An Effective Approach for Improving a Program Curriculum at an Undergraduate Level Utilizing the Importance-Performance Analysis Paradigm

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Abstract: ***Higher education institutions have emphasized ever more their position in developing the skills and knowledge of their graduates, the more knowledge and skills individuals have the greater their chances of success. As a result of this major role of higher education system in supporting the nation's development and in developing graduates' attributes, many in academia, industry, and administrations have given a great concern to higher education programs. In higher education, quality enables the nation to achieve sustainable development through providing a high level of learning and accordingly ensures graduates acquiring those competencies which enable them to perform at the required level and compete with their peers. The university's curricula are aiming at preparing graduates for success in the workplace focusing on the specific program competencies required to employ in service, research, and development that serve the society. This study is aiming at improving a program curriculum utilizing importance-performance analysis which is characterized by its ease of measuring the performance of providing competencies to students, recognizing the potentials problematic areas, and facilitating the process of improving the program curriculum.***

Keywords: Higher education, Quality education, engineering curriculum

1. Introduction

1.1 Higher Education

"Education is deemed as the one of the essential human rights for every individual" Nasrin R. Khalili et al. The importance of higher education has been well acknowledged worldwide. Higher education is necessary for the development for every nation leading to better standards of living and helps in building up thoughts and logic thinking [1].Every nation has been attempting to progress and success by encouraging higher education among citizens. Universal organizations such as UNESCO, World Bank, and the Organization for Economic Co-operation and Development (OECD) have been working for emphasizing the importance of higher education [2]. In accordance, higher education institutions play a leading role in putting the foundations for the society to progress and well-being through creating conveying the knowledge, and ensuring the economic development and transformation of the society [3].

In addition, higher education institutions have emphasized ever more their position in developing the skills and knowledge of their graduates, the more knowledge and skills individuals have the greater their chances of success. Yet, the importance of the graduates' attributes has been influenced by three factors: higher education is a lifelong process; the focus on the relationship between higher education institutions and the employment; and the development of outcome measures as a part of the quality drive [4, 5]. As a result of this major role of higher education system in supporting the nation's development and in developing graduates' attributes, many in academia, industry, and administrations have given a great concern to higher education programs.

1.2 Quality in Higher Education

"Quality is a concept; it is a philosophy. It facilitates walking towards excellence. It is a nonstop journey; whatever is the superior quality now, there also is a room for improvement" [6].

Education that is being linked and adapted to the nation' needs is recognized as quality education. In higher education, quality enables the nation to achieve sustainable development through providing a high level of learning and accordingly ensures graduates acquiring those competencies which enable them to perform at the required level and compete with their peers [7]. In the same context, according to the U.S. National Science Foundation (NSF), quality engineering education is the development of intellectual skills and knowledge that will prepare graduates to contribute to society as innovators, decision-makers and leaders in the global economy of this century [8]. For HEIs to survive in today competitive setting, quality is becoming compulsory, not optional.

The term quality has been considered by many scholars since the early of the 1980s, but still less understood. Harvey and Green define quality as "exceptional, perfection, as fitness for purpose, and value for money" [9].Swan, D. defines quality as fitness of purpose where the university should be doing the right things and in the right ways [10]. Dill. aligns quality with academic standards and the specific knowledge, skills, and abilities achieved by students through their involvement in higher education [11].

However, the definition which is still considered applicable to the current context of higher education is the definition given by Harvey and Green. It is the most cited definition of quality in higher education. As in all other areas, higher education has experienced many important changes. Improving quality, ensuring transparency and comparability of education systems, and trying to make these systems more practical and easier to adapt are the key changing aspects [12].

As a result, higher education institutions are facing the pressure of the external quality audit processes. The main approach used by quality processes is the assessment of performance against the institution's objectives. That is, assessing the institution performance in terms of the graduates' attributes [13, 14].

1.3 Engineering Program Curricula

The term curriculum is intended to "refer to the whole process of education for a degree and at other times only to the list of courses included. This list of courses by name generally refers to the content, but may also comprise, for example, the working method or learning objectives" [15]. Yet, engineering programs at various universities are being concerned about the manner by which "employment-ready" graduates are to be produced by their curriculum. They are seeking to narrow the gap between the graduating engineering student and the qualified engineer and thus ensuring a high level of employability [16].

