



A Continuous Improvement Model to Enhance Academic Quality in Engineering Programs

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A CONTINUOUS IMPROVEMENT MODEL TO ENHANCE ACADEMIC QUALITY IN ENGINEERING PROGRAMS

Abstract

One of the main challenges in all areas of education is to ensure that the academic quality of the teaching – learning process is enhanced continuously. In this work, we present a continuous improvement process based on Deming’s Plan-Do-Check-Act (also known as PDCA) continuous quality improvement model which was implemented in the School of Engineering and Sciences at Tecnológico de Monterrey campus Puebla. This model encompasses a one-year cycle, it starts in August and ends in July. Faculty of the Academic Departments participate in the evaluation and collection of evidences of the level of achievement of student outcomes every semester at some specific courses of the curricula of the engineering academic programs offered by the School of Engineering and Sciences of Tecnológico de Monterrey campus Puebla. A minimum level of achievement is established which is used as a reference to compare the results obtained at the end of the semester to define whether or not the students accomplished the minimum expected individual level of student outcomes achievement. These results are uploaded into an Administration System for Academic Program Evaluation (SAEP) in which statistics are calculated for all students in a given class. SAEP is an institutional system designed to evaluate student outcomes defined for all academic programs offered by Tecnológico de Monterrey. Faculty must reflect on the results of their classes to identify good practices that must be maintained and areas of opportunity in which he or she must work to improve the results for the following semester. As a result, improvement actions are defined and uploaded into SAEP each semester. At the end of the two-semester cycle a meeting with all faculty of each department is held in which the results of the cycle are presented and discussed. The outcome of the meeting is a list of good practices shared by the faculty and a list of actions for improvement that will be conducted the following cycle. Also, the need for technological or laboratory infrastructure are identified. In addition, a meeting is held with the advisory board to present them the results and to ask them for feedback and suggestions to obtain better results the following cycle. This continuous improvement cycle has been highly valuable in national and international accreditation processes of academic engineering programs.

This work provides a framework for universities in regions where accreditation programs are starting and can help the institutions prepare for international accreditation processes such as those demanded by ABET.

Introduction

A common concern among education institutions at any level is to ensure that the education processes are delivered with the highest quality standards [1]. This is a priority all over the world

and an evidence of this is that it is the fourth sustainable development goal of the United Nations 2030 Agenda for Sustainable development [2]. This goal states “Ensure inclusive and equitable quality education and promote lifelong learning opportunities”. To tackle this concern education institutions must work on hiring faculty with high quality credentials, developing a relevant and up to date education models, designing and implementing pertinent academic programs that fulfill employer’s and society needs.

In particular, in the case of universities, the most important factors that are relevant but not sufficient for a high-quality teaching-learning process are to recruit faculty with high quality credentials, to have adequate infrastructure such as well-equipped classrooms, laboratories, libraries, an updated educational model as well as to use proper technological tools for education [3,4].

Also important are the academic programs that are offered by universities which have to be designed based on the needs of employers and society, education, discipline and technological trends as well as on the requirements of national and international accreditation agencies related to such academic programs. In addition, well-designed operation processes must be designed and implemented to ensure that the students receive courses with high academic quality.

A very important process that accreditations agencies pay attention to, and that universities have to comply with, is to show that a well-defined continuous improvement process is established, implemented and used for the design, delivery and assessment of academic programs [5]-[9]. This process must provide evidences that the academic programs are improved steadily using information and feedback from various resources such as faculty, students and employers.

In the case of engineering, there are various accreditation institutions that accredit programs in some particular countries or internationally. The main task of these institutions is to evaluate and assess the quality of academic programs taking into account faculty, academic infrastructure, admission processes and mentoring of students among other factors.

All of the nine engineering academic programs that are offered by the School of Engineering and Sciences at Tecnológico de Monterrey campus Puebla have been accredited by the Mexican accreditation agency Consejo de Acreditación de la Enseñanza de la Ingeniería, Asociación Civil (CACEI) [10] and four by the Accreditation Board for Engineering and Technology (ABET) [11]; three by the Engineering Accreditation Commission (EAC) and one by the Computing Accreditation Commission (CAC).

