Refinement Measures for Engineering Education Accreditation
From a Department Perspective

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INTRODUCTION

This article presents the refinement measures that were successfully enacted in the department of computer science and information engineering, National Chung Cheng University (CCU), Taiwan such that several key point indicators of engineering education were improved by a significant margin. The measures were applied for the past decade from 2005 to 2014 and evaluations results demonstrate the effectiveness of these measures from both the departmental, as well as, the student/professor levels.

1 COMMON ISSUES IN ENGINEERING EDUCATION

In this work, we will mainly discuss engineering education accreditation [1] and investigate on how to address the common issues found in engineering education, in the perspective of department-level accreditation. The six issues covered by this work include inadequate coverage of outcomes, intra-course inconsistent self-evaluation, inter-course inconsistent self-evaluation, lack of post-course lecturer assessment, non-real-time course improvisation, and lack of an integrated accreditation platform. We will propose working solutions that have been proved to be quite effective across the department of the authors.

1.1 Continuous Improvement Cycle

An engineering department usually sets the educational objectives and student outcomes for its lecturers and students through a review on the strengths of the

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educators and the quality of incoming students. These are then reviewed again every few years through information by collected surveying the opinions of graduating students, alumni, parents, employers, and industry experts. Continuous improvement in achieving education goals and in strengthening student outcomes is generally performed by the following actions on the part of the department:

- *Target Outcome Selection*: Each course needs to select some of the student outcomes to target at via different teaching activities such as assignments, exams, quiz, reports, and term projects.
- *Course Outcome Assessment*: Students taking a course need to perform self-evaluation on how the course has helped them achieved the selected student outcomes. 5 levels of self-grading is adopted, with 5 being the highest achievement and 1 the lowest. Average scores of a course for each selected target student outcome are then calculated.
- *Department Outcome Assessment*: At the end of a semester, the average of all course averages for each student outcome is then calculated and compared to that in the previous three years for ensuring continuous improvement.
- *Course Evaluation*: The average of grades obtained by students in each course and the number of students failing each course are collected and discussed in a formal department level meeting.
- *Outside Outcome Assessment*: Annual surveys of the importance and achievement of student outcomes are made by graduating students, alumni, parents, and employers.
- *Improvement Cycle*: The above three sets of data, including department outcome assessments, course evaluation, and outside outcome assessment are then sent to the *Department Development Committee* for reviewing. Review comments are addressed by either making changes to the educational objectives, student outcomes, or courses. This forms an effective improvement cycle that matches our goals to the current needs of the students and lecturers.

1.2 Department Educational Objectives and Student Outcomes

The CCU undergraduate program has 4 educational objectives and 11 student outcomes, while the graduate program has 4 educational objectives and 8 student outcomes. Details of these educational goals can be found in [2]. The outcomes are all listed in the Appendix.

1.3 Assessment Results

The above described continuous improvement was implemented in the Department of Computer Science and Information Engineering, National Chung Cheng University for more than a decade, starting from 2005 until now. Some assessment results can be summarized as follows.

Table 1 shows the coverages of 3 of the 11 undergraduate student outcomes. Outcome 1.1 was fairly well covered by courses. Note the data for 2005 was only for one semester, that is, 1/3 year. The coverage of outcomes 2.3 and 4.1 were very low in the initial three years.

Table 1. Coverage of Undergraduate Student Outcomes [No. of Courses]

Year	Outcome 1.1	Outcome 2.3	Outcome 4.1
2005 (1/2)	13	7	4
2006	45	8	2
2007	56	5	2

Table 2 shows the average of some of the undergraduate student outcome assessments as self-evaluated by the students taking the courses in that year. The self-evaluation had 5 grades, i.e., 1 to 5, with 1 implying not achieved the corresponding outcome and 5 implying full achievement. As we can see that only for some of the outcomes (e.g., outcome 1.1), the average reached above 4, while for the rest (such as outcomes 2.1, 2.2, 2.3, 3.3) the averages could never go beyond 4. The main reason was the students did not know how to perform self-evaluation.

