

A Model for Assessment and Incremental Improvement of Engineering and Technology Education in the Americas

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Abstract

The European Union has strengthened the economy of its member nations through, not only establishing a standard for money, but also a standard for recognition of engineering education. The Americas need the latter standard to permit an engineer to practice across national frontiers, and strengthen the economy of the Americas. Having such a standard would allow engineering institutions to form a consortium to offer or accept distance learning courses originating from recognized institutions. A first step toward having a Union of the Americas for recognizing engineers, is moving towards a mechanism for assessment and recognition of engineering institutions. In the United States, this accreditation is done by Accreditation Board for Engineering and Technology, Inc (ABET), which also evaluates international educational credentials and certifies equivalence to ABET accredited programs to international institutions. This evaluation results in accreditation or no accreditation.

This paper proposes a new model for assessment and incremental improvement of engineering and technology education in the Americas, called the Engineering and Technology Education Capability Maturity Model. The proposed model classifies an engineering educational program as being in one of five levels: initial (or chaos), repeatable, defined, managed or optimized. Achieving Level 5 would indicate that the program is ready to undergo ABET or similar accreditation. The Latin American and Caribbean Consortium of Engineering Institutions (LACCEI) could be a vehicle for accepting this model, facilitating communications among peer institutions at the same level, providing expertise from institutions one or more levels higher to assist in the improvement of engineering and technology programs, and providing the recognition of engineering institutions required to form viable distance learning consortiums and true research and academic collaboration among member institutions.

Keywords

Engineering Accreditation, Quality Assessment, Incremental Improvement, Professional Engineer Certification for the Americas, Capability Maturity Model.

1. Introduction

The Americas is lagging behind the European Union in many ways. In the future the Americas must close that gap in order to compete in the world economy. By achieving agreement and unity in standardizing monies, trade and education the European Union has strengthened the economy of its member nations. China is fast improving its economy and competitiveness in the world market, again

through unity. If the Americas are to remain competitive, Latin America, the Caribbean, the U.S.A. and Canada must join their education efforts and form a recognized standard for engineering and technology programs. Having such a standard would allow engineering institutions to form a consortium to offer or accept distance learning courses originating from recognized institutions. The Americas need a standard to permit an engineer to practice across national frontiers, and strengthen the economy of the Americas. A first step toward having a Union of the Americas for recognizing engineers, is moving towards a mechanism for assessment and recognition of engineering institutions.

In the United States, the Accreditation Board for Engineering and Technology, Inc (ABET) [1] is the recognized accreditor for college and university programs in engineering, technology, computing and applied science. ABET is a federation of 31 professional and technical societies from these fields. About 2,500 programs are accredited over 550 colleges and universities in the United States. ABET also offers educational credentials evaluation services to those educated outside the U.S. and provides certification of equivalence to ABET accredited programs to international institutions of higher education. This evaluation results in accreditation or no accreditation, with comments on commendations, deficiencies, weaknesses, and concerns.

To become a licensed Professional Engineer in the United States is a four step process.

1. Graduate from an approved four-year engineering program (ABET accredited if the institution is in the United States).
2. Register with the state's Board of Examiners for Professional Engineers and Land Surveyors to take and pass the Fundamental in Engineering Exam (FE), which is administered in April and October each year [2].
3. Complete four years of additional engineering experience.
4. Pass the Principles and Practices of Engineering Examination (PE) that is administered through the National Council of Examiners for Engineers and Surveying (NCEES) [2].

Completing the first two steps certifies the individual as an *Engineer-in-Training* or an *Engineer Intern*. Completing all four steps certifies the individual as a *Professional Engineer*, licensed in to practice in that state.

As we can see, the first step attaining an engineering license is graduating from an approved (ABET accredited or equivalent) engineering program. In Latin America and the Caribbean the approval is often done through the Ministries of Education and standards and requirements vary. There is a need to move towards a standard of recognizing the level of quality of an engineering or technology program in Latin America and the Caribbean. Once that standard is developed, a recognized standard across the Americas can be attained.

