Make your Data Work: *Infusing CMMI Culture in Assessment and Continuous Improvement for ABET Accreditation*

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Abstract

Designing a proper metric framework to support assessment of student outcomes is always a challenge. This challenge is even more pronounced in large computer science programs where many required courses have multiple sections, and many of these sections are staffed by adjunct faculty. Furthermore, some might contend that the culture of attainment of student outcomes and its connection to continuous improvement are still evolving in the discipline of computer science. Therefore, it is not uncommon to see that assessment and continuous improvement remain priorities of just the administrators. These concepts which typically remain dormant for several years but receive frantic and urgent attention a year before an ABET visit continue to be of little importance to busy faculty. In this paper, basic principles of quality assurance that are integral parts of software development and software engineering are adapted to the assessment and continuous improvement system in the preparation for ABET/CAC accreditation. This paper chronicles the successful establishment of a routine and valued outcomes-driven process to support continuous improvement while tracking ABET specific Student Outcomes (SOs). While the implementation is done in a computer science program, the methodology is equally applicable to engineering programs with little modification.

Introduction

Assessment and improvement processes in outcomes-based education have roots in the quality movement pioneered by William Edwards Deming several decades ago. The adaptation of the principles of quality and the Capability Maturity Model (CMM) into software engineering was developed by the Software Engineering Institute of Carnegie Mellon University in 1987. The integrated version (CMMI) evolved from this early work. ABET's Criteria 2000 was inexorably linked to the quality assurance fervor of the 1990's [2-7]. However, the work involved in preparing for accreditation is enormous, and faculty members do not always find the direct benefit of such work. As a result, some nontechnical faculty members have even resorted to excoriating the entire outcomes-based approach of the accreditation process publicly [8].

The classroom instructors of many undergraduate courses are burdened with several challenges such as large class sizes, dwindling instructional support and the need to juggle research and teaching. While fulltime instructors participate in committee deliberations and are generally aware of the department level issues such as accreditation, part-time instructors often teach in the evenings and are not as well-connected with departmental matters. While they bring valuable industrial experience and often engage in teaching as the proverbial labor of love, their activities are mostly limited to just the course they are teaching. The need for periodic or ongoing assessment of student learning and improving the processes are viewed as additional activities beyond teaching responsibilities. There is a widespread feeling that accreditation is primarily the prerogative of administrators such as the department chair, undergraduate coordinator or the dean. For these reasons, the participation of part-time faculty members in the accreditation process at our university has been limited.

There are additional issues beyond the participation by part-time instructors involved here. Sometimes the data collected by the program could not be readily traced or connected to Student Outcomes (SOs). It is always a struggle to maintain consistency of data when multiple sections are offered and taught by different instructors. The time consuming data collection, analysis, and reporting occasionally evolve into an accreditation game instead of being a process focused on continuous improvement.

With enrollment hovering over 40,000, California State University Fullerton (situated in Orange County, an urban setting) is one of the largest universities in the State. The Computer Science Department has over 1,800 students, about 20 full-time faculty members and in any given semester nearly 50 part-time instructors. Even though the program has a long history of continuous accreditation, lack of institutionalization of the accreditation process has historically resulted in *ad hoc* attempts engaged with vigor on the eve of each ABET visit. These efforts have had little sustainability or at least, this has been our experience so far. In addition, the assessment and continuous improvement processes undergo changes with the periodic changes in department chairs as well as other administrators and their preferences.

The program faces many more challenges related to accreditation. Revisions in accreditation criteria, however small, require reformatting the entire process. The shift from the iconic "(a) thru (k)" student outcomes to the newly minted "(1) thru (5) plus one [1]" may have been an improvement, but the effort involved in the transition at the program level has been huge. Furthermore, a major disconnect continues to exist between the vocabulary used in industry (affecting part-time faculty) and that used by accreditation professionals. Several authors have investigated these issues and reported their findings but very few results are applicable to EAC and CAC programs equally [9-19].

As a result, the proverbial wheel of assessment and continuous improvement to address the accreditation needs has been routinely reinvented every six years.

This paper addresses these issues through the development of an assessment and improvement framework that has the following elements:

1. Institutionalization of a traceable, transparent, and metric-based process, (Student Outcomes–Course Outcomes–Performance Indicators Measure) framework using software engineering practices.
2. Automation of assessment and evaluation workflow for a sustainable process by building a One-Stop website and automation tools for all platforms that incorporates data collection, analysis, communication, presentation, and information dissemination.
3. Institutionalization of a metric-based continuous improvement cycle.
4. Illustrative examples to demonstrate how Performance Indicator (PI) data is used to identify, improve and validate a curriculum improvement initiative.