To formalize the evaluation and assessment processes of those engineering academic programs and to optimize such processes, an Academic Program Evaluation Process was designed and implemented to ensure that all the information and evidences for the evaluation and assessment

process required by the accreditation agencies ABET and CACEI were fulfilled in the accreditation processes mentioned above. In particular, to comply with the continuous improvement criterion stated and required by these accreditation agencies.

It must be mentioned that Tecnológico de Monterrey is a Mexican multi-campus university integrated by 26 campuses located at different major cities in Mexico. One of these campuses is located in the city of Puebla.

In the following, this Academic Program Evaluation Process will be described in detail. Although this process is used for the evaluation and assessment of the nine engineering programs offered by the School of Engineering and Sciences at Tecnológico de Monterrey campus Puebla, to illustrate this process an example for the Mechanical Engineering Academic Program will be presented and described only.

The Continuous Improvement Cycle

Continuous quality improvement processes have been of interest for the operation of production processes, and even the operation of entire organizations, in order to enhance and optimize the quality of the products and services they offer and deliver. To this end, total quality management tools are used [12]. This approach has also been used to enhance the quality of the teaching-learning process [13], [14].

One of the total quality management tools most widely used is the so-called Deming's Cycle or Plan Do Check Act (PDCA) cycle [12]. This methodology has also been intensely used to design continuous improvement processes with the aim of enhancing the quality in education and of academic programs [15]. In this work, we have adapted this methodology to design a continuous improvement model which was implemented to evaluate and assess the engineering academic programs offered by the School of Engineering and Sciences of Tecnológico de Monterrey campus Puebla.

The Academic Program Evaluation Process

In this section, a standard for student outcome evaluation processes of academic programs offered by the School of Engineering and Sciences at Tecnológico de Monterrey campus Puebla that was designed and implemented for the evaluation and assessment of these academic programs is presented and described. The objective of this standard is to define a formal process that leads to the continuous improvement, based on student outcome evaluation, of engineering academic programs that are useful for a national and an international accreditation processes conducted by CACEI and ABET, respectively. In particular, this process is useful for the following:

- To make an efficient collection and documentation of evaluation elements for the Academic Programs to be accredited by CACEI and ABET.
- To analyze the results and evidences from the evaluation of the academic programs to be used for the definition of actions to be undertaken for the continuous improvement of these programs.
- To strengthen the collaborative work among faculty through the transfer of knowledge obtained from the experience of student outcomes evaluation and assessment.

It is important to mention that collaborators from the Accreditation and Institutional Effectiveness office, Academic Department Heads, Academic Program Directors and Faculty participate in the Evaluation Process of Academic Programs. The roles of these collaborators involved in process are described in Table 1.

Table 1. Participants in the Academic Program Evaluation Process

Role	Responsible
Accreditation and Institutional Effectiveness	Accreditation Specialist
Accreditation Coordinator	Accreditation Coordinator
Director of Division	Director of the Division of Engineering and Sciences
Head of Department	Heads of Department that administer the courses for the academic programs
Academic Program Director	Academic Program Directors of the Division of Engineering and Sciences
Faculty	Faculty of the Division of Engineering and Sciences who evaluate student outcomes, deliver evidences or both.

The Accreditation Coordinator is a full-time faculty member who supports the Head of the Department in some activities related to the evaluation process such as solving doubts of part-time faculty. This coordinator is on close communication with the Accreditation Specialist to ensure the correct operation of the process.

As mentioned in the introduction, this process has been used for the accreditation process of the nine engineering academic programs that are offered in our university and which were accredited by the Mexican accreditation agency Consejo de Acreditación de la Enseñanza de la Ingeniería, Asociación Civil (CACEI) [10]. At the time of the accreditation process, the number of students registered in these nine programs was 1575, the full time and part time faculty were 55 and 105, respectively.

