International Journal of Engineering Education Vol. 39, No. 5, pp. 1167–1180, 2023
Printed in Great Britain

0949-149X/91 $3.00+0.00

A Successful Framework for the Accreditation of an Electrical Engineering and Automation Program*

YU GAO**, LEI YU and LIANG CHEN
School of Mechanical and Electrical Engineering, Soochow University, Suzhou 215137, China. E-mail: ygao@suda.edu.cn

The academic accreditation for an engineering program in higher education institution is helpful to enhance comprehensive qualities of graduates. Taking the Electrical Engineering and Automation (EEA) Program as an example, a framework is constructed based on the concept of Outcome Based Education (OBE) for a high quality measurement, which ensures the program to satisfy the requirement of engineering education accreditation. Particular steps are designed by taking into account the evaluation methods for educational objectives and students' outcomes. Then, a closed-loop continuous improvement process is applied to develop the program based on the assessment result of students' performances in collage and society. The achievement level of the program outcomes is evaluated by efficient methods periodically, and the assessment results are presented in the paper. The situation of graduates' competencies developed by the program is indicated, and improvements of the program are implemented based on shortcomings. In this research, work experiences for the engineering education accreditation are shown, which can be studied by institutions and universities offering corresponding programs.

Keywords: accreditation; education; outcomes; evaluation; continuous improvement

1. Introduction

The accreditation is the formal recognition to educational institutions or programs, which is executed by non-governmental and non-profit third-party organizations. It is a kind of qualification assessment rather than superiority evaluation, and is more comprehensive than examination method [1, 2]. In other words, it is an inspection of whether the education process meets the specified standards. The aim of engineering education is to cultivate personnel with engineering knowledge, skills and experience, which is crucial for economic and social development [3–5]. The accreditation for engineering education can ensure the worldwide recognition of the degrees from programs and promote the cooperation between institutions and enterprises [6, 7]. Therefore, the social adaptability and international competitiveness of engineering personnel are improved.

The Accreditation Board for Engineering and Technology (ABET) accredits college and university programs in the disciplines of applied and natural science, computing, engineering and engineering technology at the associate, bachelor's and master's degree levels [8–12]. Note that ABET is not only an authoritative nonprofit organization which controls most of accreditations in the United States, but also one of the six initiating engineering organizations of the "Washington Accord" [13]. By ABET accreditation, a program that meets the quality standards can produce graduates prepared to enter a global workforce [14, 15]. Many research results are published to discuss the experiences in a variation of disciplines, e.g., electrical engineering program [16], information system program [17], mechatronics program [18], civil engineering program [19], control engineering program [20], industrial engineering program [21], and computer science program [22]. The ABET accreditation process is carried out by four commissions. Each commission sets well-defined standards for specific program areas and degree levels. Programs leading to the professional practice of engineering are assigned to Engineering Accreditation Commission (EAC) [23], which sets eight general criteria for baccalaureate level programs [24]: (1) Students, (2) Program Educational Objectives, (3) Student Outcomes, (4) Continuous Improvement, (5) Curriculum, (6) Faculty, (7) Facilities, and (8) Institutional Support. These criteria measure the effectiveness of engineering education programs by an evaluation process focusing on the achievement of educational objectives and outcomes. Here, the most important step is to design a continuous improvement process by the assessment results of objectives and outcomes, which is directly related to criteria (2), (3) and (4). This model is known as OBE, which generally focuses on students' abilities before graduation and working careers after graduation [25–27]. The feedback information is widely collected by multiple channels for the quality assurance and accreditation purposes of engineering programs [28–32].

China Engineering Education Accreditation Association (CEEAA) was established in April

** Corresponding author.

* Accepted 14 May 2023.

2015, which is a national social organization composed of institutions and individuals in engineering domains. The association is mainly responsible for the organization and implementation of engineering education accreditation in China. It is in the charge of the Ministry of Education (MOE) and is a group member of China Association of Science and Technology (CAST). In June 2016, China represented by CAST officially joined the "Washington Accord". Consequently, engineering programs accredited by CEEAA are recognized by other member organizations of the accord.

