ABET accreditation of the Mining Engineering program of the PUCP: Challenges and Opportunities

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***Abstract*– Accreditation is a complex process that must be approached taking many factors into consideration. As part of an engineering program with a global vision, it was necessary to implement an ABET accreditation process. For this, it was necessary to join efforts and commitments of professors, students and industry professionals as main actors. At the end of a four-year period the accreditation and continuous improvement program was implemented.**

Keywords-Assessment, ABET, continuous improvement, mining engineering, students' outcomes,

I. Introduction

Accreditation is an important aspect that an educational institution should realize. In fact, the accreditation of an academic program allows, among other things, to implement a culture of continuous improvement. Also, it ensures that the graduates of the program have met the educational level of skills and competencies necessary to have an adequate profession [1]. Likewise, it provides opportunities for the industry, where the graduate will be inserted, to guide the educational process to reflect current and future needs (Figure 1). Also, it promotes the national and international mobility of professionals [2]. In this sense, ABET (Engineering and Technology Accreditation Board) is one of the most widely used accreditation bodies to assess whether an engineering program meets the minimum educational quality standards [3-8].

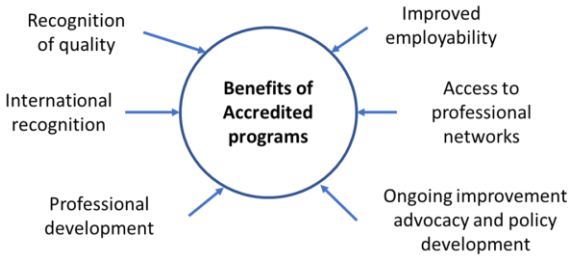

Fig. 1 Benefits of the accredited academic program..

All accreditation process must be adequately planned. The hardest part of planning is deciding what to measure and for what [9]. In this case, it is necessary to define the students' outcomes, prepare matrices with indicators and data collection tools [10-12]. Likewise, professors or teaching assistants must be adequately trained to optimize the measurement process [13]. An adequate structure will allow obtaining results that lead to decision-making in the preparation of a continuous improvement plan [14,15].

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II. Methodology

❖ Present situation and historical background of mining engineering program in Peru

Since the 1990s in Latin America, there has been a growing interest in the implementation of a quality accreditation system for higher education programs [16-19]. Globalization has contributed to making comparisons with similar programs in Universities in the United States of America [20,21] and Europe [22]. It has been shown that there is a similarity in the stages of the educational accreditation models: self-evaluation, peer evaluation and final evaluation by the corresponding body.

In Peru, university higher education is taught in public and private institutions. Peru currently has 86 universities (37 public and 51 private). Of all of them, 36 are concentrated in Lima (15 public and 21 private). There are 23 mining engineering schools (21 public and 2 private), which means close to 600 graduates per year. Until 2015, no mining engineering program was accredited. Therefore, it was necessary to start with the process in our institution so that it can later be replicated by the other mining schools.

❖ Methodology

The accreditation process of the mining engineering program was carried out following several planning stages:

First year

- The program director appoints the Program Accreditation Committee (PAC)
- The External Accreditation Committee (EAC) is appointed, made up mainly of professionals from the mining industry and the public sector related to mining. The EAC establishes the Educational Objectives (EO) (Table 1).
- Review of the curricula of the mining engineering program [23].
- The Student Outcomes (SO) are proposed, reviewed and validated based on the ABET model [24,25] (Table 2).
- The rubrics are designed based on the SO and the performance indicators are also proposed [26] (Table 3).
- The first courses to be evaluated are chosen by the PAC (Table 4)
- The first evaluations begin [27].

TABLE I
EDUCATIONAL OBJECTIVES (EO) OF GRADUATES

EO	Description
EO1	**Technical and Analytical Capacity:** The graduate applies knowledges and abilities in the analysis and resolution of the mining industry problems, integrating his analytical thinking and his conceptual reasoning.
EO2	**Management and Leadership Capacity:** He works with teams, is cooperative and/or multidisciplinary in various cultural environments, showing his leadership and effective communication capacities, being responsible for making decisions and showing openness towards different points of view
EO3	**Self-learning and Continuous Improvement Capacity in the Professional Development:** Shows a continuous professional growth through specialization or post-graduate studies that allow him to reach new competences and to enrich his performance in the mining industry.
EO3	**Reflective Capacity and Ethical Commitment:** He knows the impact that mining engineering activities have on the society and the environment, showing social and ethical responsibility while exercising his profession, achieving a sustainable development through time.