As is the case with software systems, the actual data collection and validation is tedious and time consuming. It could place a big burden on instructors and it could generate negative feeling toward the accreditation process in general. The burden was ameliorated by deploying the SOOP (Student Outcome–course Outcome–Performance Indicator-Measure) framework since it provides a good foundation to automate the process. We have developed a system that automates data submission, data summarization, and data presentation. The system described here significantly reduces the effort required. It also provides support to let data submitters to see the results.

The challenges were many. *How do we make it a routine part of the academic culture? How do we make it sustainable and robust enough to withstand personnel changes at the department or college levels? How do we make faculty the owners of the courses, their PIs, and their improvement even though the individual courses must contribute in very specific ways towards the attainment of SOs?*

We have successfully addressed most of these challenges through three distinct pathways.

1. Automation

For a sustainable and effective assessment and evaluation process, it is critical to simplify the process with a strong support of process automation to reduce as well as avoid unnecessary workload for both instructors and administrators so that they can mainly focus on teaching, student learning, and curriculum improvement: their primary job responsibilities.

2. Institutionalization

Institutionalization is the ingrained way of doing business that an organization follows routinely as part of its corporate culture: "That's the way we do things around here." Institutionalization involves implementing practices that provide needed infrastructure support; ensures processes are defined, documented, and understood; and enables organizational learning to improve so those processes can take place [2, 3]. Effective institutionalization is evidenced by the fact that the processes are continuously improved as a result of that action.
Without institutionalization, the challenges faced include:

1. Processes are not executed or managed consistently;
2. The processes will not survive staff changes;
3. Process improvement may not relate to business goals;
4. The organization will find itself continuously "reinventing the wheel" ;
5. There will be no commitment to provide resources or infrastructure to support or improve the processes; and
6. There will be no historical basis for estimation of the needed effort.

3. Adoption of the CMMI Culture

The culture in Engineering and Computer Science programs is generally closer to that exist in industry. It is this affinity that justifies the deployment of industrial practices such as CMMI for quality assurance of computer science programs [2], [3].

A brief overview of CMMI

"Capability Maturity Model Integration (CMMI) is the culmination of an effort to define the stages that software organizations pass through as they gain better and better control over their processes. The effort was kicked off by the US Department of Defense and undertaken by the Software Engineering Institute (SEI) at Carnegie Mellon University. The original product that most software developers are familiar with is CMM and it was designed to measure the process maturity of a software development organization.

In the 1990's, a veritable galaxy of quality frameworks emerged and CMM was divided into versions for software development (SW-CMM) and versions for software engineering (SECM) and product development (IPD-CMM). Later in the decade, SEI began an effort to integrate all of the approaches to CMM into a common integrated version - CMMI, which was initially released in 2000. At the same time, SEI has attempted to generalize CMMI so that it can be used to evaluate any organization's ability to manage processes [3]." Infusing the CMMI concepts facilitates the adoption of a set of practices to institutionalize a process even in an academic enterprise.

The hardest part of deploying data driven improvement, of course, is 'institutionalization,' one of the core concepts in CMMI which is to ensure the processes are routinely performed and improved even under stress situation. Institutionalization is the foundation to routinely produce high quality products [2-4].

CMMI defines the following 12 practices that must be associated with any process to be performed in the organization for the institutionalization of a process:

1. Establish an Organizational Policy
2. Plan the Process
3. Provide Resources
4. Assign Responsibility
5. Train People
6. Control Work Products
7. Identify and Involve Relevant Stakeholders
8. Monitor and Control the Process
9. Objectively Evaluate Adherence
10. Review Status with Higher Level Management
11. Establish a Defined Process
12. Collect Process Related Experiences

Institutionalization of ABET Metrics at California State University, Fullerton

Data plays a key role in any improvement effort since it shows the areas that need improvement. However, the establishment and maintenance of a usable metric system for ABET SOs present formidable challenges such as

- Indicators defined are not traced to SOs and PEOs.
- Consistent understanding on data collection, analysis, and usage are not achieved.
- No automation; everything is manually done, thus its places a big burden to instructors potentially resulting in poor data quality.
- Data are not truly used in assessment .

Based on our ABET experience, institutionalization was found to be the foundation for routinely carrying out data collection and analysis activities related to ABET compliance.

Without robust institutionalization, efforts involved in assessment and evaluation to track, achieve and maintain student outcomes as well as our program education objectives degenerate into ad hoc activities.

Adaptation of the 12 CMMI practices involved in *Institutionalization*

The Computer Science Department started to adopt CMMI's institutionalization concept in 2016 and defined the 12 practices to institutionalize the ABET using a PDCA system [21]. Many elements of these 12 practices are part of the routine ABET assessment system but the collective framework and the methodologies used in the CMMI environment are novel.