Electrical Engineering and Automation (EEA) is an undergraduate major of colleges and universities in China, which is often a combination of electrical engineering [33–37] electronics engineering [38–40] and automation engineering [1, 41]. According to the industrial structure and development strategy, there will be a huge demand for qualified graduates of EEA, who are nurtured to be engineers with solid natural science and professional knowledge, as well as the abilities of life-long learning, international cooperation and competition. Soochow University (SU) is located in Suzhou, one of the top ten industrial cities in China. The original university was founded in 1900 by the American Methodist Episcopal Church. After more than a century of development, it becomes a key university of "Project 211", one of the first-batch universities of the "2011 Plan", a member of "the Double First-Class" Initiative and a provincial key comprehensive university of Jiangsu Province. The EEA is an undergraduate program of the School of Mechanical and Electric Engineering, and the program has been certified by MOE as one of the National First-class Undergraduate Majors in China. In order to meet the international standard, the academic accreditation is really required for the program.

In fact, an educational program should be designed and implemented to achieve the department's mission and the program's educational objectives. The collage or department must present evidence that graduates achieve acceptable levels of competencies besides technical discipline-specific knowledge. Therefore, measurements of educational objectives and student outcomes are critical for continuous improvement. The attainments are generally determined by a combination of direct and indirect methods from various stakeholders [42, 43]. Then, special faculty members selected by collage are in-charge of analyzing the data and interpreting the results for the program. This paper reveals the experience of the EEA program in the accreditation process. The quality assurance system mainly consists of the outcomes evaluation and the continuous improvement, which is carefully applied to lead a high-level engineering program to facilitate accreditation. In this framework, the use of a detailed quantitative method is involved to evaluate students' direct performances in every course, and the qualitative method is employed to complete the self-appraisal by every senior before graduation. Consequently, such mixed strategy can allow for rigorous inferences. For social information feedback, the tracking of alumni's careers is realized by questionnaire with the help of modern information and communication technologies. The weight factors for evaluations from alumni and employers are derived from correlations between positions, enterprises and the program. Moreover, relevant assessment results are demonstrated and then applied actions of the continuous improvement process are discussed.

2. Preparation for Accreditation

2.1 Missions of the EEA Program

It is known that EEA is a highly comprehensive discipline which involves many fields, such as power electronic technology, computer technology, motor technology, network control technology, and mechatronics technology. The EEA program of SU has been included in the "Excellent Engineer Education and Training Plan" by China's MOE. According to the actual situation of local manufacturing industry and the trend of "Intelligence, Greening and Cross Integration", the major is developed to focus on "Made in China 2025" scheme. The mission of the EEA program is to provide the professional education which is aimed at cultivating a new generation of senior engineers and managers for industries of power system, electronic manufacturing and intelligent equipment. Subject areas related to the discipline are demonstrated in Fig. 1.

2.2 Objectives and Outcomes of the Program

Program Educational Objectives (PEOs) describe what kind of students are expected to became within five years after graduation. The PEOs of EEA program are presented as follows:

(1) PEO-1: By using professional knowledge and engineering skills, graduates can independently find, study and solve complex engineering problems in power system, intelligent manufacturing and other related fields.
(2) PEO-2: Graduates are able to engage in related work of EEA, such as software and hardware design, application development, system integration and equipment maintenance.
(3) PEO-3: Graduates have higher scientific accomplishment and project management abil-

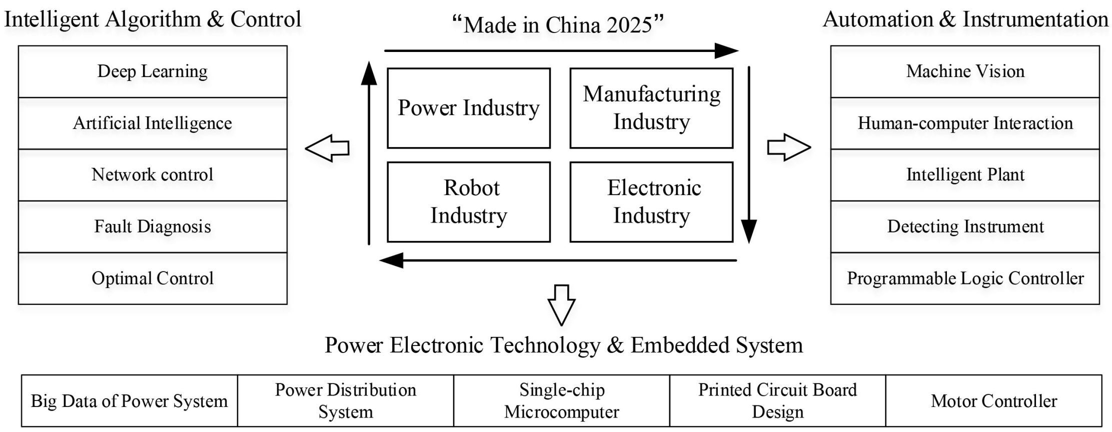

Fig. 1. Subject areas related to the discipline.

ity to play an effective role as a leader or core member in the team.

