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Evaluating and Improving the Quality of an Engineering Specialization Program through the QFD Methodology*

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This research considers a methodology for quality evaluation and improvement of long-term engineering specialization programs. The methodology proposed is based on an adaptation of QFD applied to education. The proposal is followed by the study of a real implementation case in the Product Management and Engineering Specialization Program, which is part of the Continued Education Centre of the Polytechnic School of the University of São Paulo (PECE-EPUSP). The questionnaire and matrices developed and the results obtained are also shown.

INTRODUCTION

MANY CHALLENGES emerge when attempting to evaluate the quality on an engineering specialization program, or even education as a whole. This occurs for many reasons, amongst them:

- the 'product' (education) will be used by the student for an indeterminate span of time and in the most different situations;
- students' and educational institutions' goals are not usually clearly defined;
- the assessment parameters are often subjective [1] and difficult to quantify [2];
- the results of education are not necessarily immediate;
- students profiles are mostly varied and indeterminate [3];
- quality certifying organisms for the education sector are not common [4].

As can be seen, 'the *product* of education is often intangible and difficult to measure because it is reflected in the transformation of individuals, in their knowledge, in their characteristics, and in their behavior' [5]. Due to these difficulties, many universities have been working on their education quality improvement. However, the processes that are being used are not sufficient and/or not adjusted to the desired results [6].

Since the industrial revolution, different methodologies have been developed in order to facilitate the assessment and control of product quality. Some of them have been widely used. However, most of these methodologies were specifically developed for application in industrial products. Thus, due to the related singularities of the services sector where education is inserted, the traditional methodologies for guaranteeing quality should be adapted prior to their implementation.

This work therefore intends to propose a methodology for evaluating and improving the quality of long-term engineering specialization programs through the adapted implementation of Quality Function Deployment (QFD). The proposal was implemented in the Product Management and Engineering Specialization Program, MBA/USP, which is one of the programs offered by the Continued Education Centre of the Polytechnic School of the University of São Paulo (PECE-EPUSP). The implementation by the authors allowed the identification of strong and weak points as well as operational difficulties for a real use of the proposed methodology.

QFD METHODOLOGY

QFD was first applied in 1966 by Akao [7]. 1972 was an important year for the QFD methodology development because that was the year in which the quality chart was used for the first time, in the Mitsubishi Kobe Shipyard. QFD has been widely taught and experimented so far and in different sectors.

QFD is a technique that can be applied either for the development of products (more usual) or for services. Its main advantage is to allow the customers' needs to be transformed into points, which facilitates comparisons and classifications among these needs. By means of a set of matrices and a deployment process, the customers' requirements are transformed into technical product specifications. By analyzing the points, QFD is also capable of indicating the processes in which efforts should

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be concentrated in order to implement improvements. Its use in different sectors raised many different methodology versions, though none of them escaped the idea of transforming qualitative into quantitative requirements [8].

The QFD matrices offer support to the group in charge of implementation, guiding the work, registering queries, allowing the evaluation and prioritization of requirements and characteristics and, eventually, will be an important source of information for the conduction of the project.

The strength of the QFD methodology is to make explicit the relations between the customers' needs, characteristics of the product, parameters of the productive process and costs; it helps the harmonization and prioritization of the decisions taken during the product development process, as well as team work improvement.

At the beginning of the application, a questionnaire can be elaborated in order to understand the customer's vision regarding the product/service offered. To set the questionnaire, a survey on the customer's needs (demanded qualities) should be carried out. Generally, this survey is accomplished through a carefully prepared quiz with the customers or with people involved in the day-by-day of the institution who have ample contact with the product/service. In the questionnaire, grades to the importance and to the satisfaction of each need should be accredited.

The identified processes derive from the deployment of the quality elements and the customers' needs from the deployment of the required quality [8]. Then, the processes that are directly related to satisfying the customers' needs have to be identified. The relationship matrix, that relates customers' needs (required quality) with processes (quality elements) [9], is the base for conducting the Quality Function Deployment. In this matrix, one relates the processes with the requirements, classifying such relation in three levels: strong correlation, medium correlation or low correlation. Then, with the customers' importance and satisfaction rates and with the relation between the processes and the needs, the following stages are initiated, resulting in a quality chart called 'House of Quality'. The House of Quality is the result of the deployment and graphically transmits the relations the methodology is intended to supply. This means it is through the House of Quality that the quality perceived by the customer is evaluated and the processes to be improved are identified.