Table 2. Average of Undergraduate Student Outcome Assessment

Year	Outcome 1.1	Outcome 2.1	Outcome 2.2	Outcome 2.3	Outcome 3.3
2005	3.96	3.79	3.54	3.38	3.84
2006	4.13	3.95	3.79	3.54	3.88
2007	4.13	3.95	3.74	3.56	3.91
2008	3.89	3.84	3.50	3.37	3.63

Table 3 shows the outcomes selected by two classes of the same course, given by different lecturers. Except for computer organization course, the other 3 courses had different target outcomes.

Table 3. Target Undergraduate Student Outcomes for Some Courses in 2007

Courses	Class	Target Outcomes*
Linear Algebra	A	1.1, 1.2, **3.1**, 3.3
	B	1.1, 1.2, 3.3
Programming Language	A	1.1, 1.2, 2.1, 3.1
	B	1.1, 1.2, **1.3**, 2.1, 3.1, **3.3**
Computer Organization	A	1.1, 1.2, 1.3, 2.1, 2.2, 3.2, 4.2
	B	1.1, 1.2, 1.3, 2.1, 2.2, 3.2, 4.2
Algorithm	A	1.1, 1.2, 1.3, 3.1,
	B	1.1, 1.2, 1.3, **2.1**, **2.2**, 3.1, **3.3**

*The outcomes are all listed in the Appendix

The above assessment results highlight some issues not covered by the continuous improvement cycle given in Section 1.1. We will address these issues in details in the rest of this section and then provide solutions in the next section.

1.4 Accreditation History

The department has already gone through two cycles of engineering education accreditation in Taiwan called *IEET Accreditation* [3]. Each cycle spans six years. The first cycle (2005 to 2011) was a foundation period for the full department [4]. The professors, students, and administration were trying to get accustomed to the routine work on collecting and organizing all sorts of information, including course syllabus, course records (grades, course work), student performance records (exams, assignments, projects), student outcome self-evaluations, and objective/outcome importance/achievement surveys by graduating students, alumni, parents, and employers.

After the foundation period, the second cycle (2011 to 2017) is still undergoing and we have seen marked progress in this period due to not only the continuous

improvement cycle implemented successfully and thoroughly by the department, but also due to the departmental improvisations implemented in the recent 3 years.

1.5 Issues in the First Accreditation Cycle

The department was granted its first accreditation in 2005, thus the first cycle covers 2005 to 2011. As mentioned earlier, this was foundation period and we encountered 3 different issues as discussed below.

- *Lack of course assessment*: Though students performed self-evaluations of the target outcomes and there were discussions on the results of course completion (average marks obtained by students and the failure rate), there was a lack of actual course assessment which created a gap between the end of a course and the next time the course is given again. This gap created problems especially if the lecturer was changed after a few years.
- *Non-real-time course improvisation*: The above issue occurred between two iterations of the same course; however, another more critical issue occurs within an iteration of the course, that is, while the course is being given. Since improvisations could only be made between two iterations of the course, the students did not get real-time benefits of course improvisation. Somehow, there was a lack of temporal effectiveness in course improvisation. Furthermore, a semester in the Taiwan education system is as long as 18 weeks which created more serious problems because the students lagging behind just could not catch up with the rest of the class and a large portion of them just gave up, after the mid-terms.
- *Lack of integrated accreditation platform*: Self-evaluations of student outcomes have to be conducted for each course each semester and the averages calculated all manually. This created serious overheads for both the administration and the lecturers. The co-relation between outcome achievements and student grades was also an interesting aspect of information that need to be investigated in more depth. Thus, an integrated accreditation platform was required.

1.6 Issues in the Second Accreditation Cycle

As illustrated by Tables 1, 2 and 3 and discussed in Section 1.3, we were faced with 3 different issues in this second cycle. We will first describe these issues here and then propose solutions in the next section.