This paper proposes a new model for assessment and incremental improvement of engineering and technology education in the Americas, called the Engineering and Technology Education Capability Maturity Model. The model, an extension of the Capability Maturity Model (CMM) in Software Systems Engineering, classifies an engineering educational program into one of five levels, one being the lowest capability and 5 the highest. Achieving Level 5 would indicate that the program is ready to undergo ABET or equivalent accreditation. The Latin American and Caribbean Consortium of Engineering Institutions (LACCEI) could be a vehicle for accepting this model, facilitating communications among peer institutions at the same level, providing expertise from institutions one or more levels higher to assist in the improvement of engineering and technology programs, and providing the recognition of

engineering institutions required to form viable distance learning consortiums and true research and academic collaboration among member institutions.

2 Background

In 1986, the Software Engineering Institute (SEI) at Carnegie Mellon University with the Mitre Corporation began developing a multi-level model-based process improvement model, called the Capability Maturity Model (CMM) [3,4], which was based on earlier quality management work by Deming [5], Crosby [6], and Juran [7]. The model measures an organization's *process capability*, the inherent ability of a process to produce planned results. As the process capability increases, the results become predictable and measurable, and the most significant causes of poor quality and productivity are controlled or eliminated.

The original CMM model was the Capability Maturity Model for Software (SW-CMM), used to enhance the capabilities of the software development organization to deliver software on time, within cost, and meeting the objectives of the system and the customer. Its documented success resulted in the proliferation of CMM-based models to improve engineering processes, which in 1998, prompted industry, the US government, and the SEI to begin the Capability Maturity Model Integration (CMMI) project [8], providing a single, integrated framework for improving multi-disciplinary engineering processes in organizations. Their success, acceptance and maturation prompt a closer look at the potential application of CMM-based models to improve the process of engineering education.

The next sections presents an overview of the CMM, and the proposed CMM-based model for engineering and technology program assessment, called Engineering and Technology Education Capability Maturity Model (ETE-CMM). The process of using this model would facilitate incremental improvement and produce the documentation required for higher education accreditation by Professional (ABET) [1], Regional, and National accrediting organizations.

3. The Capability Maturity Model

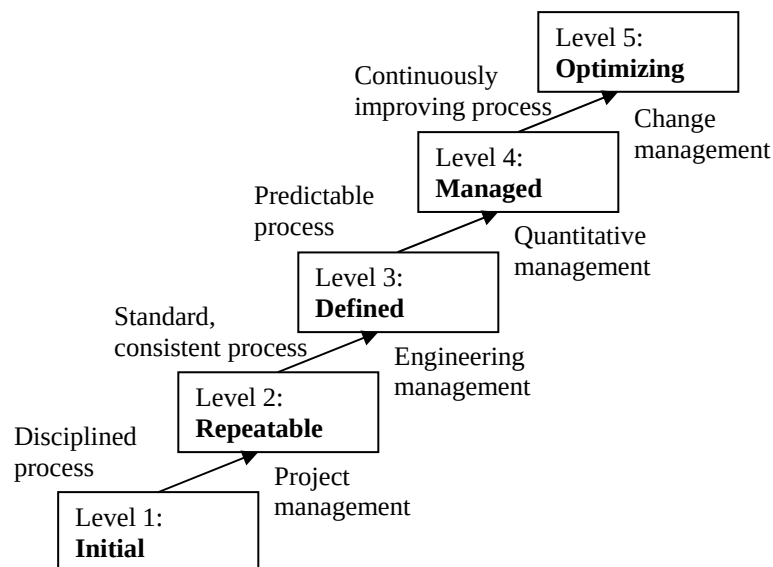


Figure 1: The Five Stages or Maturity Levels of the Capability Maturity Model [3]

The SEI developed the CMM to assist the Department of Defense in assessing the quality of its contractors. It rates an organization's process maturity on an ordinal scale from 1 - low to 5 – high. The CMM bases the rating on a survey with required documented evidence to verify the answers. The model provides principles and practices that lead to better outcomes. These are organized in five levels, providing a path to incremental adoption of best practices, more process visibility and control, and improved outcomes.

Figure 1 shows the progression through the levels. Each level forms a foundation from which to achieve the next level, so trying to skip maturity levels could be counterproductive. An organization can adopt specific process improvements at any time, however, it should be understood that processes without proper foundation fail under stress. Following the CMM framework tends to produce stability in process improvement since the required foundations have been successfully institutionalized.