As a result, the university's curricula are aiming at preparing graduates for success in the workplace focusing on the specific program competencies required to employ in service, research, and development that serve the society [17]. However, the engineering curriculum, which has been in place in almost all universities, is based on a solid foundation of science and mathematics needed to understand advanced engineering topics and applications [18]. It has been believed that the undergraduate engineering students should be provided with the fundamental knowledge of mathematics and engineering sciences and design [16]. As such, graduates would be able to employ their knowledge, analysis, and design skills to understand the engineering systems and move ahead of the boundaries of science and technology. In addition, other essential life experiences should be integrated into the curriculum such as laboratory courses, Computer-Aided Design (CAD) tools, an internship program, field trips, a senior design project, teamwork, ethical standards, and communication skills [17]. Moreover, graduating engineering students are facing ever-increasing competitiveness. Manufacturing companies, for example, have included in their strategies the concurrent engineering method with the help of computational tools. Over the last few years, engineering industries have also reduced using of experimentation to a minimum by employing the so-called CAx tools such as Computer Aided Design (CAD)/Computer Aided Manufacturing (CAM)/Computer Aided Engineering (CAE). Currently, industry requires the university graduate who is being able to apply the engineering fundamentals to the everyday problems using appropriate modern CAx tools. Therefore, an engineering graduate student who is not having knowledge and ability these tools will face difficulty after graduating in this highly competitive environment [19]. Furthermore, companies are more tending to value engineering graduates having additional non-technical qualities and technical know-how for the job as well. For this reason, the engineering programs are required to instill in their graduates' leadership qualities, continuous learning, and job development [20]. In the same way, graduates are expected to apply the knowledge of economics, business awareness, and management principles [21].In fact, curriculum development is essential for the success of the engineering programs. Thus, there is a need for a dynamic process for developing a curriculum that deals with the challenges and meets changing industry needs.

Yet, the initiative of developing curriculum is not a new. For the past few years, a vast amount of literature concerning college curriculum has been conducted by educational scholars. Consequently, many studies have proposed methodologies supporting the process of curriculum development in various disciplines. In addition, most of the work regarding curriculum development begins with identifying the desired attributes of the program graduate (OECD 2011). Deciding on the curriculum development and the methodology that might be utilized requires a clear vision and understanding of the program mission, vision, and expectations; the stakeholders' participation; employer's requirements; industrial experience; peer programs at other institutions; lifelong learning development; improving quality; accreditation requirements [22].

In the view of work has been conducted in the area of curriculum improvement, in this article an attempt has been made to utilize an effective approach to make a change for improving the curriculum of undergraduate programs of higher education institutions. This aim can be achieved through the following objectives:

1) Identifying the knowledge, skills, and attitudes an engineering graduate need to possess. To achieve this objective:
   - A set of engineering competencies was developed from existing literature and job advertisements. This set of competencies is then used in the development of a comprehensive survey of graduates, employers, and academics.
   - Identifying the areas on where improvement efforts should be targeted.
2) Determining the satisfaction level of achievement of the identified competencies.

2. Methodology

For the purpose of the study, the department of manufacturing engineering in accredited ABC University was decided on as a case study. For the sake of anonymity, the name of the university was termed using alphabetic figures. Manufacturing engineering program are required consider the current needs and changes of industry and accordingly prepare new engineering graduates to meet the requirements of the competitive manufacturing workplace so that they succeed in their current and future careers.

The courses in the manufacturing engineering program are organized in such a way to build up in students the following knowledge and skills:

- The basic knowledge of MFGE theory
- The skills and knowledge that is relevant to the profession of manufacturing.
- Deep technical knowledge and skills in the field of manufacturing
- Understanding of the integrated manufacturing environment

In this section, the effort is directed toward developing a broad set of the competencies required for preparing graduates in achieving the entry level of the engineering profession. Then, the collection and analysis of quantitative data on how to set the priority of incorporating those competencies into the curriculum are described. Of particular importance, the analysis of the perceptions of the respondents surveyed in this study about the manufacturing engineering program curriculum and where the improvement efforts should be directed. The process for developing the required set of the desired competencies was constructed on reviewing relevant articles in the existing literature. The required set of competencies was then used in developing a comprehensive questionnaire which in turn delivered to the defined respondents –graduates, academics, and employers of graduates.