- *Inadequate coverage of outcomes*: Since each course targets only some of the student outcomes, it was found that some of the student outcomes were selected by very few courses. For example, as shown in *Table 1*, in the year 2007, outcome 2.3 and outcome 4.1 () had, respectively, only 5 and 2 courses targeting them. In contrast, outcome 1.1 had 56 courses. This inadequate coverage of outcomes directly hindered the achievement of corresponding educational objectives. For example, the 5-year average (2006-2010) of the achievement of the corresponding undergraduate educational objectives 2 and 4 were only 3.46 and 3.24, respectively. In contrast, that of educational objectives 1 and 3 were 3.62 and 3.54, respectively. Based on the data, we can conclude that achieving objectives was directly related to coverage of outcomes.
- *Intra-course inconsistent self-evaluation*: Though self-evaluation of outcome achievement by students were classified into 5 grades, *Table 2* shows the low 4-year average grades of 3.88, 3.64, 3.46, 3.81 for several outcomes 2.1, 2.2, 2.3, 3.3, respectively, all of which was below 80% (4.0) achievement.

- *Inter-course inconsistent self-evaluation*: It was also found that two classes of the same course had different target student outcomes, which created several issues on the connection between courses in consecutive grades (sophomore and junior, etc.) As *Table 3* shows, there were several such cases in 2007.

2 DEPARTMENTAL REFINEMENT MEASURES

The two cycles of engineering education accreditation uncovered six main issues as described in Section 1, namely lack of post-course assessment, non-real-time course improvisation, lack of an integrated accreditation platform, inadequate coverage of outcomes, intra-course inconsistent self-evaluation, and inter-course inconsistent self-evaluation. In the rest of this section, we will propose solutions corresponding to each issue and then show the results of such refinement techniques in Section 3.

2.1 Post-Course Assessment

To resolve the lack of post-course assessment, at the end of each course the lecturer was required to complete an online form. To allow the lecturer to have more information, the online form consisted of how the class fared in each target student outcome, including the average, minimum, and maximum grades achieved by the class based on which learning activities corresponded to which outcome. For example, a course could have exams and final project correspond to outcome 1.2. Then, the grades of these activities were considered for evaluating how the students fared. Further, the students could also have text suggestions/comments for the lecturer. Based on the information, a lecturer had to write a note on how he/she plans to change the course contents, learning activities, etc. for the coming year.

2.2 Mid-Term Course Assessment

To resolve the issue of non-real-time course improvisation issue, mid-term course assessment was employed by having students fill in suggestions/comments, so that lecturers could dynamically change the course contents and/or teaching activities based on students' reactions. This helped not only steer the course into a slightly better direction, but also helped students achieve the target outcomes more easily.

2.3 Accreditation Integrated Course Platform

To alleviate the overhead of administration and lecturer responsibilities, the information required for accreditation was directly integrated with the course platform. For example, in the course syllabus, each learning activity was mapped to at least one of the target student outcomes. Self-evaluation of outcomes can be performed on the platform and averages computed automatically at the end of the evaluation. Mid-term course assessment and post-course assessment could be performed on the platform by referencing the evaluation results.

2.4 Setting a Minimum Coverage of Outcomes

To resolve the issue of inadequate coverage of outcomes, the department checked the number of courses for each student outcome at the beginning of the second semester in an academic year, and if any outcome had less than 5 courses, the lecturers of courses that could have covered the outcome but did not target it would be persuaded or encouraged to include that outcome as one of its targets.

2.5 Explicit Grading Standards for Self-Evaluation

To minimize the discrepancy between how a student performs self-evaluation of target outcomes in a course, explicit grading standards for self-evaluation must be provided by the lecturer at the start of the semester. The following is an example:

Grade 5: At least 80% in final marks, or in projects, or in assignments.