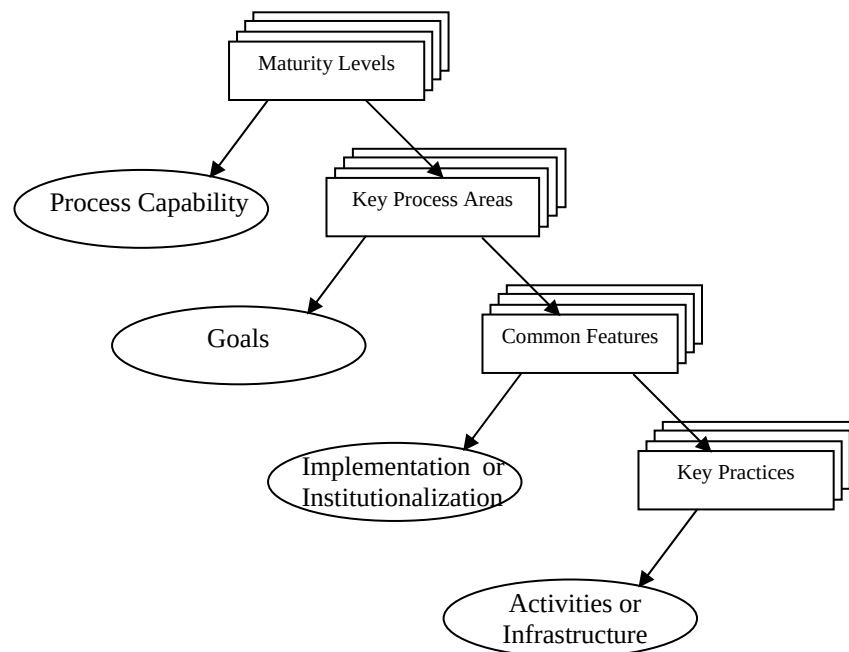


Figure 2. The Internal Structure of the Maturity Levels in CMM [3]

Except Level 1, each maturity level has an internal structure shown in Figure 2. A maturity level indicates a capability to perform a process with predictable results and is associated with a set of *key process areas* on which an organization should focus as part of its improvement effort in order to achieve their goals. Each key process area is organized into five sections called *common features*:

- *Commitment to perform* – the policies, leadership practices and actions that ensure that the establishment and continued use of the process
- *Ability to perform* – the practices that address resources, training, orientation, tools, and organizational structure that ensure that the organization is capable of implementing the process.
- *Activities performed* – the practices that address plans, procedures, work performed, corrective action, and tracking.
- *Measurement and analysis* – the process measurement and analysis practices that ensure that procedures are in place to measure the process and analyze the measurements.
- *Verifying implementation* – the management reviews and audits practices that ensure that activities comply with the established process.

These common features specify the *key practices* described by activities or infrastructure, that when collectively addressed accomplish the *goals* of the key process area. An organization is satisfies a key process area when the process area is both implemented and institutionalized.

3 Proposed Engineering and Technology Education Capability Maturity Model

The proposed model, called Engineering and Technology Education Capability Maturity Model [10], has been presented to the American Society of Engineering Education, together with two related models for assessment of engineering students and faculty. The model is still under development and comments are invited. The model uses the same framework of the CMM when describing the capability maturity of an engineering program. The names of the 5 levels of process capability maturity described in Figure 1 remain the same. Below we describe the 5 levels of capability maturity and the related key practices in terms of an educational, rather than a business, domain.

Level 1: Initial – At this lowest level few processes are defined. Processes are adhoc and mostly reactive. Productivity and quality vary. Success depends on individual effort. Current levels of quality and productivity of peer programs/institutions are not known. To advance to the next level, the institution needs to identify and analyze peer programs, define its mission, goals, and objectives, and impose more structure and control on the process to enable more meaningful measurement.

