctor of Philosophy Degree (Ph.D.) in Engineering," Prepared for Robert Morris University, July 2004.

8.0 Biographical Information

KOFI NYAMEKYE

Dr. Kofi Nyamekye is the founder of Nyamekye Research & Consulting. As a former college educator and a researcher, he has published extensive articles on the design and operation of cellular manufacturing systems. He is a member of the National Institute of Standards and Technology's IMS MISSION for designing simulation models for planning and operation of globally distributed enterprises systems, such as manufacturing supply chains.

YILDIRIM OMURTAG

Dr Yildirim Omurtag is the founding dean of the School of Engineering, Mathematics and Science at Robert Morris University. He has served as a faculty and academic administrator at University of Missouri-Rolla, the Wichita State and Iowa State universities, and has over six years of industrial experience in manufacturing. A licensed engineer in Iowa and Missouri, he has directed or co-directed with younger faculty, over fifty Ph.D. dissertations.