In addition, the evaluation process was also used in the accreditation process of four engineering programs that were accredited by the Accreditation Board for Engineering and Technology (ABET) [11]; three by the Engineering Accreditation Commission (EAC) and one by the Computing Accreditation Commission. At the time of the accreditation process, the number of students registered in these four programs was 869, the full time and part time faculty directly related to these programs were 22 and 40, respectively.

The continuous improvement cycle based on the Evaluation Process of Academic Programs takes place in a one-year cycle. However, every semester the evaluation of the academic programs is carried out, this process will be described in the following section.

The Semester Evaluation of Academic Program Process

The following activities of the process are carried each semester:

1. Review of the Courses in which Student Outcomes are to be Evaluated
This activity occurs two weeks before the academic semester starts. The Accreditation Specialist, together with the Head of the Department, define the “Semester Evaluation Plan” and identify the courses in which Faculty will be evaluating the student outcomes declared in SAEP. In the next section SAEP will be described in detail.
2. Planning and design of activities to be used to evaluate student outcomes.
The Accreditation Specialist and the Head of Department ask Faculty, who will evaluate student outcomes, to carry out the following activities prior to the evaluation process in SAEP: To be acquainted with the student outcomes to be evaluated in the course and to design and/or to update the activity (homework, exam, project, laboratory report, etc.) in which the student outcome will be measured. Also, to design the evaluation rubric for the activity and to introduce this rubric to the students, who are registered in the course, the first day of classes.
3. Presentation of rubrics to the students
Faculty, who will evaluate student outcomes, introduce the evaluation rubric that will be used to evaluate student outcomes in the designed, corrected or updated activity to their students and confirm the Accreditation Specialist, via e-mail, that they have presented the evaluation rubrics to their students the first day of classes.

4. Mentoring and training of Faculty participating in the student outcome evaluation process.

The Accreditation Specialist mentors and trains Faculty, who participate in the evaluation of student outcomes, on the use of SAEP or in the evaluation process continuously to ensure that this process is successful.

5. Collection of evidences.

Faculty collect evidences from the learning activities carried out by the students in their courses along the semester. The type of evidences that Faculty can collect are rubrics, project reports, essays, etc. These evidences must demonstrate the application and development of the student outcomes and must be uploaded to SAEP once the students are evaluated.

6. Evaluation of Student Outcomes and submission of evidences for the August-December Semester.

Once the semester ends, the period for evaluation of student outcomes starts. To this end, the Accreditation Specialist meets with every Faculty member to mentor and to assist them in this activity and ensures that they comply with the evaluation of student outcomes in SAEP. By doing so, all the student outcomes that have an evaluation plan are evaluated taking into account the evidences, which demonstrate the development of student outcomes, that were previously collected from the students.

7. Report of evaluation student outcomes.

Once the evaluation cycle concludes, one month after the end of the semester, the accreditation specialist generates a report with the results of the evaluation of student outcomes to identify the level of compliance of the development of the student outcomes under evaluation. This report is presented to the Head of Department who analyzes these results.

8. Actions for Continuous Improvement

The Accreditation Specialist meets with each of the Faculty members, in whose courses the minimum level of student outcome development was not attained, to define improvement actions to be undertaken the following semester and that are expected to overcome these results. That is, to achieve at least the minimum level in the development of student outcomes in his or her course the following period. These actions for improvement are then uploaded in SAEP as evidence.

End of year cycle Meeting and Collaborative Work to Define Actions for Continuous Improvement

The final stage of the annual evaluation cycle is a department meeting arranged by the head of the department. Prior to the meeting, the Head of Department:

- a. Requests an annual report of the results and information uploaded in SAEP.
- b. Defines work-teams based on the student outcomes that the Faculty evaluated in SAEP.
- c. Defines Department Coordinators that will be responsible for observing and ensuring that all Faculty members that must evaluate student outcomes do so.
- d. Invites all Faculty – including those that evaluated student outcomes - to hold a meeting so that the work teams defined previously present an analysis of the semester evaluation.