CMMI Practice 1: Establish an Organizational Policy: *Establish and maintain an organizational policy for planning and performing the process.*

The purpose of this practice is to define the organizational expectations for the process and make these expectations visible to those in the organization who are affected.

Our ABET practice:

The department established a strong policy regarding the Performance Indicator (PI) based Metric Program, which clearly traced Computer Science Core Courses with SOs. Well-defined criteria are established to assess SO obtainment; this is described later.

CMMI Practice 2: Plan the Process: *Establish and maintain the requirements, objectives, and plan for performing the process.*

The purpose of this practice is to determine what is needed to perform the process and achieve the established objectives of the project.

Our ABET practice:

GQIM (Goal–Question–Indicator–Measure) is a common practice used to establish a metric system for software quality and process improvement. It provides a methodology to build data support system for process driven improvement [5-7].

Compliance with ABET guidelines also is an outcomes driven process where the curriculum improvement is integral to the attainment of SOs. A similar concept was deployed here and a SOOP framework was built where carefully chosen and well-understood Performance Indicators formed the basis for data collection and analysis. In our Assessment and Evaluation process, the plan was instituted to collect data (a fixed set of courses collects data each semester to ensure full coverage of SOs in a year), to analyze data (each semester by the Assessment and Improvement Committee), and to communicate with program stakeholders. It includes communicating with faculty, surveying seniors, sharing information in meetings, and conducting at least one improvement brainstorming session each semester.

Table 1 shows the data collection schedule; all core Undergraduate CS Courses are covered. All sections of each course are required to submit the data. The total of 45 graduates completed the online exit survey. There is no bias in the assessment data sample collected.

Semester	CPSC 120	CPSC 240	CPSC 311	CPSC 315	CPSC 323	CPSC 332	CPSC 471	CPSC 481	Exit survey
Fall	x	x	x	x	x	x	x	x	
Semester	CPSC 121	CPSC 131	CPSC 223	CPSC 335	CPSC 351	CPSC 362	CPSC 440	Exit survey	
Spring	x	x	x	x	x	x	x	x	

Table 1. Data Collection Schedule for Required Courses in Computer Science

CMMI Practice 3: Provide Resources: *Provide adequate resources for performing the planned process, developing the work products, and providing the services of the process.*

The purpose of this practice is to ensure that the resources needed are available readily. The resources include adequate funding, appropriate physical facilities, skilled people for training, mentoring, and coaching to help the existing workforce gain the necessary knowledge and skills and the acquisition of appropriate tools.

Our ABET practice:

The department has made great effort to ensure needed resource is provided. The following resources are identified as supporting the ABET activities.

i. A five-person Assessment and Improvement Committee leads the related effort.
ii. The Committee chair receives three-unit release time from teaching duties.
iii. The Department developed a set of tools that automate data submission, data summary and presentation.
iv. The Department developed One–Stop website that all relevant stakeholders can access. The contents cover all information related to ABET and the data collection and analysis.
v. A *PI Asset Library* is posted with ample examples on how to integrate PI into a course, how to collect data, and how to analyze collected data. This material is available for all faculty and staff, full-time and part-time.
vi. The Department has automated end to end ABET workflow.

These efforts have greatly reduced the burden on faculty who have historically scrambled for data collection and submission on time. The practice described above has helped transform a once tedious and ad hoc process to predictable and routine activities. Participation by all faculty improved dramatically and process automation has significantly decreased the perception of drudgery involved in assessment tasks.

CMMI Practice 4: Assign Responsibility: *Assign responsibility and authority for performing the process, developing the work products, and providing the services of the process.*

The purpose of this practice is to ensure that there is accountability over the life of the process for performing the planned process and achieving the specified results.

Our ABET practice:

The department has clearly specified roles and responsibilities for the following individuals or groups involved in the process.

Department Chair: *Provides leadership and holds people accountable. Interfaces with part-time faculty members.*

Course Coordinator: *Leads the review and approves PIs of the course and course improvement suggestions. Leads the review and facilitates items such as textbook adoption or change. Responsible for collection of course materials to support accreditation work. Helps new faculty to understand PIs and data collection. Interfaces with part-time faculty members.*

Undergraduate Curriculum Committee: *Plans and manages multiple courses improvement or program level improvement based on assessment results.*

Course Specialty Group: *Participates in the course improvement activities.*

Faculty member: *Proactively participates in data collection, provides improvement suggestions, implements course changes based on assessment data and other sources.*

Assessment and Improvement Committee (AIC) Coordinator: *Leads Assessment and Evaluation process improvement activities.*

Assessment and Improvement Committee: *Leads Assessment and Evaluation process improvement activities. Prepares assessment activities that support ABET accreditation.*

Office Staff: *Provides needed logistical assistance.*

Students: *Provide feedback on instructional effectiveness and participate in Exit Survey.*

Industrial Advisory Board (IAB): *Reviews and critiques program educational objectives (PEOs). Provides feedback on other items as appropriate.*

Alumni: *Review and provide feedback on PEOs and improvement suggestions on curricular and programmatic issues.*

CMMI Practice 5: Train People: *Train the people performing or supporting the planned process as needed.*

Training must support the successful performance of the process by establishing a common understanding of the process and imparting the knowledge and skills needed to perform the process or support the performance of the process.