TABLE II
DESCRIPTION OF THE STUDENTS' OUTCOMES.

SO	Description
A	The students apply their knowledge of mathematics, science and engineering to the analysis and designs related to mining engineering.
B	The students design and perform field researches and experiments, and they also analyze and interpret data.
C	The students design components, processes or systems that satisfy specific needs of the mining engineering field, taking into account economic, technical, environmental, social, political, ethical, work health and safety, and sustainability considerations.
D	The students work effectively with multidisciplinary teams.
E	The students identify, propose and resolve problems pertaining to mining engineering.
F	The students understand their professional and ethical responsibility, as well as the impact the mining activities have on people's health and safety, the environment and society.
G	The student effectively and clearly communicates information through oral presentations and written technical reports.
H	The students understand the impact of the solutions that mining engineering provides to the global, economic, environmental and social context.
I	The students acknowledge the need of and commit to learning throughout their lives, permanently reaching for excellence.
J	The students know about contemporary issues related to mining engineering and/or that influence the mining industry.
K	The students use techniques, tools, software and modern engineering equipment necessary to practice mining engineering.

TABLE III
DISTRIBUTION OF STUDENTS OUTCOMES ACCORDING TO THE YEAR OF STUDY OF THE CURRICULA.

Year in the curricula	A	E	C	G	F	J	H	D	B	I	J	K
1	8	---	---	3	---	---	---	4	---	---	1	---
2	10	---	1	---	---	1	3	---	---	1	1	---
3	3	1	2	3	---	---	---	4	---	---	3	2
4	5	6	3	5	1	3	3	2	3	4	8	7
5	8	7	5	7	6	7	5	4	7	1	8	7
Total of SO	**34**	**14**	**11**	**18**	**7**	**11**	**11**	**14**	**10**	**6**	**21**	**16**

TABLE IV
COURSES SELECTED FOR THE EVALUATION OF CRITERIA

Name of the course	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)
Rock Mechanics	X										
Auxiliary Services	X		X		X						
Mining Valuation	X							X		X	
Underground Mining	X										
Mine Ventilation	X										
Thesis Work 1		X			X		X				
Mineral Processing		X			X		X				X
Mining and Environmental		X				X	X	X		X	
Underground Mining		X			X						
Modelling and Mine Planning			X								X
Surface Mining			X		X						X
Heavy Equipment Maintenance Management				X							X
Mining Safety and Risk Management						X					
Thesis Work 2							X				
First Supervised Pre-Professional Internship									X		
Second Supervised Pre-Professional Internship									X		

Second year:

- The Student Objectives (SO) are proposed and validated by the external accreditation committee.
- The mentoring process is implemented
- Meetings are held with the EAC in order to receive a vision of the professional required by the industry.
- Meetings are held with the PAC
- Information and feedback meetings are held with students.
- Continue with the evaluations and collection of evidence from the SOs [28,29]. The preliminary results were obtained.
- The writing of the self-study begins
- Meetings are held with the administrative staff of the mining engineering section, mainly with the staff that provide support to academic activities.

Third year:

- The tutoring process continues
- The evaluations and collection of evidence from the SOs continue.
- Meetings are held with alumni to receive feedback.
- Meetings are held with teaching assistants.
- The performance indicators of some courses are reviewed.
- Meetings are held with the EAC and PAC continues
- The self-study is presented in both versions (English/Spanish). The document includes information on all the factors needed to carry out an accreditation process (Figure 2).
- Activities for continuous improvement are identified and developed (Workshops with students, refresher courses for professors and teaching assistants, skills development

workshops for professors, visiting professors, among others). (Figure 3)

- ABET accrediting missions are received
- Meetings are held with the administrative staff of the mining engineering section.
- Meetings are held with students

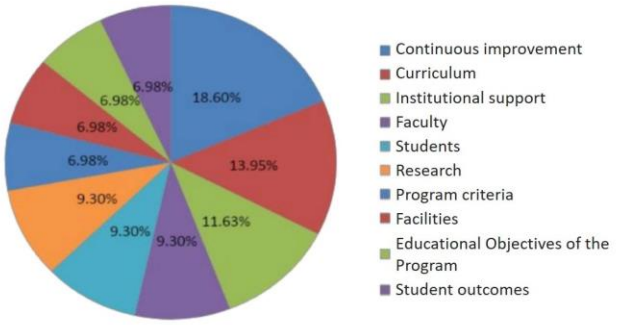

Fig. 2 Factors that contribute to the accreditation process.

