Exploring rubric use in program outcome assessment: an example with two undergraduate engineering programs.

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Abstract

A current trend in the design of curricula of engineering programs has to do with internationalization. This focus on internationalization implies the need for accreditation of the programs in order to guarantee similar quality levels to recognized engineering programs with high standards in terms of their imparted education. One example is the case of the College of Engineering at Universidad del Norte in Barranquilla, Colombia, which received in 2010 the ABET accreditation for all six of its engineering programs: Civil, Electrical, Electronical, Industrial, Mechanical and Systems Engineering. This accreditation process began more than five years ago with the formulation, design and implementation of a global model based on assessment, which was developed in stages, leading to its current status; however, a new method of standardization for the assessment process is now in development.

This work highlights the importance of formulating and executing assessment processes, not only for accreditation purposes, but also as a mechanism to assure improvement of education, focusing especially on the use of rubrics as a way to measure advances in program outcomes. The use of rubrics in engineering programs, especially in the context of Colombian programs, is not very common and tends to be used in an informal manner. Based on this situation, and the fact that rubrics may help rationalize efforts in the assessment context and may also improve the measuring process, two engineering programs at Universidad del Norte carried out an experimental use of rubrics in order to explore the impact of the rubrics in determining the level of assessment of the program outcomes established in the ABET's EC-2000 document. This paper presents the process for adopting the rubrics, a description of the educational scenario in which the rubrics were applied, the preliminary results, the next step in the implementation of the process and the primary lessons learned; all in order to help other institutions in the adoption of similar tools for evaluating assessment.

Introduction

A central aspect of contemporary education of professionals is related to the development of both generic competencies and specialized competencies that guarantee a proper practice of the profession. Particularly for the engineering profession, the colleges have developed and / or adjusted their curricula, according to international trends in engineering education for the XXI century; it is so that important studies conducted by important agencies and professional academies have raised the profile of education required for the next decades' engineer. It proposes the development of skills for coping with uncertainty, the rapid technological development, the multiculturalism and environmental degradation of the planet, as well as the capacity for lifelong learning and development of scientific and research capacity [1]; on the other hand, universities should develop models of self-sustainability in both financial-administrative aspects and academics; from the approach of the EC 2000, models of self-evaluation and accreditation change towards the formulation, establishment and maintenance of education quality assurance schemes in engineering education[2], and requires rethinking the learning assessment models from theme-specific courses and areas of expertise to the macro level of programs and performance of graduates.

All six engineering programs at the Universidad el Norte (Civil Engineering, Electrical Engineering, Electronics Engineering, Industrial Engineering, Mechanical Engineering and Systems Engineering) have developed over six years a global model of assessment, which allowed to apply and obtain ABET accreditation at the end of 2010, as a result of this process and based on recommendations by the program evaluators of ABET, it was formulated and initiated in 2010 as a pilot, the rubrics based assessment for the program outcomes of two engineering programs: Systems Engineering and Mechanical Engineering.

This paper presents the development of this experience for the two programs; the results obtained a year later, and the proposal for extension of the use of rubrics for the six programs.

Background

In the college of engineering, to ensure quality education of the graduates, a model for measuring and assessing achievement of the competencies defined in the graduate profile has been designed, and is kept under execution. This model is known in the division under the name global assessment process (based on the standard defined by ABET EC 2000), and is comprised of three main loops:

- The inner loop corresponds to the measurement and assessment of learning outcomes for each course. Actions taken in this cycle contribute to the improvement of course content and teaching methodologies.

- The middle loop corresponds to the measurement and evaluation of program outcomes. Actions taken in this cycle contribute to the achievement of competence made for the engineer.
- The outer loop corresponds to the measurement and evaluation of program educational objectives. Actions taken in this cycle will contribute to achieving the goals of engineering program.

The purpose of the middle loop is to identify the aspects that have to be improved and those that need to be potentiated, in order to reach the levels of achievement associated with the program outcomes for each program.