The following step of the methodology is to carry out similar deployments in other areas beyond quality, such as the deployment of technology, of costs and of reliability.

THE PROGRAM

The Polytechnic School of the University of São Paulo (EPUSP) was founded in 1893 and currently supports 15 departments of education and research in engineering, distributed in 9 buildings with 141,500 m^2 of constructed area; 495 professors, 404 of whom are Ph.D. The student staff is composed of approximately 4500 undergraduate students, 4000 graduate students and 5000 specialization students in the long-term continued education programs.

The Product Management and Engineering Program was established in 2000 and aims to improve the formation of the higher level professional who is already inserted in the market, in view of the constant need to update. The program is directed to professionals of areas related to the development of new products, new businesses and the control of projects, development of products in all types of private and public organizations, as well as many other sectors or branches of activity. To complete the program, the student must take 14 courses, amongst a set of 26, completing at least 420 class/hours. This set integrates courses on marketing, administration and engineering, such as, among other courses:

- Product Development with Quality and Creativity,
- Voice of the Client,
- Project Management,
- Communication Skills,
- Team Management,
- Investment Analysis,
- Product Ergonomics,
- Information Management for Product Development.

The 30-hour courses are offered in the evening on weekdays, or on Saturday mornings. The student must also elaborate a monography, which will be presented to a board of professors, on the subject of the program.

METHODOLOGY PROPOSAL AND STUDY CASE

The application of the QFD methodology consists of a set of stages. These stages consist of constructing matrices and relating them in order to converge to the information that will lead to the work conclusion. In order to perform a complete and extensive analysis, it is necessary to hold deep knowledge of the product. In the industry, detailing products consists of gathering information on intermediate components, mechanisms, products, raw materials and processes [10].

The methodology phases used in this application were adapted from the procedure used by Costa [11] to evaluate the quality of the services of a bank agency (service sector). They are:

1. Determination of students' requirements.
2. Determination of students' satisfaction rates.
3. Determination of the processes involved in the course.
4. Definition of the correlations between the

requirements and the processes of the institution.
5. Assembly of the relationship matrix.
6. Calculation of the expected performance, current performance and relative performance rates.
7. Calculation of the course impact index.
8. Calculation of the improvement rate.
9. Analysis of processes.
10. Results.

Determination of students' requirements

Each engineering specialization program has a professor from the EPUSP as a coordinator. This is the person responsible for (in the specific program) implementing courses, allocating teachers, responding to students in their didactic queries and so on. Therefore, the coordinator is the person with the most comprehensive knowledge about the program. So, the authors opted to determine the requirements and their importance rates with the program co-ordination.

Another possibility would be to ask the students directly. This was not done, as it would imply an excessive use of class time, since two surveys would be necessary: one for the requirements and their importance, another for the levels of satisfaction. Moreover, there was a great risk of getting distorted opinions regarding the program, because the student who is still attending the courses has great difficulty in providing a complete and realistic view. In order to get a satisfactory result, a questionnaire that has been applied for years in several disciplines was used as an initial base. Thus, using this questionnaire, together with the Product Management and Engineering Program coordinator, the list of needs (requirements) was developed. Using questionnaire development