2.1 Development of the desired competencies from the present data

The developed set of the desired competencies for manufacturing engineering program was obtained from reviewing relevant literature and utilizing the data on O∗NET database. In particular, this set was used for developing a comprehensive survey questionnaire on the manufacturing engineering program curriculum. However, “O∗NET is an online service developed by the US Department of Labor and provides more recent information on occupational work activities”[23]. A list of key competencies in terms of skills, knowledge, and attitudes from twenty-four articles and reports is summarized in Table 1. To this end, the resulting set of the desired competencies for manufacturing engineering (MfgE) is described in the model shown in Figure 1.

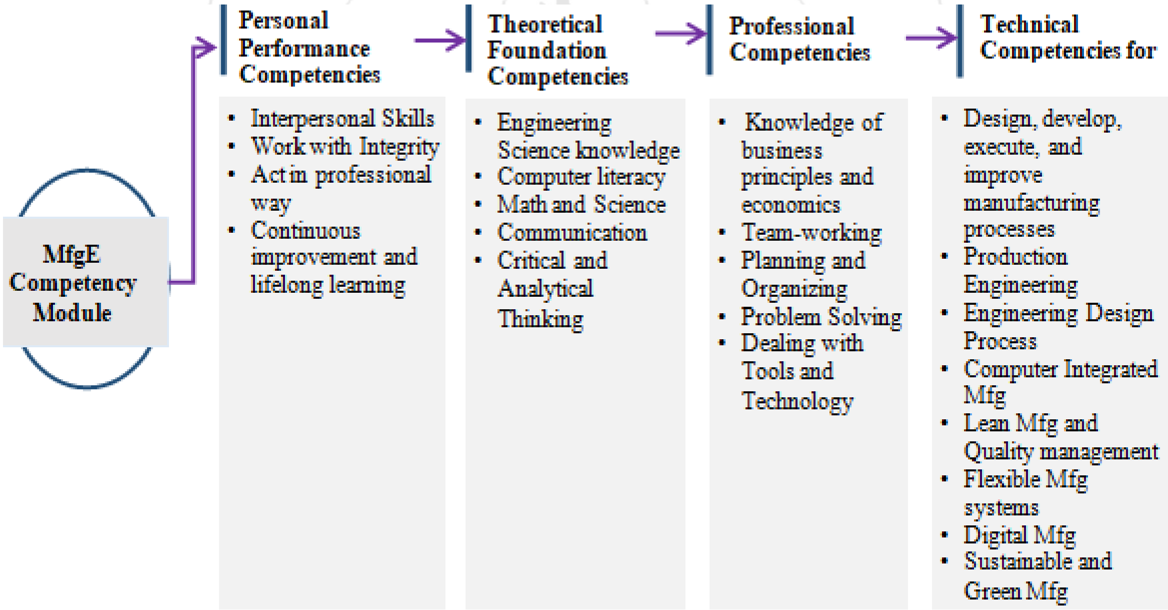

Figure 1: The MfgE competencies’ model

The idea beyond this model is to better understand and summarize the knowledge, skills, and attitudes that are necessary to be taught in order to enhance graduates/students' competitiveness in the workforce. In addition, it provides baseline of broad set of competencies applicable to different engineering disciplines.

Table 1: Reference list of reviewed resources for MFGE competencies

Author	Personal Performance, Theoretical Foundation, and Professional Skills	Technical Skills
B. Lahidji,& T. Tillman, (1997)	Success interface with customer; work with a multicultural workforce; Gather and process data, and formulate accurate concepts; Written and oral communications skills; Ethical and environmental responsibilities.	SME (1997) suggested that the graduates of manufacturing engineering program must be skilled in the following areas: Manufacturing processes; Process and Product engineering; Manufacturing systems design; Manufacturing process measurement; Project management.
Lee, J. Grand (1998)		Product and process modeling for predictability;