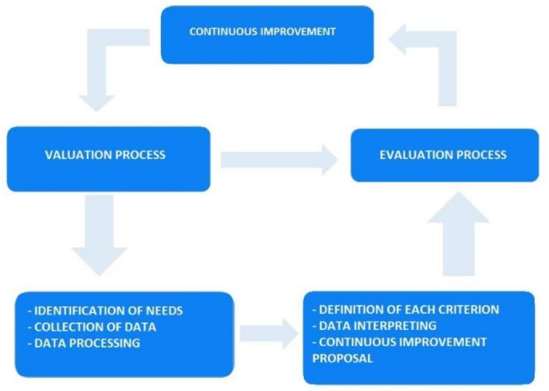

Fig. 3 Continuous improvement documentation process

Four year:

- The ABET accreditation certificate is officially received
- It begins with the process of continuous improvement

III. Results

Assessing student outcomes from the program is not an easy task. It's a Continuous process that can become tedious if an adequate methodology has not been implemented. It is necessary to integrate various actors to ensure the quality of the program [30]. During the student outcomes measurement process, various assessment instruments were used: specific test question, laboratory presentations, partial and final project reports, reports, peer assessment, test portfolio, surveys and questionnaires, and oral. presentations (recording).

A Results Matrix was prepared for each criterion in order to analyze the information collected in the different rubrics. This allowed a better follow-up of the selected and evaluated courses. Each matrix has information about the criterion to assess (a-k); the sub-criteria, achievement level, selected course, name of the professor, type of evidence and date. 70% has been defined as the minimum level of performance expected from the students. This value is calculated taking into account the sum of the results obtained in levels 3 and 4 of each criterion. The detail of the Students Outcomes obtained for criterion A is shown in Table V.

TABLE V
CRITERION AN ASSESSMENT RESULTS FOR THREE CONSECUTIVE SEMESTERS.

Criterion		Level 3 and 4:			Course where the assessment was performed:
		Semester 1	Semester 2	Semester 3	
a.1	Applies physical, mechanical and geological sciences.	80,00%	37,5%	84,26%	Rock Mechanics / Auxiliary Services
a.2	Applies mathematics and economic sciences.	57,89%	60,73%	66,64%	Mining Valuation / Auxiliary Services
a.3	Applies technical concepts of mining engineering.	64,58%	90,28%	93,98%	Auxiliary Services / Underground Mining
b.1	Supports a scientific research design.	94,74%	80%	19,12%	Mineral Processing / Thesis Work 1
b.2	Identifies and relates variables of an experiment.	92,30%	86,67%	32,61%	Mineral Processing / Thesis Work 2
b.3	Executes the data processing and analysis.	66,66%	51,0%	74,78%	Mining and Environmental / Underground Mining
c.1	Applies content and methodologies in a design and/or plan.	45,83%	67,23%	67,9%	Surface Mining / Modeling and Mine Planning / Auxiliary Services
c.2	Relates and integrates the components of a Mine Plan.	41,18%	51,85%	57,41%	Modeling and Mine Planning / Auxiliary Services
c.3	Prepares a design and/or Mine Plan that satisfies the needs.	41,18%	75,92%	67,33%	Surface Mining / Modeling and Mine Planning / Auxiliary Services
d.1	Works with others.	80%	89,48%	25%	Heavy Equipment Maintenance Management
d.2	Shows openness to his/her classmates.	90,48%	63,17%	42,88%	
d.3	Prepares quality work.	-------	68,42%	52,17%	
a.1	Applies physical, mechanical and geological sciences.	80,00%	37,5%	84,26%	Rock Mechanics / Auxiliary Services
a.2	Applies mathematics and economic sciences.	57,89%	60,73%	66,64%	Mining Valuation / Auxiliary Services
a.3	Applies technical concepts of mining engineering.	64,58%	90,28%	93,98%	Auxiliary Services / Underground Mining
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d.2	Shows openness to his/her classmates.	90,48%	63,17%	42,88%	
d.3	Prepares quality work.	-------	68,42%	52,17%	
e.1	Prepares the approach to a problem.	95,24%	93,34%	50,61%	Thesis Work 1 / Auxiliary Services / Mineral Processing
e.2	Design and execution of the evaluation	100%	85,41%	53,00%	Surface Mining / Underground Mining / Auxiliary Services
f.1	Takes a stance in relation to ethical and social responsibility issues.	95,23%	72,42%	68,42%	Mining and Environmental
f.2	Recognizes the environmental risks.	100%	24%	78,95%	
g.1	Conveys written information in an organized and clear manner	78,57%	68,42%	100%	Thesis Work 2
g.2	Expresses himself/herself clearly and effectively.	84,02%	83,50%	71,03%	Thesis Work 1 / Thesis Work 2 / Mineral Processing
g.3	Prepares effective visual presentations.	78,57%	72,96%	80,13%	Mining and Environmental Mineral Processing / Thesis Work 2
h.1	Recognizes the economic and social contribution of mining.	78,57%	86,37%		Mining Valuation
h.2	Knows mining methods and technologies for the prevention of environmental impacts.	90,47%	24%	78,95%	Mining and Environmental
i.1	Recognizes the need for professional update.	100%	95,45%	82,5%	First and second Supervised Pre- Professional Internship
i.2	Defines a professional development plan.	100%	75,18%	82,5%	
j.1	Knows the country's social difficulties related to mining.	100%	89,66%	84,22%	Mining and Environmental
j.2	Knows the economic and political successes that influence mining.	57,14%	68,18%		Mining Valuation
k.1	Uses specialized computer tools and applications.	71,43%	73,12%	52,5%	Surface Mining / Modeling and Mine Planning
k.2	Knows the techniques and work processes of specialized equipment and machines.	51,84%	44,9%	45,65%	Mineral Processing / Heavy Equipment Maintenance Management