Table 1. Requirements, importance (1) and satisfaction (2) rates

Infrastructure	(1)	(2)
1. Location and access to PECE	4,2	5,1
2. Safety offered by the location	5,5	4,2
3. Parking easiness	4,7	3,8
4. Thermal comfort of the classrooms	4,7	2,4
5. Acoustics of the classrooms	4,5	5,0
6. Comfort concerning the presence of insects	5,0	3,0
7. Visual comfort (illumination, colors of the walls, etc.) of the classrooms	4,5	3,0
8. Comfort of chairs and desks	4,5	3,9
9. Adequacy of the bathrooms	4,5	2,8
Program Structure		
1. Supply of information regarding the program aims	5,5	4,4
2. Degree of previous knowledge that the students must have to follow the program	4,2	4,2
3. Prerequisite supply of information to follow the program	4,5	4,1
4. Open structure of the program (to be able to choose a course out of a package)	5,2	5,7
5. The extention/duration (14 courses plus monography) of the program	4,5	5,2
6. The number of class hours of each course (30 hours)	4,0	5,1
7. Weekly frequency of lessons for courses (once a week)	4,0	5,5
8. Convenience of the beginning and ending schedules of the lessons (19:20–22:40)	4,0	5,6
9. Degree of depth of the topics approached in the course	4,2	5,7
10. Integration between courses of the program	4,7	4,0
11. Size of the groups (amount of students per room per course)	4,5	3,7
Professors		
1. Mutual respect between professors and students	5,7	5,1
2. Punctuality and assiduity of the professors	5,2	5,4
3. Exploitation on the part of the professors of the lesson time	4,2	4,3
4. Preparation of the lessons by the professors	5,2	4,3
5. Technological resources used by the professors in the disciplines	4,2	4,9
6. Easiness of communication, on the part of the professors	5,2	4,8
7. Accessibility to the professor out of the classroom	3,2	4,5
8. Bibliographical material (revision aid, books, etc) made available	4,2	3,9
Support		
1. Access to information on the courses (hourly, accomplishment cycle, etc.)	5,0	4,8
2. Access to information regarding grades, courses etc.	5,0	4,4
3. Snacks served	4,5	3,9
4. Registration process	4,7	4,2
5. Efficiency of administrative staff	5,5	4,4
6. Efficiency of classroom support employees	4,2	4,7
7. Affection of the Program employees	5,5	4,9
Evaluation		
1. Adequacy of evaluation method in general	4,5	4,6
2. Evaluation criterion demands on what the student needs to know	3,5	4,3
3. Level of evaluations compatible with level of given content	5,0	4,7
4. Strictness of criterion for evaluations	3,7	4,0
5. Stated period for evaluation result delivery is met	4,5	2,9

principles as well as principles related to the grades scale, a final questionnaire was brought together. The questionnaire had several questions distributed in 3 pages, to which a grade between 1 and 6 should be accredited, where the highest grade (6) represents maximum importance or satisfaction. The Professor of Marketing disciplines revised the questionnaire, concerning mostly aspects of question formulation, which was of great value to the efficiency of the process as a whole.

A questionnaire that contained all requirements identified was handed to the coordinators of the Programs of Quality Engineering/Quality Technology and Management, Business and Enterprise Management on Civil Construction, Environmental Technologies and Management, General and Chemical Industries, and the Product Management and Engineering itself. The task was for the coordinators to assign a degree of importance to each item (from grade 1 for no importance up to 6 for maximum relevance). The values presented in Table 1 were obtained by arithmetic mean of the coordinators' answers (degree assignment) for each item.

The requirements and their importance concerning rates are divided into five categories, as shown in Table 1.

Determination of satisfaction levels

Once the questionnaire with the identified requirements was elaborated, it was sent by e-mail to the 35 students who had already attended all courses of the program. E-mail was chosen for its efficiency and easiness. The information is processed quickly and with less trouble for the person who answers. It is important to point out that the decision not to send it to students whose course was still in progress was carefully analyzed. Even though it seems the most logical attitude, it is not the one to yield more benefits. Asking these students would mean creating an expectation (sometimes individual) that not would necessarily be met. When answering the questionnaire, the student expects the accomplishment of the changes suggested. The Continued Education Centre, however, is offered by a complex institution, with limited resources and rules and criteria that are not necessarily under the control of the coordinator of a specific program. Thus, the immediate compliance with the student's suggestions gets very difficult, frustrating expectations. Moreover, it is very important to obtain impartial and global evaluations. However, this cannot be asked to a person who still has not finished the Program, who perhaps is not fully aware of the reasons of its peculiarities. The question regarding satisfaction towards a program in course could provide distorted data.

Of the 35 questionnaires sent, 25 were answered. The answers were compiled and the satisfaction rates were obtained by arithmetic mean, as can be seen in Table 1.

Table 2. Processes

1.	Allocation of rooms
2.	Allocation of the day of the week for disciplines
3.	Purchases for administrative and support staff
4.	Purchases of material for disciplines
5.	Training and motivation of the support and administrative employees
6.	Allocation of professors
7.	Organization of the calendar
8.	External dissemination of the program
9.	Dissemination of information to students
10.	Selection of students
11.	School registration/payments
12.	Preparation of the course by the professor
13.	Administration of the course by the professor
14.	Process of student evaluation
15.	Equipment and premises maintenance

Determination of the processes involved

Through a careful analysis of the processes involved [12] in the Product Management and Engineering Specialization Program, the following list (shown in Table 2) of processes/activities was obtained.