Level 2: Repeatable – The institution has developed policies for managing the educational programs and procedures to implement those policies. Disciplined processes are established to identify the inputs and outputs of the process, the constraints and the resources used to produce the final product. Basic project management practices are used to track cost, retention and productivity and compare them with peer institutions. There is some discipline among faculty in documenting course syllabi, goals, objectives, learning outcomes, results and feedback, so that successful course delivery can be repeated. A strong curriculum for each degree program includes engineering sciences, humanities, social sciences, communication skills and an appropriate professional component. The institutional requirement for achieving Level 2 is that there are policies that guide the degree programs in establishing the appropriate management processes, their program planning and tracking are stable and earlier successes can be repeated. The program's process is effectively controlled by a program management system, following realistic plans based on the performance in previous terms. The key process areas addressed by Level 2 institutions are:

- Degree program and course management
- Quality assurance
- Management of adjunct faculty
- Program and course tracking and oversight
- Program planning
- Identification of peer institutions

Level 3: Defined – The educational process for both management and educational activities is documented, standardized, and integrated into a standard process for the institution. Mission, goals and objectives are published in the catalog and posted. All programs use an approved, tailored version of the institution's standard process for developing and maintaining degree programs and courses. This level includes all characteristics for Level 2.

- Learning outcomes for each course is published in syllabi
- Documentation of strategies to achieve learning outcomes
- Mission statement for University and College of Engineering are published
- Educational objectives for each engineering program are published and appear in the catalog
- Peer reviews of proposed programs and courses
- Integrated program management
- Training program

- Involvement of constituencies in reviewing and updating educational objectives
- Institutionalized processes
- Faculty credentials are documented

Level 4: Managed – Detailed measures of the educational program and courses are collected and used to quantitatively understand and control both the process and the programs. This level includes all characteristics for Level 3.

- Documentation and implementation of functional feedback and assessment processes designed to determine whether intended outcomes are being achieved
- Comparison with peer institutions
- Quality management
- Documentation sufficient staff allocation and compensation
- Quantitative process management
- Documentation of good facilities and strong institutional support
- Involvement of constituencies in evaluating program outcomes

Level 5: Optimizing – Continuous process improvement is enabled by quantitative feedback from the process and from testing innovative ideas and technologies. This level includes all characteristics of Level 4.

- Process change management
- Total faculty involvement
- Technology change management
- Documentation feedback results in changes in program
- Defect prevention: Student retention management, Graduation rate management

These five levels and the key process areas that have been identified with each level are a beginning towards building a Capability Maturity Model for Engineering and Technology Education. Accreditation agencies, such as ABET tend to accredit institutions that are at level 5 in our model. The proposed model gives institutions that have not been accredited a framework that could yield the necessary process definition, implementation, assessment and improvement to eventually attain accreditation. The model provides a common language to discuss progress in process improvement and a logical progression in achieving higher capability maturity levels.

In the CMM advancing from level 3 to level 4 requires having software applications that store and provide access to important documents, automatically accumulate metrics, and track progress through the process. Such a tool would be very useful for storing program descriptions and requirements, course syllabi and expected learning outcomes, sample exams and assignments, scanned examples of student work, program and course assessment and survey results, and a myriad of other documents that usually are only compiled and examined when a program is undergoing accreditation. The archive of documents provided by such a tool would allow

- ongoing evaluation and process improvement,
- comparison of course outcomes and assessments to
 - courses offered in subsequent semesters within the institution and
 - courses offered at peer institutions, and
- the tracking of collection and timely submission of required documents

4 Future Work

The proposed model will be developed in more detail, identifying the key process areas at each level and the activities that would produce improvement to the process capability. Two additional CMM-based models are under development to assess the capability maturity of engineering students and engineering

faculty. A grant proposal is being prepared to develop an integrated model and tool to assess the capability maturity of an engineering institution. The model and tool will integrate assessments and supporting documentation from the engineering student, faculty, and program to provide feedback and documentation for the engineering institution assessment plan. Once the tool is in place a long term study will be conducted to study the impact of the use of the proposed CMM models on the quality of engineering education. LACCEI institutions are invited to collaborate in the design and assessment of this model. The model will hopefully facilitate moving towards an accreditation mechanism to recognize and license engineers recognized throughout Latin American and the Caribbean and, ultimately, the Americas.

5 References

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