The main input in this loop has been the results obtained in the course assessment reported via the curricular committee report assessment and the FCAR. The tools that have been used for the measurement of PO are:

- Curricular committee report: Report that presents the global results of the course assessment for each program.
- Comprehensive tests I and II: They are administered in two different stages in the curriculum. Comprehensive exam I tests the basic education component in science and mathematics, physics, chemistry and communication courses; the comprehensive exam II includes the professional education of each engineering program.
- ·ECAES (Quality Exam of Higher Education).This exam is required by the Colombian Ministry of Education for all college seniors. The exam is part of a series of instruments through which the national government evaluates the quality of the education service [3].
- Internship student report: These are the evaluations of a student’s performance given by their immediate superiors at the end of his/her internship.
- Fifth year student survey: This survey was designed and applied by the college of engineering and is aimed to senior students (students who have finished their academic courses).
- National Accreditation Report: This report is elaborated by the national evaluators delegated by the Consejo Nacional de Acreditación (National Council of Accreditation), to determine if the program complies with Colombian high quality standards. All the engineering programs currently count with the national accreditation given by the CNA.
  Measuring the student learning outcomes as well as understanding the learning experiences are necessary for the continuous improvement and complying with the requirements of accrediting agencies [4].

As of 2010, taking into account recommendations of the program evaluators of ABET, and, for a more objective and accurate measurement of PO, it was established to conduct a pilot experience with the mechanical engineering and systems engineering programs, which consisted on the application of rubrics as PO evaluation tool of the of these programs.

The rubrics allow assessing based on the descriptions of the performances to be achieved by a student in a learning process [Designing scoring rubrics for your Classroom]; they allow the identification of the performance dimensions that are being evaluated and being taught and what is expected of them [5].

The performance criteria of the rubrics used corresponds to the type that represents the broader learning objectives, rather than specifics to a particular task, which facilitates the universal application of these rubrics [6] [7], as the situation required. Although the used rubrics are generic, they have the advantage that they can also be applied to specific tasks and scopes required in different situations. [8]

An important aspect of the rubrics used was that of measuring the performance levels on a continuum which allows differentiating between levels and formulating improvements for each level. [8]

Since the objective was to measure the achievement of program outcomes to establish the improvement cycles and provide formative feedback, it was decided to use analytic scoring rubrics [6]; in contrast to the holistic rubrics, these allow specifying the score achieved in accordance with individual categories or criteria that are associated with learning outcomes [9]; these rubrics do not remove the holistic factor, because a holistic view can be associated with a category structured within the rubric. [5]

Analytical rubrics with a five-level scale were used to evaluate each program outcome, for which a rating was assigned from different courses in the curriculum of each program, which required developing mechanisms for planning and implementation of rubrics that reduced variability in measurement. [5] [8]

Methodology

The assessment of programs outcomes through rubrics was launched in 2010, for systems and mechanical engineering programs.
The mission, vision, program educational objectives for each program can be accessed at the website of the Universidad del Norte [10]; some important aspects are highlighted below:

“The Systems and Computing Engineering Program at the Universidad del Norte in Barranquilla (Colombia), has as its mission to educate comprehensively a Systems Engineer with an emphasis on Computer Science; to teach the areas of knowledge related to this science in its basic and applied levels, and contribute through its presence in the community to the development of Computer Science.

The program fulfills the university mission in the undergraduate modality, being characterized by providing the future Systems Engineer with a broad social and humanistic content. In this sense, the program seeks to educate a Systems Engineer to be critical, analytical, creative, intellectually and morally autonomous, with cultural identity, capable of producing knowledge, solve problems, make decisions, communicate effectively and build values. With all this, it is intended to promote the human development of the person, in such a way as to continue his/her education at the master's and doctorate levels, or join the labor market of Systems Engineering or Computer Science" [11]

"The Mechanical Engineering Program educates its graduates to excel in the engineering profession by applying scientific and technological knowledge in the solution of mechanical and thermal system design and operational problems using engineering criteria and modern technological tools. Our graduates will display the institutional values of leadership, teamwork, critical thinking, and commitment with the solution of societal problems. Through its graduates and faculty, the Mechanical Engineering Program contributes to the recognition and advancement of the Mechanical Engineering profession." [12]

In accordance with the recommendations of the program evaluators of ABET, each program defined a cycle for the annual evaluation of the program outcomes, generally comprising the steps of planning and design, evaluation, results analysis and generation of actions proposed for improvement , as shown in the figure below. [13]

Each program formulated a relationship table between courses and PO's, and these tables have been reformulated in accordance with recommendations of the program evaluators, after the accreditation visit.