Definition of the correlations between the customer's requirements and the company processes

At this stage, the relationship levels between the qualities demanded and the elements of the quality are determined. Values 0, 1, 3 or 5 (being 0: no correlation; 1: possible correlation; 3: some correlation and 5: strong correlation) were attributed [9]. Some authors use other values for this correlation. Cases were found in which the correlations were determined with 0, 1, 2 and 4; others used 0, 1, 3 and 9 [10]. However, these relation options were not employed because it is understood that the geometric relationship scale distorts the relation between different items and between items and processes. A strong correlation does not mean that the item is three times more related than in the case where it has some correlation. It would be interesting to use these other measures in cases in which the study aims to analyze only the extreme cases, detaching more or less correlated items.

Assembly of the relationship matrix

The relationship matrix is the one whose lines show the customer's needs; the columns show the importance and satisfaction rates and the program processes. The body of the matrix is filled by the relationship rates (see Table 3).

Calculation of the expected performance, current performance and relative performance indexes

At this stage, the importance and satisfaction rates are multiplied by the relationship levels. The values obtained in each column are added. When the importance level is considered, the expected performance index is obtained. The current performance level is obtained when the satisfaction rates are used. The ratio between them is the relative performance. That is to say, with the calculation of the performance levels you can

Table 3. QFD matrix

	Importance	Satisfaction	1. Allocation of room	2. Allocation of the day of the week of courses	3. Purchases for the administrative and support staff	4. Purchases of material for courses	5. Training and motivation of support and administrative employees	6. Allocation of professors	7. Organization of calendar	8. External dissemination of the program	9. Dissemination of information to students	10. Selection of students	11. School registration / payments	12. Preparation of the course by the professor	13. Administration of the course by the professor	14. Students evaluation process	15. Equipment and premises maintenance	Improvement rate (%)
Infrastructure																		
Location and access to PECE	4,3	5,1	1															-17
Safety offered by the location	5,5	4,2	1	1														31
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	
Supply of information regarding the program's aims.	5,5	4,4					3				5	1				1		25
Degree of previous knowledge that the students must have to follow the program	4,3	4,2									5	5		1		3		1
Prerequisite supply of information to follow the program	4,5	4,1									5	5	3					10
Open structure of the program (to be able to choose a course out of a package)	5,3	5,7	3	5				3	3		1							-8
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	
Strictness of evaluation criterion	3,8	4,0						1				3		3	3	5		-6
Stated evaluation result delivery period is met	4,5	2,9					1	3							3	5		55
Expected performance (absolute)			*185*	*120*	*52,5*	*54*	*194*	*317*	*41*	*51*	*153*	*98*	*70*	*186*	*296*	*172*	*135*	
Expected performance (relative) in %			*9*	*6*	*2*	*3*	*9*	*15*	*2*	*2*	*7*	*5*	*3*	*9*	*14*	*8*	*6*	
Current performance (absolute)			*157*	*122*	*42*	*52*	*178*	*322*	*48*	*45*	*139*	*93*	*61*	*187*	*296*	*171*	*112*	
Current performance (relative) in %			*8*	*6*	*2*	*3*	*9*	*16*	*2*	*2*	*7*	*5*	*3*	*9*	*15*	*8*	*6*	
Current/Expected (relative - %)			*85*	*102*	*80*	*95*	*92*	*101*	*116*	*88*	*90*	*95*	*87*	*100*	*100*	*100*	*83*	
Impact on the course			5	9	13	12	3	1	15	14	7	10	11	4	2	6	8	

have the information about what the student would like to get from the institution, what he really gets and what is the relation between these two variables.

Calculation of the index of impact in the program

Once the expected performance index is calculated, the program impact index can be obtained, considering that the higher the expected performance, the higher the processes impact on the program will be. The expected performances of the processes are ordered decreasingly and then classified (the number 1 process is the one with the highest performance level expected).