In the evaluation meeting, Professors suggest and propose actions for continuous improvement to be implemented in the courses in which student outcomes will be evaluated the following semester. The actions and activities for continuous improvement that will be carried out the following year are defined by consensus among the faculty. In addition, a report with the agreements and responsibilities is prepared. The report is sent to all Faculty so that they implement the actions for improvement in the courses in which they will evaluate student outcomes the following semesters. Figure 1 shows the faculty of the department of Mechanical Engineering that attended the meeting at the end of the evaluation cycle in the 2019 summer.



Figure 1. End of year Department Closing Meeting

Meeting with the advisory board.

An important input for the continuous improvement of the academic programs is provided by the advisory board. This advisory board is constituted by a group of members of local companies where our alumni are working. Once a year, in the summer, a meeting is held with the members

of the advisory board. The head of the department, the academic program director, the accreditation specialist and the Director of Division attend this meeting. In the meetings, results of the student outcomes evaluation and assessment are presented to the advisory board in order to ask them for their feedback and to identify jointly areas of opportunity and strengths and thus, together, establish strategies for improving the development of student outcomes to be implemented the following cycle. Figure 2 shows a picture of a meeting with the advisory board that was held in the summer 2019.



Figure 2. Attendants to the Advisory Board Meeting

It is important to mention that there is an advisory board for groups of academic programs which share common disciplines. Figure 2 corresponds to the advisory board for the academic programs: Industrial Engineering, Mechanical Engineering and Mechatronics Engineering. In the advisory board, there are three members from industry – employers – for each academic program. That is, a total of nine employers constitutes this board.

As mentioned above, the continuous improvement model that was described above is based on Deming’s Cycle or Plan Do Check Act (PDCA) cycle. Figure 3 shows this model in the PDCA cycle format.

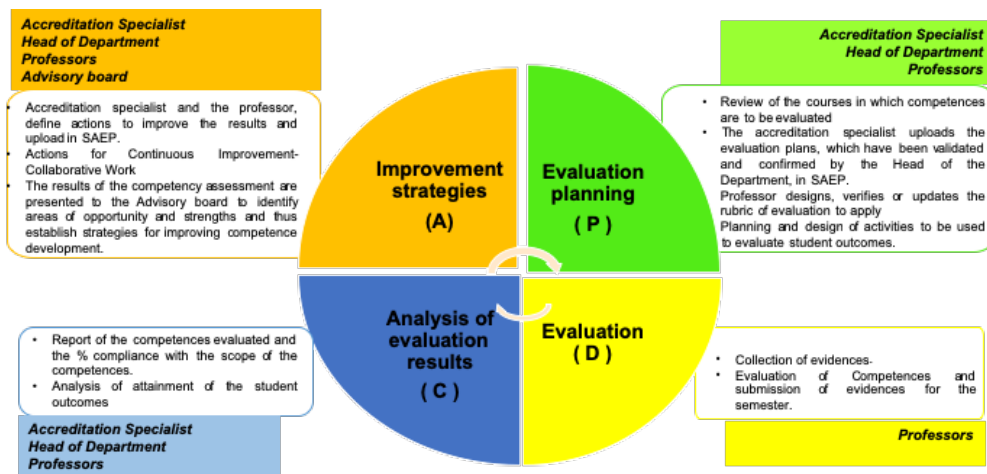


Figure 3. PDCA cycle of the continuous improvement model

The System for the Administration of the Evaluation of Academic Programs (SAEP)

All undergraduate academic programs offered by Tecnológico de Monterrey are evaluated in a systematic, continuous and documented way to determine the level of achievement of student outcomes defined for each of these academic programs. To this end, a computational platform called System for the Administration of Program Evaluation (SAEP) is used. This platform was designed, developed and implemented at Tecnológico de Monterrey for the administration and monitoring of the evaluation and assessment of the attainment of student outcomes related to the academic programs that this Institution offers. That is, academic programs offered by the Schools of Architecture, Arts and Design, Business, Humanities and Education, Social Sciences and Government, and Engineering and Sciences.

This System has been particularly useful for national and international accreditation processes of some of the academic programs offered by these schools. However, in this work the use of this tool for the evaluation of the academic programs offered by the School of Engineering and Sciences at Tecnológico de Monterrey campus Puebla is presented only. The accreditation processes for which SAEP was used are those conducted by ABET – 4 academic programs - and CACEI – 9 academic programs.