Every program used different criteria to link the program outcomes with the courses. Mechanical engineering program considered that each course should not commit to the assessment of many program outcomes, and each program outcome has to be evaluated along the study plan by a relevant number of courses, chosen from those with strong correlation. Systems engineering program decided to link courses with the PO's so that no more than three program outcomes per course except for a course named Capstone Design and no less than three courses by each program outcome.

According to curricula of Systems Engineering and Mechanical Engineering, these are the reformulated relationship tables for some courses and the POs [14][13]. See Table 1 and Table 2.

Table 1: Courses vs POs, Systems Engineering

Systems Engineering	Program Outcome										
Course Name	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**
Introd. to Systems Engineering						X	X			X	
Algorithmics and Programming I											
Algorithmics and Programming II											
Data Structures I			X								
Object Oriented Programming											X
Data Structures II			X								
Digital Design		X			X						
Discrete Structures	X										
Algorithms and Complexity	X				X						
….			…						…		…
…				…				…			
…						….					….

Table 2: Courses vs PO, Mechanical Engineering

Mechanical Engineering	Program Outcome										
Course Name	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**
Introd. to Mechanical Engineering						X	X				
Material science	X									X	
Thermodynamic I	X				X	X					
Dynamics	X				X						
Solid Mechanic	X								X		
Fluid Mechanics	X	X									
Thermodynamics II	X							X			X
Manufacturing processes				X			X				
Mechanics of Machinery									X		X
….			…						…		…
…				…				…			
…						….					….

After that, the faculty adapted the rubrics for the outcome assessment process, previous process of review and analysis of rubrics that are being implemented by various American engineering programs. For each program outcome is defined a target level, which serves as a reference for comparing the performance of students with the expected level in the relevant PO. Faculty defined a coordinator per program outcome, who is in charge of the collection of assessment results and evidences in the chosen courses, so at the end of the semester he/she is able to prepare a report to evaluate the attainment of the program outcome.

Rubrics designed for both programs follow the model presented in Table 3.

Table 3: Program Outcome b

Program Outcome b: The ability to design and conduct experiments, as well as to analyze and interpret data				
Criteria /Level	**Lowest level**	**…**	**…**	**Highest level**
Criteria #1	Student performance respect to criteria #1 to get the calification of lowest level	…	…	Student performance respect to criteria #1 to get the calification of highest level
Criteria #2	Student performance respect to criteria #2 to get the calification of lowest level	…	….	Student performance respect to criteria #2 to get the calification of highest level
⋮	⋮	⋮	⋮	⋮
Criteria #n	Student performance respect to criteria #n to get the calification of lowest level	…	….	Student performance respect to criteria #n to get the calification of highest level

The rubrics consist of criteria or dimensions that are to be assessed for a total score for each program outcome; each criterion has defined in a continuum the performance criteria, which are to be evaluated in the students through tasks specifically designed to measure the different levels that make up the continuum.

Each rubric performance level is assigned a numerical scale, so that the level achieved by students in the various evaluation factors can be established. To obtain the total score of each rubric's criteria, the grades of students who belong to the course where they were applied are averaged. The overall score of the PO that has been evaluated by the complete rubric is calculated by averaging the scores of the criteria that comprise it. Generally, each course related to a PO evaluates only one or some of the assessment criteria for the relevant rubric. When two or more courses evaluate the same criteria of the rubric, the grade of this is calculated by averaging the values obtained in the different courses.

Based on the rubrics that were established, every PO is assessed in the selected courses using outcome-specific assignments or tasks. The rubrics allow the assessment of individual or group achievements and later develop statistics to infer the degree of attainment of the whole class. Annually, each department analyzes the POs evaluation results and the level of accomplishment, based on which, actions are designed and chosen in order to improve the achievement level.