		Quality control.
Riley, L.A., et al., (2000)	Perceived communication skills influencing success of recent graduates in the workplace.	
Barbara de la Harpe, et al. (2000)	Writing and presentation skills of technical graduates; Communication; problem-solving; Critical thinking; teamwork.	
J.C. Swearengen, et al. (2002) A. Lizzio et al. (2002) Bob Lahidji, , Jihad Albayyari, (2002)	Automotive Industry Communication; prioritization and time management; creativity; ability to sell ideas. Aero-Space Sector Ability to work in multi-cultural environment; Respect for others; Ability to function on virtual (distributed) teams; Desire to learn, Problem solving; Analytical analysis; Team member; Written communication; Planning own work Communication Skills; Team work; Business Skills; Lifelong Learning	Automotive Industry Manufacturing systems; Information technology; Computer-aided design, simulation; Design for manufacturability (DFM); Tool and die design; Production management. Aero-Space Sector Optimizing production systems at the enterprise level; Effective use of production capabilities and capacities; Effective use of people; effective use of IT. Manufacturing Principles; Project Management; Manufacturing Processes; Quality; Statistics and Probability
Juliedyke Ford, 2003	Oral and written communication skills.	
Dave Hodges and Noel Burchell, (2003)	Teamwork & Cooperation; Organizational awareness; Interpersonal communication; Written communication; Personal planning and organizational skills; Achievement orientation; Problem solving	Computer knowledge; Customer service orientation
Zuleika jamahdin, (2005)	Written communication; identifying and solving problems; working in groups or teamwork; Communication with customers.	Project management; understanding business processes; designing a system, component or process to meet task requirements.
Luis Rabelo, (2006)	Problem solving; Interpersonal skill; Strong analytical ability; Team working	Project management.
Guillermo Reyes& Luis C. Rabelo, (2007)	Team integration,; development under stress conditions; critical analysis and creativity; self-learning; professional ethics.	CIM companies demand a graduate with a profile having: Knowledge of computer assisted technologies (CAx), integration technologies (Flexible Manufacturing Systems, Enterprise Resource Planning, CIM); Abilities with computer software applied in CIM. Manufacturing processes, resources management (human resources, materials, waste, economics,); Manufacturing technologies; Machine tools management and control; Process planning and programming, (MRP, MRP II, 6Sigma); Quality management.
Juan A. Marin-Garcia1, et al,. (2008)	Ability to formulate a problem, to model it and to think up solutions; ability to motivate colleagues and assess their progress; ability to organize information flows.	Marketing and economic concepts.
Nair, C. S., Patil, A. & Mertova (2009)	Interpersonal skills with colleagues and clients; Capacity to analyze and solve problems; Ability to develop new or innovative ideas, directions, opportunities or improvements; Ability to apply knowledge in the workplace and capacity to learn new skills.	
R Pitts & R Camilo ,(2010)	Problem solving and analysis; leadership	Information technology; engineering management. CAD/CAM; CAPP; Design for manufacturing and automation; Group technology; CNC programming; Design and simulate a variety of automation systems using 3D graphics; Model and determine solutions for various manufacturing scenarios.
Elizabeth May & David S. Strong, (2011)	Team design projects; Open ended; problem solving; Interdisciplinary design projects; Teamwork; Design reports (written); communication skills; interpersonal/team work	Engineering design specifications; Design for manufacture; Overall design process; Design for assembly; Project management; Product testing; Tolerancing; CAD Solid modeling.
T. M. EL-Sakran & A.Awad, (2012)	Interpersonal skills with colleagues and clients; Leadership skills; Problem-solving skills; A clear understanding of social responsibility and ethical practices; Time management skills; Ability to work under pressure; Teamwork skills and ability to work in multidisciplinary and multicultural teams; Professional communication skills (presentation skills; writing proposals; writing reports; writing calls for meetings; preparing meeting agendas; minute-taking; documenting decisions; writing formal email messages).	

Sherif El Wakil & Kareem El Wakil, (2014)	Teamwork; Verbal communications; Written communications; Intensive graphical communications skills; Ability to read and prepare drawings as part of the design process' documentation phase; Problem solving	Design for manufacturability;
Ronald S Harichandran, et al., (2014)	Technical Communication Plan, design and produce letters, technical memos, short reports, formal e-mails, reports documenting experimental or simulation methods and results, and formal reports (proposals, analyses, progress reports, senior design documents) Plan, prepare and deliver oral presentations and poster displays.	
J. A. Odukoya, et al. (2016)	Communicative skill; Problem Solving skill.	
Sushant Khare, et al. (2016)	Using MATLAB for solving mathematical (algebraic) computation problems.	Using SolidWorks; Solid Edge to solve designing problems
Brian Glowiak, (2017)	Analytical and problem-solving skills. Having strong background of math and science.	
H. Nejad, (2017) O∗NET -Summary Report for MFGE	Written and oral communication; Teamwork; Problem-solving skills. Being able to Apply eng. science and technology, Knowledge of arithmetic, algebra, geometry, calculus, statistics, and their applications. Problem Solving Critical thinking Communication - Understanding written sentences and paragraphs in work related documents Being able to listen and understand information and ideas presented.	CAD, CATIA, SolidWorks CAM, Computer numerical control CNC software Knowledge of raw materials, production processes, quality control Knowledge of machines and tools Knowledge of design techniques, tools, and principles involved in production of precision technical drawings, and models