Our ABET practice:

The One-Stop ABET is a location to deposit information and find any needed information. The Assessment and Improvement committee also conducts an ABET retreat each semester to train new and existing instructors, explain changes made and seek feedback.

The department also established a Course Specialty Group to help new instructors understand how PIs work and get specific help from more experienced peers.

CMMI Practice 6: Control Work Products: *Place designated work products of the process under appropriate levels of control.*

The purpose of this practice is to establish and maintain the integrity of the work products throughout their useful lives.

Our ABET practice:

The department designated a cloud-based storage space for all assessment data and documents. A proper access control management for the storage has been established and maintained.

CMMI Practice 7: Identify and Involve Relevant Stakeholders: *Identify and involve the relevant stakeholders as planned.*

The purpose of this practice is to establish and maintain the expected involvement of stakeholders during the execution of the process.

Our ABET practice:

This was a problem in the past, when we were gaming the system and not focusing on program improvement *per se*. Only a limited number of faculty members were involved in the effort. Since 2016, the department has made it clear that ABET accreditation is the responsibility of the entire program and everyone associated with the program has a role to play. The steps listed below have systematically improved the participation of all relevant stakeholders:

- Establish, assign roles and responsibilities, and seek feedback from participants
- Hold monthly department, and AIC to check the level of involvement
- Follow up on late submissions of data (Department Chair)
- Convey the message that ABET participation is part of instructor's performance review considerations

CMMI Practice 8: Monitor and Control the Process: *Monitor and control the process against the plan and take appropriate corrective action.*

The purpose of this practice is to perform the monitoring and controlling of the process implementation, which includes these steps:

- *Collect and analyze measures of actual performance against the plan.*
- *Review results of the implemented process against the planned process.*
- *Identify and evaluate the effects of significant deviations from the planned process.*
- *Identify problems in the planned and implemented process.*

- *Take corrective action when requirements and objectives are not being satisfied, when issues are identified, or when progress differs significantly from the plan.*
- *Track corrective action to closure.*

Our ABET practice:

The department established a monitoring and controlling mechanism to ensure the all tasks are performed according to the plan and make early adjustments if needed. ABET related issues are always included as agenda items in the monthly department meetings to elevate their importance. The annual AIC report summarizes the status of assessment and evaluation. AIC holds several meetings to review the progress and resolve issues. The department chair is also actively involved in resolving issues encountered.

CMMI Practice 9: Objectively Evaluate Adherence: *Objectively evaluate adherence of the process and the work products and services of the process to the applicable requirements, objectives, and standards, and address noncompliance.*

The purpose of this practice is to provide credible assurance that the process has been implemented as planned, the planned process satisfies the relevant policies, requirements, standards, and objectives the implemented process satisfies the planned process and the results of following the process satisfy their requirements and standards.

Our ABET practice:

Each ABET visit has given us opportunities to evaluate adherence to ABET requirements. Since 2018, the department has designated a resident ABET expert to provide critical oversight.

CMMI Practice 10: Review Status with Higher Level Management: *Review the activities, status, and results of the process with higher level management and resolve issues.*

The purpose of this practice is to provide higher level management with the appropriate visibility and control.

Our ABET practice:

The Department Chair is the leader of the accreditation efforts. By setting up milestones for the status of self-study report preparation and college-level ABET Retreats, the college also has assisted the development work at the department level.

CMMI Practice 11: Establish Defined Process

Establish and maintain the description of the defined process. The purpose of this practice is to establish a description of the project's process that is tailored from the organization's set of standard processes to address the needs of a specific instantiation on a project.

Our ABET practice

The department has established a comprehensive process governing assessment activities based on our unique contexts and ABET requirements. The processes have changed several times since its inception many years ago. The current process is posted in the department ABET website to share with department community.

CMMI Practice 12: Collect Process-Related Feedback

Collect work products, measures, measurement results, and improvement information derived from planning and performing the process to support the future use and improvement of the organization's processes and process assets. This generic practice provides a reminder to all organizations and projects to constantly and forever keep improving the process.

Our ABET practice

The department has made great strides in the assessment, evaluation and implementation of continuous improvement activities.

Plan-Do-Check-Act (PDCA) Cycle Applied to Criterion 4 of ABET

The Computer Science Department has been using the CMMI norms diligently in implementing the PDCA Cycle shown in Figure 1 [20, 21].