Calculation of the improvement rate

The difference between the importance and satisfaction indexes, divided by the satisfaction index of a certain requirement represents the improvement rate of this requirement. Through this calculation, one discovers how much a certain satisfaction index should be improved. From the results in these forms it is possible to assess how much the satisfaction index must be modified to attain an ideal condition, in which the satisfaction and the importance indexes are equal. Negative rates represent requirements that are well executed but that have less importance to the student.

Processes analysis

Once the matrix and its results are assembled, the following step consists of analyzing the impact of each process on the customers' satisfaction. From the indexes, it is possible to determine the processes of greater and minor impact on satisfaction (those with better or worse current performance and those with better or worse relative performance).

RESULTS

Interpreting the data related to the importance and to the satisfaction levels, it is possible to conclude, for example, which improvements will be significant to the customers' satisfaction and which processes could be superfluous investments. The QFD Matrix is shown in Table 3.

ANALYSIS OF THE RESULTS

The customers' needs (required quality) can be distributed in quadrants through the analysis of the points as shown in Fig. 1 [11].

In Quadrant I are the requirements that were well evaluated both in importance and in satisfaction. To requirements that have satisfaction levels inferior to importance levels, improvement actions should be defined. These requirements are those marked with (*).

In Quadrant II are those requirements that are well evaluated in satisfaction terms, but are of little importance to the student. Generally they indicate a situation of low return investment. However, they can be requirements associated with services that are important for the quality of the program as a whole.

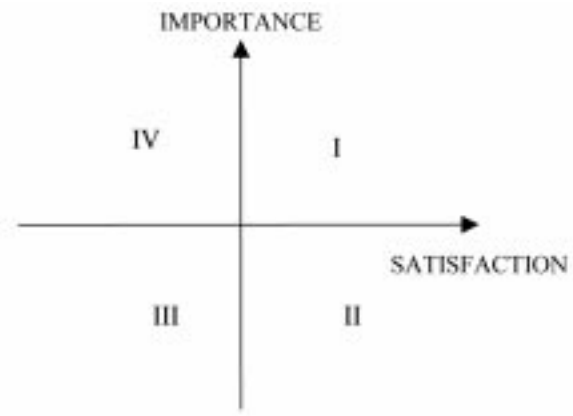

Fig. 1. Presentation of results.

In Quadrant III are the requirements that present low satisfaction and importance rates. Case to case analysis is necessary in order to determine whether investment in improvements is necessary.

In Quadrant IV are the requirements that should be improved as soon as possible. That is: those requirements that have been defined as important to the student, but were less favorably evaluated in satisfaction terms. The weak points of the Program are shown in this quarter.

In relation to the classification criteria, importance indexes between 0 and 4.5 were considered low. Indexes between 4.6 and 6 are seen as high. In the satisfaction levels, values between 0 and 4.0 are considered low, and values between 4.1 and 6 were considered high. Such criteria allow a critical vision of the data, without distractions with nuances of subjectivity. These limits were obtained by adding the lower importance/satisfaction grade with the highest one and dividing the result by two. For example: for the satisfaction level the lowest is 2.4 and the highest 5.6 (see Table 1). That means limit between *low* and *high* satisfaction level is 4.0. A synthesis of the results obtained can be visualized in Table 4. It is important to note that the results are better visualized in the format of Fig. 1. Unfortunately, due to page size, the authors chose to show the results in the form of a table in this paper.