2.2 Developing the questionnaire survey for MfgE program curriculum

The developed set of the desired competencies for MfgE program which was obtained earlier provided a basis for preparing a set of questions in the following areas:

- The importance of the desired competencies
- The performance of the MfgE graduates to the set of the desired competencies

The respondents were asked to rate the importance and the corresponding performance for the developed competencies.

2.3 The surveyed groups and sample size

The questionnaire survey was delivered to the three groups of respondents; manufacturing engineering department staff, graduates, and the employers of graduates. Because the study is concerned about the manufacturing engineering program curriculum, all the respondents are involved in manufacturing and mechanical, industrial, and production engineering programs. Among 170 of delivered questionnaires, a total of 116 questionnaires were obtained.

2.4 Analysis of survey data

The statistical analysis was conducted with the SPSS software. The SPSS 23 was used to determine the summary statistics. The SPSS software was employed because it comprises advanced and quite simple statistical analysis tests. The main descriptive statistics that were carried out to describe the results are: the percentage of responses for each point on the rating scale, the mean ratings, and standard deviation values. In addition, 95% confidence level was used.

2.4.1Reliability measures of the scale dimensions

"Reliability measures are required for ensuring that the same results can be consistently reproduced in the subsequent management of the instrument". The so called Cronbach's alpha coefficient is used in estimating the degree of reliability. The estimates of Cronbach's alpha coefficient range from 0 – 1.0. As long as alpha coefficient comes close to 1.0 the scale is deemed highly reliable [24]. The measurement instrument, the questionnaire, used for this study has shown adequate reliability measures; that is, the instrument has worked well in terms of reliability. As depicted in Table 2, the overall measures of reliability using Cronbach's alpha coefficient ranged between 0.737 and 0.925 for the importance and performance scales. Clearly, these measures exceed the normal recommended value of alpha which ranges between 0.65 – 0.80 while establishing internal consistency of the scale.

Table 2: The reliability statistics for importance and performance scales

Scales	Dimensions	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	No. of Items
Importance	Personal Performance Competencies	0.737	0.744	13
	Theoretical Foundation Competencies	0.799	0.802	16
	Professional (Workplace) Competencies	0.821	0.827	15
	Technical Competencies for MfgE	0.885	0.887	21
Performance	Personal Performance Competencies	0.923	0.924	13
	Theoretical Foundation Competencies	0.904	0.907	16
	Professional (Workplace) Competencies	0.906	0.905	15
	Technical Competencies for MfgE	0.925	0.925	21

2.4.2 Importance-performance analysis paradigm (IPA)

The Importance-performance analysis paradigm, developed by Martilla and James, is being deemed as the most applicable approach for measuring the educational service quality. This is because of the derived information achieved by this approach is proven to be very useful. Besides, it has been perceived that the importance-performance analysis paradigm can effectively be applied to higher education. Of the key advantage of this paradigm is that, the attributes can be shown clearly on a two-dimensional grid format which facilitates interpreting of results in a rapid and effective manner. The grid is represented by the importance values on the vertical axis and the performance values on the horizontal axis. Constructing the importance-performance grid requires using the overall importance and performance means [25, 26].

For the purpose of this analysis, the scale items were grouped around the previously identified a set of competencies of personal performance competencies, theoretical foundation competencies, professional competencies, and technical competencies. The survey enabled respondents to rate both importance and performance for each competency of the graduate. Using both ratings allows identifying the following areas:

High importance-high performance area

This area is the indication of the good performance. This is the area where the department of manufacturing engineering has to build on in improving its curriculum.

High importance-low performance area

This is the key area where the department has to concentrate. It is the area where low satisfaction with the department performance. Regarding the corresponding importance rating scores, an extensive amount of effort is needed for improving the curriculum.