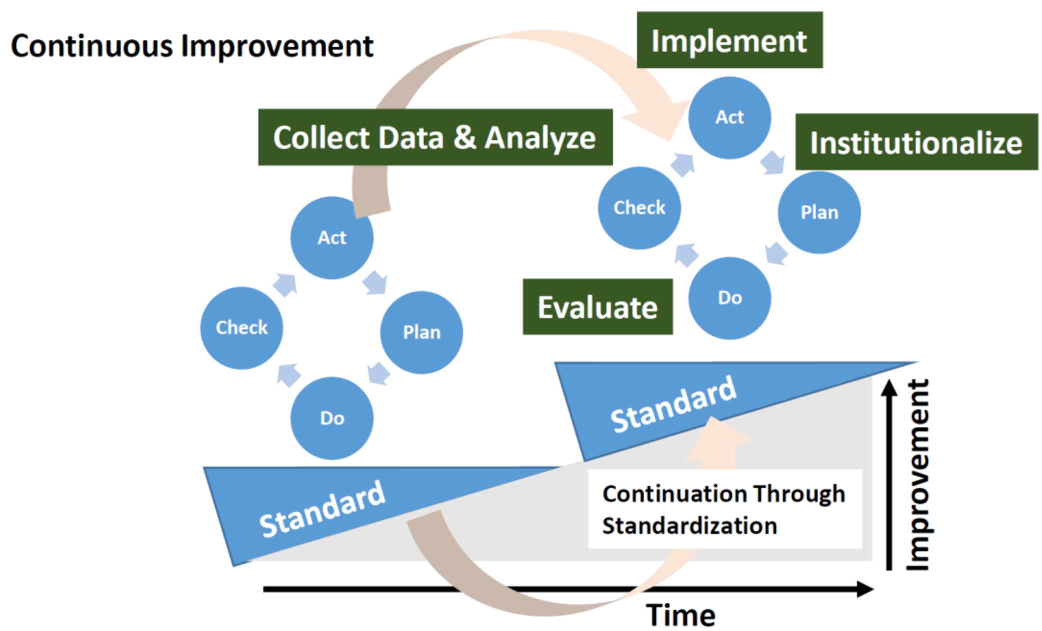

Fig. 1 PDCA Cycle and Continuous Improvement- *A CMMI Perspective*

Improvement in Assessment and Evaluation Process

The AIC has been active in implementing the CMMI-based process since Fall 2017. During the 2017-18, the SO attainment was evaluated against the then present SOs, (a) thru (k). Effective 2019-19, the program changed the assessment to seek compliance with the new ABET SOs 1 thru 5 plus one.

During the first semester of testing three triggers prompted changes. They were

1. Changes from ABET: Announcement of the upcoming changes in SOs (2017);
2. Findings from ABET's 2014 visit; and
3. Return on Invest (ROI) and institutionalization considerations

The 2014 ABET Review Team remarked that the participation of faculty in the accreditation process was limited. This remark (though it did not result in an eventual, actionable citation) provided the impetus to create an assessment method more widely embraced by faculty that can be carried out routinely without burdening the faculty. The AIC also determined that more internal resources should be deployed to automate the process.

Assessment Results and Evaluation of Data

Assessment led to evaluation of the results by the AIC, and then by the entire faculty. The discussions led to several action items of which the following were implemented:

1. The Assessment and Improvement Committee established a comprehensive assessment and evaluation process in 2016 and several simple tools to help PI data collection.
2. The Assessment and Improvement Committee consolidated the PIs based on changes in SOs and CS curriculum changes. The total number of PIs were reduced so that the SOs can be assessed without burdening the faculty.
3. Additional automation tools of data submission and analysis were developed to ease the routine workload.
4. Assessment workshops are conducted each semester to ensure all faculty understand the changes made.
5. A One-Stop ABET Site as well as process automation tools were developed and released in Fall 2018. This site provides information needed to carry out most assessment and evaluation activities.

What is important to note is that the spirit of continuous improvement transcended the strict curricular boundaries. Many of the changes made were in the process of assessment and evaluation. The process initiated in 2016 and 2017 was improved in 2018 and 2019. The "One-Stop ABET website," and our refined data collection and analysis tools helped the front end of the assessment process. The efficiencies of these improvements provided more time to the faculty to deliberate issues related to evaluation and implementation.

The new assessment system defines key performance indicators (Table 2) that are related to the essential core of the computer science discipline. These indicators are used to demonstrate compliance with the SOs. A Traceability Matrix (Table 3) is used to show the relationship among courses, performance indicators used and student outcomes. If there are any compliance issues and corrective actions needed, the traceability matrix traces to the points of origin. This traceability matrix is also one of our automated tools. Before automation, a manually written document (e.g., Excel sheet) was used, which created difficulty of changing and maintaining consistency.