As can be seen, the weak points of the program

Table 4. Requirements associated with the quarters

Quadrant	Needs
I	Safety offered by the location*
	Supply of information regarding the aims of the program*
	Open structure of the program (to be able to choose a course out of a package)
	Mutual respect between professors and students*
	Punctuality and assiduity of professors
	Preparation of lessons by the professor*
	Easiness of communication on the part of the professors*
	Access to information on the courses (hourly, accomplishment cycle, etc.)*
	Access to information regarding grades, courses etc*
	Registration process*
	Efficiency of the administrative staff*
	Affection of the involved program employees*
	Level of the evaluations compatible with level of given content*
II	Location and access to PECE
	Acoustics of the classrooms
	Degree of previous knowledge students must have to follow the program
	Prerequisite supply of information to follow the program
	Extent/duration (14 courses more monography) of the program
	Number of hours per course (30 hours)
	Weekly frequency of lessons per course (once a week)
	Convenience of beginning and ending schedules of lessons (19:20–22:40)
	Degree of depth of the topics approached in the courses
	Exploitation of the lesson time on the part of the professor
	Technological resources used by the professors in the disciplines
	Accessibility to the professor out of the classroom
	Efficiency of the classroom support employees
	Adequacy of evaluation method in general
	Evaluation criterion demands of what the student needs to know
III	Visual comfort (illumination, colors of the walls, etc.) of the classrooms
	Comfort of the chairs and desks
	Adequacy of the bathrooms
	Size of the groups (amount of pupils per room per course)
	Bibliographical material (revision aid, books, etc) made available
	Snacks served
	Strictness of evaluation criterion
	Stated period of evaluation result delivery is fulfilled
IV	Parking easiness
	Thermal comfort of the classrooms
	Comfort concerning the presence of insects
	Integration between courses of the program
	Access to information regarding grades, courses etc

are the requirements presented on Quadrant IV (high level of importance and low level of satisfaction). The items related with comfort in the classrooms were solved through the installation of air conditioners; that allowed the windows to be kept closed by nightfall when insects used to come into the classrooms. The last two were solved through an active operation by the coordinator of the program, organizing regular meetings with the professors to point out what is happening in each course and asking them to provide information about tests, homework, etc. as soon as possible and not after two weeks of the fact itself. In relation to 'parking easiness' it is more difficult to achieve a good solution due to the necessity of infrastructure works.

After this effort was made, the coordinator of the program noted that the satisfaction of the students with respect to these points increased.

The methodology applied yielded sufficiently coherent results. The information obtained confirmed weak points and qualities that had already been subjectively foreseen. Students had complained about items that appeared in the table with low punctuation, and items normally praised appeared with good punctuation. The greatest advantage achieved with the methodology proposed was to obtain the 'quality indexes' (points) for requirements that nobody knew whether they had been satisfied. The other advantage was obtaining a scale of requirements in terms of satisfaction and the corresponding processes that mostly affect their improvements. With this scale, it is easier to define where efforts should be concentrated in order to get quality improvement. With the requirement process relationship, it is also possible to know which processes should be improved in order to increase the satisfaction index of a certain requirement.

A good alternative for results analysis is the periodical application of the QFD methodology. In this way, graphs can be built that demonstrate the performance variation according to the investments. That is the proposal of the Product Management and Engineering Specialization Program coordinator for the next years.

It is important to be aware that the results presented in the QFD matrix are properly evaluated. Items with very approximate satisfaction and importance levels can be treated differently if observed only through the results presented in Table 3. For example: if a certain requirement has importance level 4.5, satisfaction level 4 and another requirement has importance level 4.6 and satisfaction level 4, the first one will be evaluated as pertaining to Quadrant III and second to Quadrant IV. Then, observing only Table 4, these two topics would be dealt with in different ways. However, it is obvious that they need the same type of treatment.

CONCLUSION

This work attempted to develop a methodology for the evaluation and the quality improvement of long-term engineering specialization programs through an adaptation of the QFD methodology applied to education. As main conclusion, it was observed that the QFD is feasible, though laborious. The greatest advantage is the amount and quality of information obtained about the students and the related processes that should be improved to increase the program quality. Many of the difficulties presented in the beginning of the work regarding evaluation of the education quality evaluation were eliminated, or at least attenuated with the application of the methodology proposal. As a complementary result, it must be mentioned that the requirements (customers' needs) and the processes described in the Tables and Figures presented through the case study can be of great value to the coordinators of long-term specialization programs, especially those concerning engineering subjects, to serve as a support to the implementation of their evaluation programs and to the improvement of quality. Many of the requirements and processes can be adapted for a particular case of a specific program. The set of ten activities described in item 2 of this work could be used as a guide for the implementation of the QFD methodology for other engineering specialization programs or even for other higher educational programs.

A matter to be carefully analyzed is the required quality (customers' needs) items classification in quadrants. For coming works, the authors intend to study the viability and coherence of other forms for limits determination like the determination of the limit level through the mean of the importance/satisfaction indices.

As a future research, the authors are working to define and experiment a systematic approach to obtain the processes that affect the quality of an engineering program. Another point that needs more research is the process for obtaining the importance grades of each customers' needs.

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