2.4.3 Importance-performance ratings on graduates' competencies

Details about the ratings of importance and performance on each competency are displayed in Table 3. The 22 competencies are plotted importance-performance grid shown in Figure 2.

High importance and high performance

In this area, eight items received high importance and high performance ratings as perceived by the respondents in the four groups. These items comprise the graduates' competencies where respondents rated high on importance with mean > 3.83 and high on performance with mean > 3.17 for all the groups.

a) Interpersonal Skills with mean = 3.95 on importance and with mean = 3.48 on performance.
b) Work with Integrity with mean = 4.23 on importance and with mean = 3.45 on performance.
c) Acting in professional way with mean = 3.95 on importance and with mean = 3.35 on performance.
d) Communication (verbal & written) with mean = 4.04 on importance and with mean = 3.24 on performance.
e) Team-working with mean = 3.84 on importance and with mean = 3.47 on performance.
f) Planning and Organizing with mean = 4.00 on importance and with mean = 3.22 on performance.
g) Problem Solving with mean = 4.12 on importance and with mean = 3.28 on performance.
h) Design, develop, execute, and improve manufacturing processes with mean = 4.06 on importance and with mean = 3.27 on performance

High importance and low performance

Four items received high importance rating corresponding to low performance as perceived by respondents. These items are identified as those competencies with mean rating > 3.83 on importance and mean rating < 3.17 on performance.

1) Engineering design process with mean rating = 3.91 on importance and mean rating = 3.04 on performance.
2) Computer Integrated Manufacturing (CIM) with mean = 3.99 on importance and mean = 2.97 on performance.
3) Critical and analytical thinking with mean value on importance = 3.95 and with mean value on performance = 3.05.
4) Lean Manufacturing and Quality management with mean value on importance = 4.00 and with mean value on performance = 3.14.

Table 3: Analysis of importance-performance ratings on graduates' competencies

Importance rating	Item no.	Survey Items	Performance rating	P - I	Significance (two-tailed) p
x̄			x̄		0,000*
3.95	1	Interpersonal Skills	3.48	- 0.48	0,000*
4.23	2	Work with Integrity	3.45	- 0.78	0,000*
3.95	3	Acting in professional way	3.35	- 0.60	0,000*
3.78	4	Continuous Improvement and Lifelong Learning	3.26	- 0.52	0,000*
Personal Performance Competencies					
3.69	5	Engineering Science knowledge	3.43	- 0.26	0,000*
3.66	6	Computer literacy	3.23	- 0.43	0,000*
3.49	7	Math and Science	3.00	- 0.49	0,000*
4.04	8	Communication	3.24	- 0.80	0,000*
3.95	9	Critical and Analytical Thinking	3.05	- 0.90	0,000*
Theoretical Foundation Competencies					
3.58	10	Knowledge of business principles and economics	3.15	- 0.43	0,000*
3.84	11	Team-working	3.47	- 0.37	0,000*
4.00	12	Planning and Organizing	3.22	- 0.78	0,000*
4.12	13	Problem Solving	3.28	- 0.84	0,000*
3.69	14	Dealing with Tools and Technology	3.47	- 0.22	0,000*
Professional (workplace) Competencies					
4.06	15	Design, develop, execute, and improve manufacturing processes	3.27	- 0.79	0,000*
3.71	16	Production Engineering	3.40	- 0.31	0,000*
3.91	17	Engineering Design Process	3.04	- 0.87	0,000*
3.99	18	Computer Integrated Manufacturing	2.97	- 1.02	0,000*
4.00	19	Lean Manufacturing and Quality management	3.14	- 0.86	0,000*
3.47	20	Flexible manufacturing systems	2.63	- 0.84	0,000*
3.46	21	Digital Manufacturing	2.18	- 1.28	0,000*
3.64	22	Sustainable and Green Manufacturing	2.94	- 0.70	0,000*
Technical Competencies for manufacturing engineering					