Mnemonic	Definitions
HW	Demonstrate understanding of the architecture of computer hardware (i.e. CPU, memory, storage, etc.), low level programming (Assembly), operating system, middleware, and computer communication protocols. **(Hardware)**
RESPEC	Translate an informal description of a problem into a precise requirements statement and develop specifications for a software system based on requirements. **(Requirements and Specifications)**
CODE	Write syntactically-correct source code, making appropriate use of fundamental constructs such as variables, branches, loops, and functions that solves a well-posed computational problem. Understand how computers process data, how to model domain concepts and procedures as data types and code, and how to formulate a human problem as an abstract computation. **(Write codes)**
DESC	Design software exhibiting design best practices, such as clarity, structured programming, separation of concerns, and/or design principles and patterns, and describe it clearly using pseudocode, database schema, flowcharts, etc. **(Design)**
TEST	Determine whether a program correctly meets its requirements, either through direct observation or the use of testing tools. **(Testing)**
ACODE	Write syntactically-correct and more advanced, nuanced C++ programming source code that make appropriate use of object-oriented concepts such as classes, encapsulation, and templates; and includes pointers, recursion, and memory management. Write source code with clear and informative comments following some coding standards or conventions. **(Advanced coding)**
COOP	Cooperate effectively on a group project. **(Team Work)**
PROC	Demonstrate knowledge of a formalized software engineering process such as spiral, waterfall and agile. **(Process)**
FDBK	Demonstrate ability to make improvements after receiving constructive feedback. **(Feedback)**
ETH	Demonstrate an understanding of professional ethics appropriate to the use or development of computer science artifacts, and social impact of computer technology. **(Ethics)**
ISPEC	Demonstrate an understanding of intellectual property laws and ethics, software licenses, and commensurate rights. Demonstrate an understanding of security, privacy, and other ethical or legal issues, that arise in the context of computing. **(Intellectual Property and Security)**
WRITE	Write a clear document which meets the needs of the intended reader(s). **(Writing)**
SPEAK	Deliver a clear oral presentation which meets the needs of the intended listener(s). **(Speaking)**
ALG	Design an algorithm to solve a novel computational problem that builds upon classical techniques (e.g. data structures, discrete mathematics tools, divide-and-conquer, dynamic programming) and analyze the algorithm in terms of formalisms such as asymptotic efficiency, lower bounds, or computational complexity. **(Algorithms)**
FB	Demonstrate knowledge and competence in such fundamental areas of computer science as algorithms, design and analysis, computational theory, computer architecture, and software engineering. **(Foundational Breadth)**

Table 2 Definitions of new Performance Indicators

Core Courses Prefix: CPSC	Student Outcomes					
	SO 1	**SO 2**	**SO 3**	**SO 4**	**SO 5**	**SO6**
120		CODE				
121		ACODE				
131	ALG	ACODE				ALG
223		CODE, TEST				
240	HW					
311			WRITE, SPEAK		FDBK	
315			WRITE, SPEAK	ETH,IPSEC		
323		DESC			COOP, FDBK	
332	RESPEC				COOP, FDBK	
335		DESC				ALG
351	HW	DESC				
362	RESPEC	DESC, TEST			PROC	RESPEC, DESC, TEST
440	HW					
471	HW					
481	RESPEC	DESC, TEST				RESPEC, DESC, TEST, FB
Exit Survey				ETH,IPSEC	PROC	

Table 3 Traceability Matrix

Student Outcomes and Assessment Results (2018-19)

As an example of the approach taken by the department, analysis of the 2018-19 results using the new ABET Criteria for Computer Science programs is given in this section. The new criteria necessitate the tracking of five student outcomes as part of the general criteria and one program criterion for a total of six. Note that core courses and related PIs under each SO are listed. The overall “Satisfactory” percentage, “Developing” percentage, and “Unsatisfactory” percentage of all PIs are calculated. The student outcomes data for 2018-19 is given in Table 4.

COURSE	PI	S	D	U	COURSE	PI	S	D	U
120	CODE	88	23	31	332	REQ	42	15	2
121	ACODE	108	57	62	332	SPEC	34	18	7
121	CMNT	163	38	33	332	COOP	29	6	4
131	ALTS*	58	27	39	332	FDBK	30	7	2
131	ALG	51	35	38	335	DESC	105	42	31
131	ACODE	61	22	33	335	ALG	106	37	35
131	EFF	51	35	38	335	EFF	106	42	30
223	CODE	25	23	10	351	ALTS	90	55	27
223	TEST	25	23	10	351	HW	66	64	41
240	HW	52	15	10	351	DESC	64	69	38
240	CMNT	25	6	18	362	REQ	60	64	0
240	ALG	56	13	8	362	SPEC	64	60	0
311	WRITE	21	11	6	362	DESC	95	29	0
311	SPEAK	21	7	10	362	TEST	73	42	9
311	FDBK	22	11	5	362	PROC	83	34	7
315	ETH	72	17	8	362	SPEAK	112	11	1
315	IP	66	23	13	440	ALTS	102	35	26
315	SECISS	78	19	3	440	HW	84	47	30
315	WRITE	74	17	11	471	HW	54	25	25
323	DESC	59	3	4	471	GRAPH	77	23	5
323	COOP	61	1	4	481	ALG	68	9	1
323	FDBK	54	6	6	481	COMP	78	0	0