At the end of each semester, the professors of the evaluated courses were informed of their results with the purpose of obtaining their opinions about them. Furthermore, meetings were held with the professors in order to propose improvement alternatives. In some cases, it was considered to modify the type of evidence, adjust the rubric or incorporate some courses to properly assess the component of the rubrics.

The improvement of education requires everyone's commitment, that is, not only of the students and professors, but also the effort of the Government's organizations with a cross-sectional perception of the civil society: companies and international cooperation agencies. Self-evaluation facilitates the identification of strengths and weaknesses in the

management of the university studies at an undergraduate and postgraduate level. The Continuous Improvement process of this self-study is based on the management of the Educational Objectives and the undergraduate Student Outcomes of the Mining Engineering Program at the Pontificia Universidad Católica del Perú.

Taking into account that the Continuous Improvement process is dynamic, the following shall be considered:

- The learning process must be focused on the students and their complete development.
- The teaching process should include tools that allow the professors to guide the students towards the expected levels of learning achievements.

During this self-study process, the Mining Engineering program students look for academic excellence, that is, they try to improve their abilities to keep with the demands of the mining companies at a national and international level.

The Continuous Improvement Plan considers all the members: faculty, students, alumni and employers, as well as the Program Coordinators. The Continuous Improvement Plan aims to start a modification process of not just pedagogical aspects in the search for an educational alignment between the curriculums, which is requested by the ABET, but as well as a coherence between the professors' teaching practices and the student's learning processes throughout the entire studies, based on technical and scientific knowledge.

At the end of each semester the faculty members of the assessed courses were informed about their results with the purpose of obtaining their feedback. There were also meetings with the faculty members in order to propose alternatives for the improvement. In some cases, it was considered modifying the type of evidence, adjust the rubric or include certain courses to the assessment group to perform a more adequate measurement.

Considering the results obtained a group of activities were scheduled, with the purpose of developing and improving the professional competences the students must acquire within the systematic continuous improvement processes.

❖ Continuous Improvement Plan

- **Training Talks, Workshop, Seminars**

As part of the Continuous Improvement Plan, different professionals of the mining industry were invited to give training talks, workshops and seminars to the undergraduate students. These talks were organized by the Accreditation Office in coordination with the faculty and the representatives of the mining industry. They were carried out on Thursdays and Fridays, taking into account the students' academic schedules.

- **Leadership Workshops**

In coordination with the Lidera Program of the Student Orientation Office and the Psychopedagogical Service, two Leadership and Teamwork Workshops were carried out, where the Mining Engineering students worked in soft abilities, such as assertive communication, teamwork abilities, identification of resources and the application of contents to achieve an objective in the academic environment, as well as in the work field in the mining industry.

