

Proposed Research Based Curriculum of PhD in Industrial Engineering

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Highlights

- Only 17% of faculty members in higher education are doctoral degree holders
- Only one higher education institution has a doctoral program in industrial engineering.
- Mapúa University will open a doctoral program in industrial engineering as an advancement of industrial engineering education in the Philippines.
- The proposed approach can be adapted by other engineering programs that plan to start a doctoral program.

Abstract

Doctoral degree is one of the most well-known, distinct and well-established postgraduate qualifications because of their roots in research and the pursuit of knowledge through original and independent study. However, the Philippines reported the lack of doctoral degree holders in science and technology and engineering which is one of the primary reasons why the country is lagging behind in terms of science and technology development. Industrial Engineering is a branch of engineering which mainly focuses on the design, improvement, and installation of integrated systems of men, materials, equipment, and energy. At present, 107 universities in the Philippines are currently offering the BS IE program but only one university is offering the doctoral program in Industrial Engineering. This condition was found as a new opportunity to provide a new doctoral program in industrial engineering. Thus, Mapua University is proposing a research based doctoral program in Industrial engineering for the advancement of industrial engineering education in the Philippines. The new doctoral program could also contribute to the pool of experts that would lead the industrial engineering-related research and development in the country.

Key Words: Industrial Engineering; Mapúa University; Doctoral Program; Engineering Education.

1. Introduction

The doctoral degree is one of the most well-known, distinct and well-established postgraduate qualifications because of their roots in research and the requirement for the candidate to produce work demonstrating original thought, based on independent study. (UK Quality Code for Higher education, 2015). Earning a doctoral degree has established itself as a qualification recognized internationally, as the standard qualification for entry into the research and academic professions, and as an important qualification for other labor markets (ABRC, 1996). Because of the increasing importance of doctoral degree holders to universities, it is essential that universities also open their doctoral programs to contribute to the pool of experts. For instance, the doctoral program for science teachers in secondary schools was opened to enable teachers to conduct educational research, which is aimed at improving their educational practice (Bakx et. al., 2016).

Aside from its importance in universities, doctoral degree holders can play a crucial role in the economic and social development of a country. However, the Philippines' Commission on Science Technology and Engineering reported the lack of science and technology and engineering doctoral degree holders which is one of the foremost reasons why the country is lagging behind in terms of science and technology development (COMSTE, 2010). The Philippines has very few doctoral degree holders as against its population with 1 doctoral holder for every 54,060 people (COMSTE, 2010). On the other hand, Japan has 1 doctoral holder per 11,621 people, in the USA there is 1 per 6,533, and Germany has 1 per 3,316 (COMSTE, 2010). Furthermore, the number of faculty members at state and private universities with doctoral degrees is only at 17% (Table1). Most faculty members teaching in higher education have only a BS/BA degree, which lacks the necessary skills and experience in doing advanced research.

Table 1. Higher Education Faculty by Highest Degree Attained, AY 2018-19

Institutional Type	BA/BS	MA/MS	PhD	Grand Total
State/Local University	25,463	20,919	12,631	59,013
Private University	36,935	30,282	9,956	77,173
Grand Total	62,398	51,201	22,587	136,186
% to Total	46%	38%	17%	100%

Source: Commission on Higher Education, 2018

The lack of doctoral degree holders in the Philippines can be attributed to the same education system which produce barely a hundred new PhD graduates a year in the basic, applied and social sciences, technology, engineering and mathematics with the University of the Philippines accounting for more than 80% of the miniscule number (Saloma, 2016). This is very far from the PhD graduates of other countries as shown in Table 2. In 2015, United States produced the highest number of PhD graduates at 68,923. This is followed by China that produced 54,891 graduates and Russia, on a far third, with 29,632 graduates.