Key: S-Satisfactory, D: Developing and U: Unsatisfactory
**ALTS (that signified Analysis & Tradeoffs) was removed as a key performance indicator in 2019.*

Table 4 SO Compliance and Traceability AY 2018-19

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
	IP	**ETH**	**Proc**	**Proc**	**SECISS**	**MILE**	**LANGS**	**IMP**	**IMP**	**ETH**
Total: 168 participated in the survey	**109**	**64**	**76**	**81**	**141**	**141**	**93**	**93**	**95**	**104**
Correct %	**65%**	**38%**	**45%**	**48%**	**84%**	**84%**	**55%**	**55%**	**57%**	**62%**

Table 5 Exit Survey Data (Spring 2019)

The compliance is calculated by considering 80% contribution from the direct assessment and 20% from the indirect assessment (exit survey). All “S or Satisfactory” scores and “D or Developing” scores counted as meeting a given student outcome. Sixty percent is considered a “passing” threshold.

For example, consider the SO1 data. The courses and the PI that indicate the contributions are: 131 (ALTS, ALG), 240 (HW), 332 (REQ, SPEC), 351 (ALTS, HW), 362 (REQ, SPEC), 440 (ALTS, HW), and 471 (HW). By adding the Satisfactory (53) and Developing (31) components from Table 4, we obtain 84%m in excess of the 60% needed for compliance. The compliance data calculated for all SOs is shown in Table 6.

	SO 1	SO 2	SO 3	SO 4	SO 5	SO 6
Cumulative score (%)	84	84	86	87	83	86

Table 6 Level of compliance for all SOs.

The Assessment and Improvement Committee (AIS) concluded that the above results showed that the BS program of Computer Science was academically robust. The program performance was eminently satisfactory since all six ABET Student Outcomes meet or exceed the thresholds set for compliance. However, the evaluation also indicated the following areas that could be strengthened:

1. Ethical Responsibility (Exit survey- improvement opportunity for 315)
2. Process (Exit survey- improvement opportunity for 362)
3. Relatively high UNSATISFACTORY rate in 120, 121, 131 (Course data)
4. Relatively high UNSATISFACTORY rate in 335, 351, 440 (Course data)

Automation of Workflow to Support Transparency and Ease of Use

Currently the workflow is implemented on an internal site: https://assessment.ecs.fullerton.edu. By May 2020, this site will be moved to AWS cloud and the URL of this site could be shared in the final paper. The steps involved in the workflow are:

1. Individual faculty members define and maintain program educational objectives based on the University mission and department mission as well as the input received from the constituencies, alumni, employers, and faculty.
2. Assessment committee and faculty define and maintain student outcomes and performance indicators based on program educational objectives.
3. Assessment coordinator creates a data collection schedule based on the data collection plan created by the assessment committee. The assessment coordinator can later change the data collection schedule if necessary. Data collection schedules are provided at the Assessment website.

A process for data collection and initial statistical analysis includes the details given below.

(a) Creating a data collection schedule, determining a list of courses for data collection, identifying a person responsible as the final arbiter (the course coordinator), a list of instructors to collect the data, identifying the term (spring or fall) to collect the data, assigning student outcomes and performance indicators to each course, creating a data collection form for each course, and sharing a deadline for data collection;
(b) Sending out email notifications of the data collection schedule to the all instructors;

(c) Monitoring the data collection status and sending out reminder emails to the instructors who are late (Data from student survey, employer survey will be entered by the assessment coordinator.); and
(d) Performing automatic statistical analysis for collected data using the given criteria and formula to determine whether or not each SO is met. The SO evaluation criteria and formula can be changed. All the information from the process can be visible to all faculty so they are aware of the entire process.

Establishment of Specialty Groups and Course Coordinators

To maintain consistency of content and coverage across the many multiple sections in core courses, the department established specialty groups and course coordinators for each course. Any faculty member can freely join a specialty group based on their expertise, teaching pattern and interest. The primary responsibilities of specialty groups are to define student learning goals, create model syllabi, evaluate performance indicators and assessment rubrics designed for the course critically, and provide feedback and improvement suggestions based on the assessment data. We found that the key for our success was in allowing the specialty groups to have complete ownership for their courses as well as associated assessment activities. The details of the process are on the website developed for the ABET activities (cited already in this paper).