Grade 4: At least 60% but less than 80% in marks, or in projects, or in assignments

Grade 3: At least 40% but less than 60% in marks, or in projects, or in assignments

Grade 2: At least 20% but less than 40% in marks, or in projects, or in assignments

Grade 1: Less than 20% in final marks, or in projects, or in assignments.

2.6 Explicit Requirement for Consistent Targets

To resolve the issue of inter-course inconsistent self-evaluation, the department explicitly checked the courses that had two classes by different lecturers. Syllabus and target outcomes were checked for consistency. If there was any discrepancy, lecturers had to discuss such that they are consistent. The syllabus was not required to be completely similar, but target outcomes needed to be more consistent.

3 EFFECTIVENESS OF REFINEMENT MEASURES

The first three refinement measures, namely post-course assessment, mid-term course assessment, and accreditation integrated course platform, mainly resulted in the implementation of a platform, as shown in *Fig. 1*. The students and lecturers could perform their duties in playing their roles for accreditation.

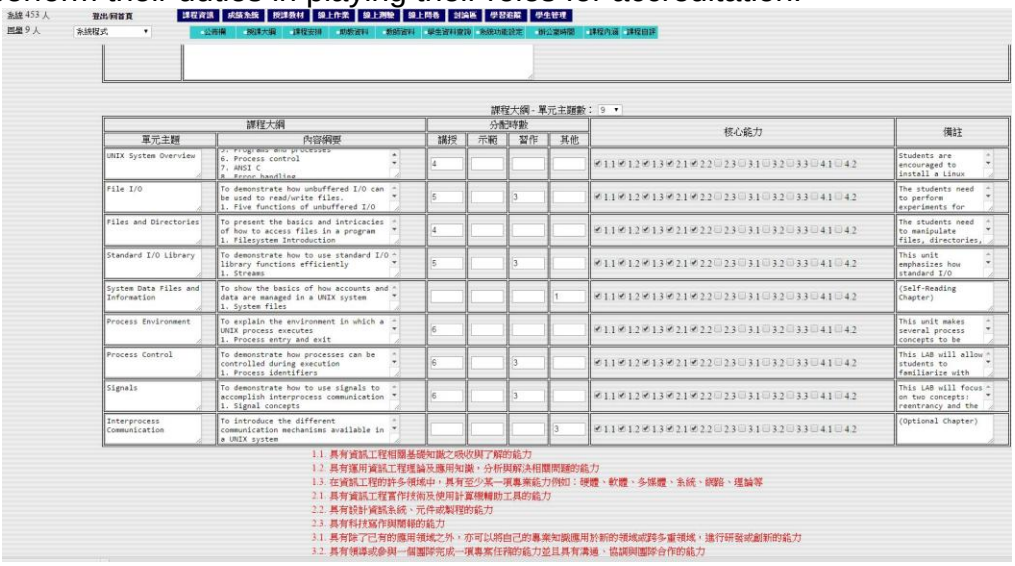

Fig. 1. CCU e-course: An Accreditation Integrated Course Platform

In the rest of this section, we will demonstrate how the other 3 refinement measures improved the accreditation results of our department.

3.1 Increased Coverage

On setting the minimum coverage of outcomes as described in Section 2.4, we could see a marked increase in coverage through the past decade. *Table 4* shows how the average coverage increased by 25% and then by 55% for outcome 2.3 in the second period of 3 years and the third period of 3 years, respectively. For outcome 4.1, the increase was even 4 folds after nine years.

Table 4. Average Coverage of Undergraduate Student Outcomes [No. of Courses]

Years	Outcome 1.1	Outcome 2.3	Outcome 4.1
2005-2007	38.00	6.67	2.67
2008-2010	56.33	8.33 (+25%)	6.33 (+137%)
2011-2013	49.66	10.33 (+55%)	14.67 (+449%)

3.2 Elevated Achievement of Target Outcomes

On applying the explicit grading standards for self-evaluation as described in Section 2.5, the initially low average student outcome assessment reached at least 4.0 for all of the outcomes. *Table 5* shows the resulting average for three 3-year periods, where finally all reached 4.0.