Table 2. Top Ten Countries Producing PhD Graduates, 2015

Country	No. of graduates
United States	68,923
China	54,891
Russia	29,632
Germany	29,218
United Kingdom	26,636
India	22,528
Brazil	18,625
Japan	15,714
France	13,774
Korea	13,077

Source : OECD, 2018

Doctoral education has often been viewed as a lower priority – given the need to attend first to the undergraduate level. But this approach underestimates the significant interdependence between these levels, as competent faculty members for the undergraduate level and a thriving and innovative research environment, to a large extent depend on the possibilities of high quality doctoral study (Park, 2007). This situation can be seen in the field of industrial engineering where 107 schools are currently offering the undergraduate degree program, and 15 schools for the Masteral level program. For the PhD program, only 1 school is currently offering the program (Table 3). Thus, there is a need to open a doctoral program that can contribute to the advancement of industrial engineering education as well as to the industrial engineering-related research and development in the country.

Table 3. Number of Schools Offering Selected Engineering Programs at Undergraduate and Graduate Levels, 2018

Program\Degree	BS	MS	PhD
Industrial Engineering	107	15	1
Civil Engineering	213	26	2
Electronics Engineering	194	14	3
Chemical Engineering	34	11	4

Source: various websites

2. Methods

The doctorate program takes a number of different forms in different countries (Noble 1994). In the USA, for example, a doctorate program usually includes both taking advanced-level taught courses and undertaking academic research. In Europe and Australia, the doctorate program is typically based on research (Park, 2007). To accommodate the needs of increasingly diverse professions employing doctoral graduates, the form of the doctorate program has diversified. This led to differently structured doctorate degrees such as the emergence of the titles 'professional' doctorate, and 'practice-based' or 'practice-led' doctorate (UK Quality Code for Higher Education, 2015).

In the Philippines, the current doctoral program is patterned from the United States, where students are required to take advanced courses and undertake academic research through the submission of a dissertation. In some universities, the submission of dissertation was changed to publication in SCI or scopus-indexed journals. The publication requirement, which is based on the number of published journals, varies per doctoral program.

The website of each university was used to identify the industrial engineering programs being offered at the undergraduate and graduate levels. Table 4 shows the 10 institutions that offer the graduate programs in industrial engineering in the Philippines. An overview of the PhD program was discussed and briefly analyzed.

Table 4. Institutions that offer Bachelor, Master, and Doctoral in Industrial Engineering.

No	School	BS	MS/ME	PhD IE
1	Cebu Institute of Technology University	BS IE	ME IE	
2	De La Salle University	BS IE	MS IE & ME IE	PhD IE
3	Lyceum of the Philippines University- Batangas	BS IE	MS IE	
4	Mapúa University	BS IE	MS IE & MS EMG & ME IE	
5	Polytechnic University of the Philippines	BS IE	MS IEM	
6	Rizal Technological University	BS IE	MS Engg Education in IE	
7	Saint Louis University	BS IE	ME IE	
8	Technological Institute of the Philippines	BS IE	ME IE	
9	University of San Carlos	BS IE	MS IE & ME IE	
10	University of the Philippines – Diliman	BS IE	MS IE & ME IE	

Out of the 107 schools that are currently offering the BS IE program, only De La Salle University (DLSU) has the doctoral program in Industrial Engineering. At DLSU, the PhD IE program consists of 12 units of specialization courses, 3 units of philosophy course, 3 units of seminar and 12 units of dissertation. As graduation requirements, PhD student is required two paper presentations on his/her PhD research in a local/international conference. In addition, PhD student must published at least two research/technical paper related to his/her approved dissertation topic in a referred national or international journal or one publication in a ISI listed journal.

Potential students to the PhD IE program are the current faculty members of the 107 institutions offering the BS IE program. Assuming each undergraduate program has at least 3 faculty members, then there are at least 300 potential PhD students to the program. Moreover, the graduates of the 10 institutions offering the Masters program could also be potential students of the PhD program. Since Industrial Engineering is concerned with the design, improvement, and installation of integrated systems of men, materials, equipment, and energy (Zandin, 2001), the PhD IE program is also relevant to other engineering fields and could also be potential students of the proposed doctoral program.

3. Results and Discussion

Because of the limited number of schools offering the PhD IE, a new doctoral program would be very beneficial for the advancement of industrial engineering the Philippines.