- **Meeting with full-time and part-time professors**

The goals for this meeting were the following:

- Presentation of the progresses of the ABET accreditation process (processes, model, benefits and importance).
- Presentation of qualitative and quantitative data of the Mining Engineering Student Outcomes - PUCP in the courses observed.
- Collecting opinions on the academic progress of the courses monitored for the accreditation.
- Gathering information regarding the knowledge, technical abilities and personal competences currently required by the industry of a Mine Engineer.
- Continuous Improvement Plan based on the Student Outcome.

A participatory methodology combining oral presentations, conversation, reflection and discussions around the proposed thematic focuses, was used.
The general organization and direction were in charge of the Accreditation Coordination Office of Mining Engineering.
The faculty proposed, discussed and supported the following personal competences which a Mine Engineer should have:

- Professional updating
- Communication skills (active listening, negotiation).
- Empathy, emotional intelligence and assertiveness.
- Personal security and self-esteem.
- Teamwork and leadership.
- Problem-solving.
- Tolerance to criticism.
- Conflict solution.

Furthermore, it was agreed that the companies should promote guided visits to encourage internships in the students of the last semesters. Among the technical competences a mine engineer should have, the following were mentioned:

- Proficiency in the English language.
- Mining management.
- Research and innovation.
- Technical topics: hydrogeology, tunnel engineering, geostatistics.

- **Technical visits**

A series of technical visits to different mining operations were organized as part of the course activities.

- **Tutoring Program**

Tutoring is part of the education and learning process of the Mining Engineering students and offers to the student an academic and professional orientation space.

Through tutoring, the tutoring professors promote the development of competences (group of knowledge, techniques and abilities of the student) and offer through their experience and good judgment, orientation to the students, allowing them to expand their reference framework, expectations and opportunities, so they can continue and finish effectively their university life. The Tutoring Program Objectives were:

- Cooperating with the development of the quality of the higher education taught in Mining Engineering - PUCP.
- Contributing to the comprehensive development of the students.
- Promoting and improving the relationship between the faculty and the students.
- Directing the students' learning process.
- Promoting an attitude of responsibility, autonomy, commitment, collaboration and interest for the degree.
- Encourage students to reflect in the face of their professional project.

- **Cause-Effect Workshop with the Undergraduate Students**

The purpose of the workshop was to identify the main difficulties the students have in the achievement of the Student Outcomes at the end of the professional degree, using the Ishikawa Method. This method consists of preparing a diagram taking into account the problem to analyze. In this case, the problem was the low average in the evaluation of rubrics of the criteria in the monitored courses.

The workshop was very rewarding because the students presented the problems they have in some courses and at the same time, they proposed solutions for the different situations taking place in the teaching-learning process. Table 6 shows a summary of the problems detected by the students during the feedback meeting.

TABLE VI

SUMMARY CHART OF THE CONTRIBUTIONS OF THE PROGRAM STUDENTS DURING THE FEEDBACK MEETING

COURSE	PROBLEM	SOLUTION
Fundamentals of Dynamics	Course with methodological approach to Civil Engineering.	Restructure the contents and methodology with a geological and mining vision.
Rock Mechanics	Theoretical Course	Improve the laboratory practice sessions.
		Schedule more field visits.
Drilling and Blasting	Loss of contact hours due to nonattendance	Increase the number of contact hours.
Underground Mining	The contents of the course are not in agreement with the current environmental impact difficulties.	Improve the curriculum.

- **Accreditation Training for the Administrative Personnel**

As part of the Self-study process for the Accreditation of the Mining Engineering Program, an Orientation Seminar for the administrative personnel was carried out. The purpose of the seminar was to train the administrative personnel working (secretaries, assistants and laboratories teaching assistants, among others) in the Mining Engineering Section.

IV. conclusions

The accreditation of an academic program is a complex process that requires the commitment of various actors. Faculty can usually agree on the general outcomes that students should demonstrate by the end of the academic program. However, without a common agreement as to what specific performances should be expected from students around each of the outcomes there is no way to have a systematic, efficient nor meaningful process of data collection to determine if the outcomes have been met.

The development of performance indicators is unquestionably the most critical part of developing a systematic and meaningful data collection process around program assessment and improvement.

Performance indicators identify what concrete actions the student should be able to perform as a result of participation in the program. Once program outcomes have been identified, the knowledge and skills necessary for the mastery of these outcomes should be listed.

It is necessary to implement a continuous improvement plan that is feasible and not very ambitious. Institutional support is very important to carry out any change in improvement, be it hiring more professors, acquiring more mining-specific software licenses or improving facilities.

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