Table 5. Average of Undergraduate Student Outcome Assessment

Year	Outcome 1.1	Outcome 2.1	Outcome 2.2	Outcome 2.3	Outcome 3.3
2005-2007	4.07	3.69	3.49	3.49	3.88
2008-2010	3.91	3.84	3.58	3.58	3.78
2011-2013	4.13	4.10	4.00	4.08	4.10

3.3 Increased Consistency in Target Outcomes

On applying the explicit requirement for consistency, the courses that had two classes could finally have lesser discrepancies. In 2013, there were only two courses that still had a slight discrepancy.

Table 6. Target Undergraduate Student Outcomes for Some Courses in 2013

Courses	Class	Target Outcomes*
Linear Algebra	A	1.1, 1.2, 3.3
	B	1.1, 1.2, 3.3
Operating System	A	1.1, 1.2, 1.3, 2.1, 2.2, 3.3, **4.2**
	B	1.1, 1.2, 1.3, 2.1, 2.2, 3.3
Computer Organization	A	1.1, 1.3, 2.1, **4.2**
	B	1.1, 1.3, 2.1
Algorithm	A	1.1, 1.2, 1.3, 2.1, 2.2
	B	1.1, 1.2, 1.3, 2.1, 2.2

4 SUMMARY

After applying the proposed refinement measures to solve the issues found in the first two cycles of accreditation, we should see a steady and marked improvement in outcome coverage, outcome assessment, intra- and inter-course consistency. The accreditation integrated course platform also proved to be very useful in reducing the overhead in maintaining the data and performing surveys. In the future, we would like to resolve not only the above 6 issues, but also other issues from the literature [5], [6].

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APPENDIX

Under-Graduate Department Educational Objectives

1. A solid foundation in computer science knowledge so as to become professionals.
2. The use of professional knowledge and theory in solving problems and in innovation.
3. The awareness of the need for self-challenge and the ability to engage in independent thinking, creative thinking, leadership, teamwork, effective communication, and lifelong learning.
4. The awareness of the need to care for society, to have a global vision, and to contribute to the nation and mankind.

Under-Graduate Department Student Outcomes:

1.1. Capability to grasp foundational knowledge in computer science.

1.2. Capability to use computer science theory and application knowledge to analyse and solve related problems.

1.3. Professional in at least one area, including hardware, software, multimedia, system, networking, and theory.

2.1. Capability to perform computer science implementations and use computer-aided tools.

2.2. Capability to design computer systems, components, or processes.

2.3. Capability to write and present technical materials.

3.1. Capability to apply one's professional knowledge to a new application domain or across multiple different application domains.

3.2. Capability to lead or participate in group projects, with effective communication, coordination, and teamwork.

3.3. Capability to adapt to rapidly changing CS technology and to develop self-learning capabilities.

4.1. The awareness of social responsibilities, humanity, and contribution.

4.2. The awareness of engineering ethics, broad capabilities, and global and contemporary vision.

Graduate Institute Educational Objectives:

G1. The capability to perform independent academic research or to research and develop novel technologies.

G2. The capability for teamwork and for multi-disciplinary technology integration by playing the role of a leader, a strategic planner, or a manager in diverse technological teams.

G3. The awareness of the need for self challenge and the ability to engage in life-long learning.

G4. The awareness of and commitment to professional ethics and responsibilities and norms of engineering practice, while still having a global international vision.

Graduate Institute Student Outcomes:

A1. Competence in computer science and computer engineering.
A2. Be creative and be able to solve problems and to perform independent research.
A3. Demonstrate good written, oral, and communication skills, in both Chinese and English.
A4. Be able to plan and execute projects.
A5. Have communication, coordination, integration skills and teamwork in multi-disciplinary settings.
A6. Recognize the need for, and have the ability to engage in independent and life-long learning.
A7. Understand and commit to academic and professional ethics
A8. Have international view and vision of future technology.