3.1 New industrial engineering PhD program at Mapúa University

Mapúa's new PhD IE program will be the second program currently offered in the Philippines. It is a research-based which provides students with solid fundamental and theoretical knowledge, as well as substantial research experience for innovative system design and problem-solving in various research areas, including human factors and ergonomics, operations research and its applications, data analysis and modelling, supply chain management, and other relevant industrial engineering topics.

3.2 Program Educational Objectives

The program educational objectives are as follows:

- 1) Find new combinations or innovate existing knowledge to provide solutions to the needs of society in the form of new materials, devices, systems or processes.
- 2) Conduct independent research and investigations to generate new knowledge or innovate existing knowledge.

3.3 Program outcomes

For program outcomes, graduates of the program should have the ability to:

1. Demonstrate a comprehensive broad understanding of industrial engineering principles and apply advanced knowledge on the specific discipline.
2. Analyze, synthesize, create, and evaluate industrial engineering systems.
3. Communicate technical knowledge effectively, both orally and in writing, on complex engineering activities.
4. Contribute to the generation, dissemination, and preservation of engineering knowledge, methodologies, techniques, and processes.
5. Engage in life-long learning.
6. Conduct oneself within professional and ethical standards.

3.4 Curriculum

The PhD in Industrial Engineering curriculum is composed of twelve (12) units of advanced research courses and twenty four units (24) of dissertation courses. For the core courses (IE311, IE312, IE313), a research paper is required which is formatted based on journal type article and can be submitted in a conference where the proceedings is indexed in Scopus. A PhD student must pass the Qualifying Examination before he/she can enrol the Dissertation courses. The coverage of the Qualifying Examination will be the core courses IE311, IE312 and IE313 (Table 5). Table 6 shows description of courses under the PhD program.

Table 5. Courses offered in the doctoral program.

Year/Term	Course Number	Course Name	Units
1 / 1Q	IE398	Seminar on Research & Publication	3
	IE311	Psychological Foundations on HFE	3
1 / 2Q	IE313	Data Analysis and Modelling	3
	IE312	Advanced Topics in Math Modelling	3
1 / 3Q	IE400X	Qualifying Exam	-
1 / 4Q	IE400-1	Dissertation 1	3
2 / 2Q	IE400-2	Dissertation 2	9
3 / 1Q	IE400-3	Dissertation 3	9
3 / 4Q	IE 400-4	Dissertation 4	3

Table 6. Description of courses under the PhD IE program.

Course Number	Course Name	Course Description
IE311	Psychological Foundations and Advanced Topics in Human Factors & Ergonomics (Bridger, 2009; Sanders & McCormick, 1993)	This is an advanced ergonomic course which covers: (1) Human information processing (2) Signal detection theory (3) Usability engineering and product design (4) Applied structural equation modelling in human factors and ergonomics (5) Human error and accident analysis (6) Technology acceptance model and theory of planned behavior (7) Applied Fitt's Law and Hick-Hyman Law (8) GOMS model and keystroke-level model (9) Applied anthropometry, work physiology, and biomechanical analysis (10) Human factors research methodology
IE312	Advanced Topics in Math Modelling	This course will address a number of advanced topics in mathematical programming with particular emphasis on optimization problems with non-linear objective function and/or non-linear constraints. Topics will include duality theory, Lagrangian relaxation, and algorithmic methods for solving non-linear programs. The algorithmic methods covered will include descent methods, Newton's method, conjugate gradient methods, and penalty & barrier methods.
IE313	Data Analysis and Modelling	This course covers the methodologies steps of a prediction exercise, statistical probabilistic modelling, stochastic modelling, artificial intelligence methodologies for prediction of both continuous and discrete variables with applications in manufacturing and service industries. It also covers practical issues in predictive analytics and how to address them.
IE398	Seminar on Research & Publication	This course involves discussions on the expectation of a doctoral research work and format of thesis manuscript and research article as well as workshops on preparation of research articles, review of grammar rules, procedures for paper submission, use of reference management, and use of Turnitin.
IE400X	Qualifying Exam	Qualifying examination on fundamentals of industrial engineering: human factors and ergonomics, mathematical programming, data analysis, and modelling
IE400-1	Dissertation 1	The course requires that the student to choose a dissertation adviser, form members of the examination committee, and presents research plan.