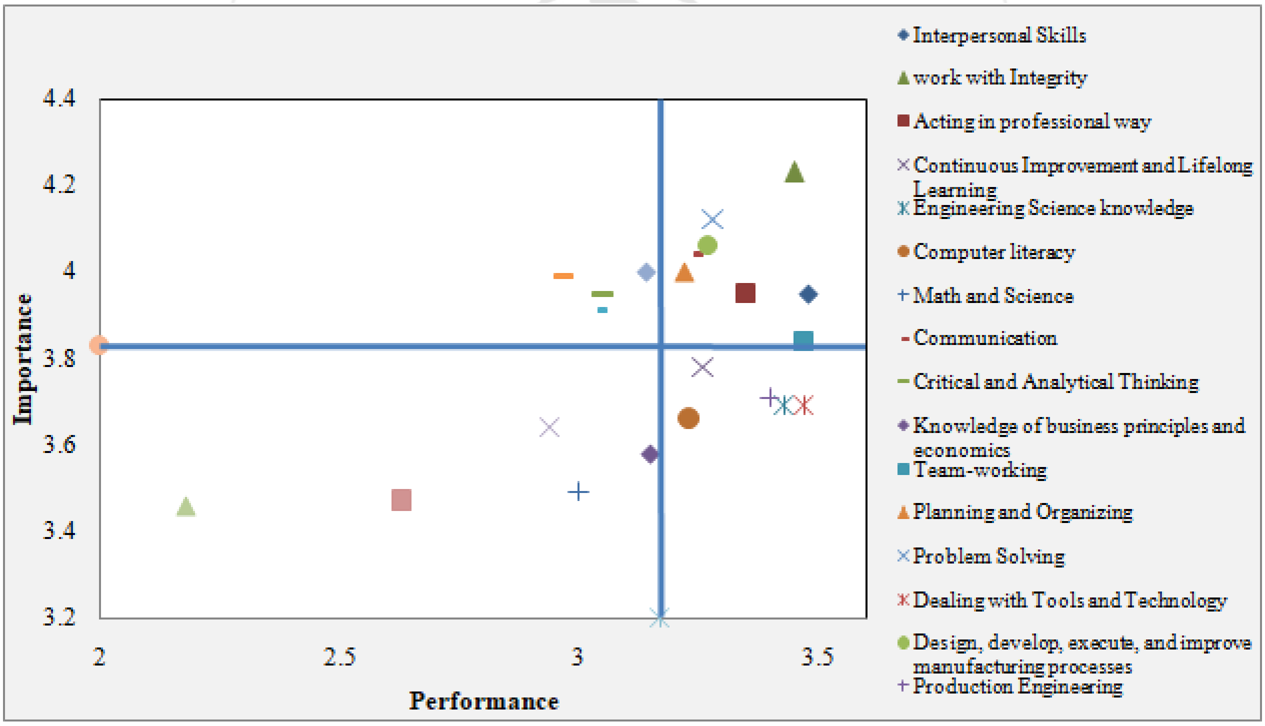

Figure 2: Importance-performance grid

3. Discussion

In this paper, an indication of the importance of the issue of the quality of graduates in higher educational institutions through equipping them with the required level of competence in terms of skills, knowledge, and attitudes has been afforded. In addition, highlights the practical benefits of implementing the importance-performance analysis as an effective approach for the assessment of the various attributes that graduates need for their success at the workplace as well as targeting the improvement. Moreover, implementing this paradigm has added an advantage in simplicity of measuring the performance of providing competencies to students, recognizing the potentials problematic areas, and facilitating the process of improving the program curriculum. Furthermore, for assessing the respondent perception, this paradigm has deemed to be attractive to curricula developers because of its usefulness.

On the other hand, the results obtained from this study indicate that respondents rating scores to various attributes so as improving graduates' quality should directed to those attributes regarded as most important. be different aspects of the administrative support encounter and that quality improvement efforts would be better directed at those attributes that are deemed most important by students. Accordingly, this will provide curricula developers with the required actions for emphasizing graduates' quality.

As a result, for this study, the department of manufacturing engineering has to carry out a great effort for improving those competencies deemed as high important whereas the corresponding performance was below the required level of satisfaction. Among these attributes are: computer-integrated manufacturing; critical and analytical thinking; lean and quality management; engineering design process. Accordingly, the manufacturing engineering department has to incorporate the required topics as well as emphasizing on critical and analytical capabilities of students. In addition, an attention should be paid to those attributes lie in the area of low importance-low performance. However, a qualitative investigation which complements the conducted quantitative analysis might be useful. To this end, the objectives of this are achieved through determining the satisfaction level of achievement of the identified competencies and identifying the areas on where improvement efforts should be targeted.

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