Preliminary results

At the end of each cycle, the assessment of each course is made, taking into account the criteria of the rubric to which the corresponding course contributes. Professors assess the performance of the entire group of students belonging to the course. They set the rubric level achieved by each of the students or subgroups of students in activities designed for the evaluation. Then the total course score is obtained in the rubric that is being evaluated by calculating the average of all students or student groups. Sometimes, several courses aimed at assessing the same criteria; in this case, the final score of the criteria is the average value obtained for each of the courses that assess the aforementioned.

An example of a PO evaluation [13] is illustrated in Table 4.

Table 4: Example of a PO evaluation

UNIVERSIDAD DEL NORTE
EVIDENCES PROGRAM OUTCOME k:
An ability to use the techniques, skills and modern engineering tools necessary for engineering practice.

FINAL ASSIGNMENT: MECHANICS OF MACHINERY AND MECHANICAL DESIGN
MECHANISM COMPACTOR OF PLASTIC BOTTLES
PROFESSORS: J.A. Pacheco, A.A. Pacheco

ASSESSMENT ITEMS
A: Detailed plans specifying the total size of the mechanism using at least two views and an isometric.
B: A detailed analysis of the kinetics and kinematics of the mechanism with graphs showing the variation of the input and output forces and the state of charge in the most critical components.
C: Charts showing the distribution of stresses on the critical elements in a preliminary design and final design configurations critical of the mechanism.
D: Charts showing the variation of the efforts in time for the critical points of the selected items in subsection C that were used in fatigue design of components.

ASSESSMENT TABLE ACCORDING RUBRIC

ITEM	GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5	GROUP 6	GROUP 7	AVERAGE ITEM	RUBRIC
A	3	4	4	3	4	4	2	3,4	ACCEPTABLE
B	3	3	4	3	4	2	4	3,3	ACCEPTABLE
C	3	3	4	3	2	2	4	3,0	ACCEPTABLE
D	2	2	4	2	2	4	2	2,6	LIMITED
GROUP AVERAGE	2,8	3,0	4,0	2,8	3,0	3,0	3,0		
RUBRIC	LIMITED	ACCEPTABLE	GOOD	LIMITED	ACCEPTABLE	ACCEPTABLE	ACCEPTABLE		

FINAL AVERAGE	3,1
RUBRIC AVERAGE	ACCEPTABLE

For reporting each of the courses, professors include evidences of activities performed, taking representative examples of high, and middle and low students' performances in the tasks evaluated.

After obtaining the total score of the criteria or criterias of each course, the overall score of the rubric is calculated, i.e., of each program outcome. This is calculated by averaging the results of the criterias that make up the rubric. Finally, a report for each program outcome is written, to establish the global rating and all aspects that led to obtaining this. Excerpts are presented as an illustration of a global report of a PO [13]. See Table 5.

Table 5: Global report of a PO

1. BACKGROUND INFORMATION

PO Identifier:	*k*
PO Description:	*An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice*
Target:	*Good*
Accomplishment:	*Acceptable*
PO Coordinator:	*A. A. Pacheco*
Evaluation tasks:	*Activities designed to assess the PO*
Courses linked to the PO:	*Mechanics of Machinery - 5 (Professor 1), Thermodinamic II - 5 (Profesor 2), - 6 (Profesor 3), Dynamic Systems Modeling - 7 (Profesor 4)*

2. RUBRIC

	1: poor	2: limited	3: acceptable	4: good	5: excellent
An engineer must demonstrate skill in applying techniques and tools in the following areas:	Student performance respect to criteria to get the calification of poor	Student performance respect to criteria to get the calification of limited	Student performance respect to criteria to get the calification of acceptable	Student performance respect to criteria to get the calification of good	Student performance respect to criteria to get the calification of excellent

3. PO ASSESSMENT RESULTS

COURSE	ACTIVITY	SCORE/ RUBRIC
Thermodinamic II	Talleres HYSIS	3,7/good
Mecanics of Machinery - Mechanical Design	Proyecto final	3,1/ acceptable
Dynamic Systems Modeling	Talleres	3,0/ acceptable
	Global	3,3/ acceptable