In SAEP the evaluations and actions for continuous improvements of academic programs offered at our university are uploaded by faculty who teach courses of each academic program in which the attainment of student outcomes is evaluated. To ensure that all faculty know how to do this they are trained in the design and application of evaluation instruments such as rubrics.

In the following, SAEP will be described using information of the Mechanical Engineering Program to illustrate its use.

Mapping of Student Outcomes into Courses

The Student Outcomes of each and every one of the academic programs offered by our university are previously uploaded and stored in SAEP. Two or more sub-outcomes are defined for each of the student outcomes to facilitate the evaluation of its attainment. All of these sub-outcomes are then carefully mapped into the courses for each academic program to define the courses where the faculty will evaluate the attainment of these sub-outcomes.

Definition of Assessment plan

An Academic Committee constituted by the Department Head, the Academic Program Director and some faculty members of the department define an evaluation and assessment plan for each sub-outcome. In the evaluation plan, the information described in Figure 4 must be specified.

Table 2. Elements of the sub-outcome evaluation and assessment plan.

PERIOD	METHOD OF EVALUATION	WHEN	WHERE	GOAL
The period in which the evaluation will be conducted	The instrument to be used to assess the development of competition /performance criterion: Rubrics	The frequency at which the evaluation will be conducted: semiannual or annual	if a rubric is used, the name and course code must be specified	The percentage of students that are expected to accomplish the performance criterion
RESPONSIBLE	Professor's course			
LEVEL OF ATTAINMENT	It is the criterion that states if a student accomplishes the performance criteria based on the indicated assessment instrument			

In addition to the definition of the assessment plan, rubrics, which will be used to conduct the evaluation and assessment of the attainment of student outcomes of each student in a specific course, are designed. The purpose of using rubrics is to measure the performance of students in activities, projects or presentations. Rubrics are useful since they provide criteria and expected levels of performance for student evaluation. This instrument helps faculty to evaluate and to assess more objectively and provide consistent and standard evaluations for student activities. In a rubric the level of attainment of a sub-outcome ranges from 1 to 4, 4 being the highest.

The Head of the Department establishes the performance goal. This goal is defined as the percentage of students in the course that obtained a level of attainment in the sub-outcome of at least 3.

Typically, this percentage is set equal to 75%. Figure 4 illustrates how the information for the evaluation plan of a specific student outcome is shown in SAEP for the Mechanical Engineering program.

Student outcome
8. Students will design and lead experiments, extrapolating their results towards the development of a product or engineering process. << >>
Results of learning outcome << >>
8.1 Students design and carry out experiments, and analyze and interpret data obtained in order to understand the phenomena, solve problems and be able to apply the results in the improvement of real situations.
Sub-outcome

Evaluation plan					
Semester	Evaluation method	When	Where	Responsible	Goal
	Rubric		M3015	Juan de Dios Calderón	75%
Evaluating faculty:					
Esteban Rodríguez Galindo.					
Course description:					
M3015-Laboratorio de termofluidos					

Figure 4. Typical Evaluation and Assessment Plan for a Student Outcome in SAEP.

In this case, the student sub-outcome will be measured in the M3015 course of the Mechanical Engineering program using a rubric as the evaluation tool.

Evaluation and Documentation Results

As described in the previous section, this stage occurs after faculty have evaluated and assessed the attainment of student outcomes in their courses. The evaluation results for each student in the courses are uploaded and documented in SAEP. In addition, an evidence of the evaluation instrument that was used needs to be uploaded in that system. It is important to emphasize that the evidences evaluated are the individual level of attainment of student outcomes for each student in the course and not of teamwork. The evaluation in each course can be every semester or yearly depending on whether the course is offered every semester or once a year, respectively.

Once a Professor has finished uploading the results of each students in SAEP, it calculates the percentage of students that obtained a level of attainment of 3 or higher in the corresponding student outcome. If this percentage is greater than or equal to 75% the goal has been fulfilled. Figure 5 shows a screenshot of the results obtained from SAEP for a particular student outcome.