Conclusions

By invoking proven process management techniques linked to software development, faculty members in the computer science program, once hesitant to add on busy work, embraced assessment and continuous improvement as a familiar, necessary and useful practice with industry flavor that they should adopt.

During the past three years, our program has nearly perfected the PDCA continuum of assessment, evaluation and improvement of the educational apparatus as shown in Figure 2. To a large extent this system resembles the dynamics involved in regular ABET-oriented accreditation processes. However, it differs in two important ways:

1. The changed vocabulary has made the assessment process more relevant to computer science education. The process has matured from a sophomoric sexennial ABET exercise to a sustainable routine whose value is felt and appreciated. Locally, we have been able to move from an assessment-driven environment to a value and improvement driven framework. The essential components of what we do are not much different from what other large engineering or computer science programs do for tracking student achievement, but our approach has helped 'institutionalize' the process in the true CMMI sense.

2. The second change involves operational issues. We have successfully addressed the details of automated data collection and analysis that enable the implementation of the CMMI approach.

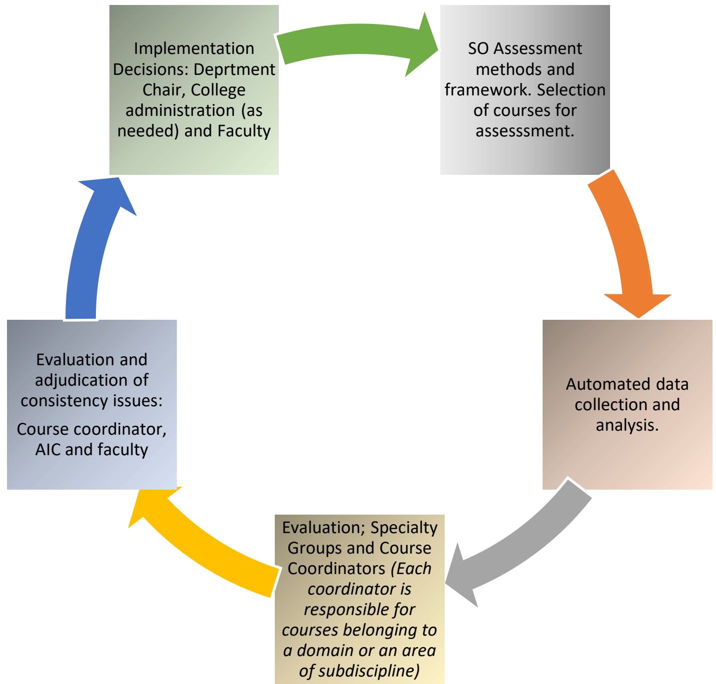

Figure 2 Continuum of Assessment, Evaluation and Continuous Improvement Continuum in Computer Science

We found that the CMMI moniker brought a familiar set of details, vocabulary and confidence to all the constituencies. However, in spite of all its strengths, it remained an abstract and elusive concept until, the sundry little details on site were worked out and implemented. And, the process itself needed to be oiled, kicked and tuned each time while undergoing its own continuous improvement cycle. Here is why the "Work Flow" was of paramount importance. We were successful in evangelizing the constituencies using CMMI and then implementing the details using technology.

The tedious details of the work flow need to be adapted to each department that adopts the techniques described above. We have completed two full cycles of the approach, painstakingly improving the process itself each time. There is more work to be done in the area workflow automation. These efforts are going on at the present time. Also, some of the recommendations of the AIC based on the evaluation of the 2018-2019 data are yet to be implemented.

As a result of the approach we have taken, we have achieved the following tangible results:

1. Part-time faculty participation increased from less than 30% before 2017 to 95% today. The accreditation process is now institutionalized within the program.

Awareness as well as involvement in accreditation activities beyond data collection by full-time faculty is now nearing 100%.

2. As a side benefit, we have been able to improve consistency of delivery in courses that have multiple sections, thanks to the creation of specialty groups and course coordinators.
3. The process is now robust and it can accommodate the changes in departmental administration or the tweaking of SOs by ABET.

We believe the concepts used here can be readily adapted to other engineering or computer science programs that may be facing issues due to faculty size, tedious data collection or an absence of institutionalization.

Acknowledgement: *The compilation and codification of the ideas and results presented in this paper evolved over a number of years through the efforts of many computer science faculty committees, course coordinators and past department chairs. Since the sheer size of these contributors prevents us from individually recognizing all of them, and naming a few might result in potential omissions, the authors wish to express their sincere gratitude for the collective work done by the entire department faculty rather than specific people by name.*

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