Average	**3,3**	
Target Score	**3,5**	**Acceptable**

OVERALL ASSESSMENT ANALYSIS	
Assessment:	Students recognize the importance of the use of computational tools in the systems analysis, they show ability to use high level simulation programs, but is evident the lack in the use of CAE tools.
Evaluation:	target value (70%) is just attained. Students have to gain experience in the synthesis of mechanisms and take advantage of modern computational tools available for systems analysis.
Actions to improve:	Reinforce the abilities in the use of basic software of mechanical drawing in the early courses; apply programming activities using mathematic softwares in intermediate courses; implement the use of professional software in the solution of engineering problems in the later courses.

Then, a joint review of the results of all the PO's is made, and all the expected values (target) against the reached values (result) are compared [15]. The department generates improvement strategies that are adapted immediately to the next evaluation cycle. Here is a review of some PO's, the expected value, the results and improvement actions to follow. See Table 6.

Table 6: Results and action to improve

PO	Target	Result	Actions to improve
Poa	**3,5**	**3,7**	In all courses the program should be continued emphasis on the use of models andjustification of the considerations used to solve it.
. . .	. . .	. . .	. . .
Pod	**3,5**	**3,8**	Continue with the strategy of the subjects included in case studies to train students in the identification, formulation of problems.
Pog	**3,5**	**3,5**	Continue with the existing methodology and to include subjects methodologies for the development and sustaining engineering reports. Type will be defined templates forstudents to apply them in projects and course work.

Finally, the department performs an analysis of the obtained results in previous periods to determine the behavior and effectiveness of improvement actions that were implemented for the corresponding evaluation cycle [15], as shown in the table 7.

Table 7: Comparison 2009 vs 2010

	2009 - 1			2010 - 1		
PO	**Target**	**Result**	**Actions to improve**	**Target**	**Result**	**Actions to improve**
Poa	**3,5**	**3,2**	The ability of students to take considerations and formulate restrictions need to be strengthened. All courses emphasize the justification for the considerations used insolving mathematical models.	**3,5**	**3,7**	In all courses the program should be continued emphasis on the use of models andjustification of the considerations used to solve it.
⋮	⋮	⋮	⋮	⋮	⋮	⋮
Pod	**3,5**	**3,7**	In order for students learn to identify engineering problems, including the method ofcase studies in some courses.	**3,5**	**3,8**	Continue with the strategy of the subjects included in case studies to train students in the identification, formulation of problems.
Pog	**3,5**	**3,4**	Because of its importance, this PO will be assessed in other courses through the program, unifying the evaluation criteria.	**3,5**	**3,5**	Continue with the existing methodology and to include subjects methodologies for the development and sustaining engineering reports. Type will be defined templates forstudents to apply them in projects and course work.

Future work

After reviewing the results of cycles in the years 2009 and 2010, the mechanical engineering program decided for year 2011, to modify part of the methodology used in previous periods [15]. It was decided to evaluate only a set of POs per semester, so that in the annual cycle the POs are evaluated once and further analysis of the results can be pursued, to propose more effective strategies for improvement. See Table 8. The systems engineering program has decided to continue working with the evaluation of all the OPs in each academic semester.

Table 8: Cycle of PO's evaluation

Program Outcome	**POa**	**POb**	**POc**	**POd**	**POe**	**POf**	**POg**	**POh**	**POi**	**POj**	**POk**
Coordinator PO	Prof 1	Prof 2	Prof 3	Prof 4	Prof 5	Prof 6	Prof 7	Prof 8	Prof 9	Prof 10	Prof 11
2011-1	X			X	X		X		X		X
2011-2		X	X			X		X		X	

Regarding the assessment by rubrics, both programs believe that this way of evaluating the PO is more accurate and less complex, but requires further review of the rubrics to improve them and develop new strategies for the collaborative work that the faculty does in the whole process of implementation of rubrics. The results obtained with the use of rubrics has helped identify more precisely specific aspects that need improvement in the of training process of students; in 2011 the remaining engineering college programs will begin the process of evaluating their PO's by using rubrics, which will allow working in the standardization process of this methodology.

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