IE400-2	Dissertation 2	The course requires the student to publish, as the first author, his first paper in a SCOPUS-indexed journal. The paper must be connected to the research plan of the student.
IE400-3	Dissertation 3	The course requires the student to publish, as the first author, his second paper in a SCOPUS-indexed journal. The paper must be connected to the research plan of the student.
IE 400-4	Dissertation 4	The course requires that the student submits the dissertation manuscript, presents his/her thesis before the examination committee, revises the manuscript, and submits the final manuscript.

3.5 Faculty

The courses under PhD IE will be taught and facilitated by competent faculty members from the School of Industrial Engineering and Engineering Management (Table 7). Also, visiting professors from our international partner universities will also be invited to teach and facilitate the different courses of the program (Table 8).

Table 7. Proposed full-time professors.

	Faculty	Research Interest
1	Dr. Yogi Tri Prasetyo	Human Factors and Ergonomics
2	Dr. Michael Nayat Young	Operation Research and Financial Engineering
3	Dr. Larry Vea	Data Analytics and Applications

Table 8. Proposed Visiting Professors.

	Faculty	Research Interest	Institution
1	Dr. Ping-Shun Chen	Operation Research, Systems Simulation, Healthcare Modelling, Network Planning	Chung Yuan Christian University, Taiwan
2	Dr. Chao-Lung Yang	Big Data Analytics and Applications, Numerical Computations, Data Mining	National Taiwan University of Science and Technology
3	Dr. Chiu-Hsiang Joe Lin	Human Factors, Occupational Biomechanics, Human-Computer Interaction, Virtual Reality	National Taiwan University of Science and Technology
4	Dr. John Francis T. Diaz	Financial Management, Managerial Economics, Corporate Finance, Business Ethics	Chung Yuan Christian University, Taiwan
5	Dr. Kristine V. Tuliao	Applied Multilevel Modelling, Cross-Cultural Management, Leadership and Communication	National Taiwan University of Science and Technology
6	Dr. Ferani E. Zulfia	Data Mining, Advance Optimization, Vehicle Routing Problem, Deep Learning	Pertamina University, Indonesia

3.6 Graduation requirements:

1. Passing all course works, with GWA of 1.75 or better
2. Passing the doctoral qualifying examinations in Human Factors and Ergonomics, Operation Research, and Data Analysis and Modelling

3. Publication of 2 research papers in SCOPUS-indexed journals. The student must be the first author and the papers are connected to his/her research plan.
4. Successful oral presentation of the dissertation before the examination committee.
5. Submission of final dissertation manuscript.
6. Presentation in a colloquium or conference (for clearance for application for TOR and diploma).

4. Conclusions

Doctoral degree is one of the most well-known, distinct and well-established postgraduate qualifications because of their roots in research and the pursuit of knowledge through original and independent study. However, the Philippines reported the lack of doctoral degree holders in science and technology and engineering which is one of the primary reasons why the country is lagging behind in terms of science and technology development. Industrial Engineering is a branch of engineering which mainly focuses on the design, improvement, and installation of integrated systems of men, materials, equipment, and energy. At present, 107 universities in the Philippines are currently offering the BS IE program but only one university is offering the doctoral program in Industrial Engineering. Thus, Mapua University is proposing a research based doctoral program in Industrial engineering for the advancement of industrial engineering education in the Philippines. The new doctoral program could also contribute to the pool of experts that would lead the industrial engineering-related research and development in the country.

For future studies, tracking of PhD IE graduates could be done to understand both the careers of the program graduates and how programs should be better aligned to support those careers. In addition, factors relating to graduation rates as well as researches done and published in the field of Industrial Engineering could be topics that can be pursued in the future.

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