Results of learning outcome << >>

8.1 Students design and carry out experiments, and analyze and interpret data obtained in order to understand the phenomena, solve problems and be able to apply the results in the improvement of real situations. << >>

Semester	Evaluation method	When	Where	Responsible	Goal	Results
	Rubric		M3015	Juan de Dios Calderón	75%	71%

Evaluating faculty:

Esteban Rodríguez Galindo.

Course description:

M3015-Laboratorio de termofluidos

Figure 5. Result from Evaluation and Assessment Plan for a Student Outcome in SAEP.

The 75 % goal is not fulfilled since the percentage of students that obtained a level of attainment of 3 or higher is 71%. Therefore, improvement actions must be defined.

Definition of Improvement actions

Based on the results of the evaluation of student outcomes, and specifically on the percentage of students that obtained a level of attainment of 3 or higher in the corresponding student outcome, an analysis of those results is performed to define the course of action to conduct. If that percentage is less than 75%, the professor must reflect on the possible causes for these non-satisfactory results and to establish improvement actions to overcome these results in the following semester. These improvement actions must be documented in SAEP. On the other hand, if that percentage is greater than or equal to 75%, the professor must reflect on the possible causes of this and identify best practices which have to be documented in SAEP.

This will be the final part of the semester evaluation cycle. Figure 6 shows a screenshot of the window where faculty document and upload the actions for continuous improvement to be conducted in the following semester.

Results of learning outcome << >>

8.1 Students design and carry out experiments, and analyze and interpret data obtained in order to understand the phenomena, solve problems and be able to apply the results in the improvement of real situations. << >>

Semester	Evaluation method	When	Where	Responsible	Goal	Results
	Rubric		M3015	Juan de Dios Calderón	75%	71%

Evaluating faculty:
Esteban Rodríguez Galindo.

Course description:
M3015-Laboratorio de termofluidos

Improvement actions << >>

Action name:	Raise the development of student outcomes
Definition date:	10/06/2019
Action description	Strengthen students' knowledge about thermodynamic engineering, fluid mechanics and heat transfer, in order to propose diagnostic methodologies for thermal and fluid systems and obtain greater competence development.
Action justification:	To achieve levels of competition development above the established goal
Responsible:	Esteban Rodríguez Galindo (erodriguezg@tec.mx)
Review date:	10/07/2019

Figure 6. Definition of actions for continuous improvement in SAEP.

Challenges in the Implementation of the Process

Some complications and challenges were encountered during the implementation of the Academic Program Evaluation Process that is presented here. Among those challenges are the following:

- To standardize the process for all programs and academic departments since there are differences in the curricula of the programs and in the way in which faculty evaluate and assess their students.
- To communicate and to accomplish that all participants in the process understood clearly their responsibilities including how to design and use evaluation and assessment tools.
- As mentioned above, about two thirds of the faculty are part-time and one third is full-time. As such, some complications were related to part-time faculty. On one side, it is difficult to get in touch with part-time faculty and as such to comply with the due dates for evaluation and assessment. On the other side, although part-time faculty turnover is low, less than five percent per semester, it was necessary to implement an adequate tracking procedure of this turnover to make sure new part-time knew how to participate in the process.

Conclusions

In this work a Continuous Improvement Model to Enhance Academic Quality in Engineering Programs has been presented and described. This model is based on Deming's Cycle or Plan Do Check Act (PDCA) cycle and has been useful for the evaluation and assessment of student outcomes of the engineering academic programs offered in our university. An important tool in the continuous improvement process has been SAEP since this platform administers the results from the evaluation and assessment of all student outcomes pertaining to each academic program. Furthermore, in this tool the actions for improvement can be documented by the faculty which helps the Head of the Department to keep track of the impact and evolution of the evaluation and assessment of student outcomes through time.

The continuous improvement model presented has been highly useful in national and international accreditation processes of the academic engineering programs offered by our university. This model could be adopted and adapted by institutions that will initiate accreditation processes or to standardize evaluation and assessment processes of academic programs.

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