(4) PEO-4: By keeping lifelong learning, graduates can update the knowledge structure and constantly improve their professional skill, so as to meet the sustainable development of society and environment.

(5) PEO-5: Graduates have professional ethics and sense of social responsibility, which help them to serve the transformation and upgrading of local manufacturing industry.

On the other hand, Students' Outcomes (SOs) describe what kind of students are expected to foster. To meet the educational policy of the country, SOs were also referred to as Graduation Requirements (GRs) by CEEAA. The descriptions of GRs for EEA program are shown in Appendix 1. The 12 GRs fully cover the requirements of engineering accreditation standards. By considering the actual situation of the major, each requirement is further decomposed into several Detailed Rules (DRs).

2.3 The Mapping of the GRs to PEOs

The relationship between GRs and PEOs are demonstrated in Table 1. The rows represent PEOs (1 through 5) and the columns represent GRs (1 through 12). Note that each of GRs supports at least one PEO, and the mapping shows how the educational objectives are appropriately addressed.

2.4 The Mapping of Courses to GRs

The curriculum is designed according to the GRs and all courses can be classified into four categories:

- Mathematics and natural sciences.
- Engineering and specialty related.
- Practice.
- Humanities and social sciences.

Students need to obtain 160 credits in four years, in which the total credits of compulsory courses are

Table 1. The intersection of GRs and PEOs

GRs	PEO-1	PEO-2	PEO-3	PEO-4	PEO-5
GR-1	√			√	
GR-2	√			√	
GR-3	√	√		√	
GR-4	√	√			
GR-5	√	√			
GR-6		√		√	√
GR-7				√	
GR-8			√		√
GR-9			√		√
GR-10			√		√
GR-11		√	√		
GR-12				√	

136.5. In Table 2, a subset of required courses in the curriculum are listed with corresponding credits. Table 3 indicates the mapping between GRs and the courses from Table 2. The expected levels of relations are indicated as High (H), Medium (M) and Low (L). Note that the support from the curriculum to GRs is first reflected in the objectives programming of every course. For instance, the Course Objectives (COs) of ELEA3039 are developed as follows:

(1) Students are expected to master the basic knowledge of control theory and have the ability to flexibly apply the fundamentals to automatic systems. This objective is designed to support DR-2 of GR-1.

(2) Students are expected to master mathematical modeling and computer simulation methods for complex systems. This objective is designed to support DR-2 of GR-3.

(3) Students are expected to master analysis methods in the time and frequency domain, and have the ability to independently design the control algorithm. This objective is designed to support DR-2 of GR-3.

Table 2. Courses and credit hours

Course Code	Course Name	Cr. Hrs
00071012	Advanced Mathematics	5.00
00081002	General Physics	4.00
00271003	C Language Programming	4.00
00361006	Career Planning	0.50
00021013	Morality Cultivation & Basics of Law	3.00
ELEA3038	Fundamentals of Electronic Technology	5.00
ELEA3044	Engineering Economics & Management	2.00
ELEA3040	Electric Motor and Drive	4.50
ELEA2015	Power Electronic Technology	3.00
ELEA3039	Principles of Control Engineering	4.50
ELEA3041	Fundamentals of Power System	3.00
ELEA1012	Detection Technology & Meter	3.00
ELEA2026	Principles & Application of Single-chip Microcomputer	3.00
ELEA1013	Practice of Electrical Installation	1.50
ELEA1014	Project Design of Electronic Technology	2.00
ELEA1020	Production Practice	3.00
ELEA1038	Computer Aided Design of Electronic Circuits	2.00
ELEA3045	Assembling Practice of Automation	3.00

Table 3. The mapping process between courses and GRs

Course Code	GR1	GR 2	GR 3	GR 4	GR 5	GR 6	GR 7	GR 8	GR 9	GR 10	GR 11	GR 12
00071012	H	L										L
00081002	M	L										L
00271003	M	L			L							
00361006								M	L			H
00021013			L			L	M	H				
ELEA3038	L	M	L									
ELEA3044											H	
ELEA3040		H								L		
ELEA2015	L	M					L					
ELEA3039	L		M								L	
ELEA3041	L	M										
ELEA1012	L			L	M							
ELEA2026	L		H									
ELEA1013			L	L	M	L						
ELEA1014			M	H	L				M			
ELEA1020						H	H	L			M	M
ELEA1038			L		H							
ELEA3045				M			M		H	H		

(4) Students are expected to master comprehensive compensation methods for the automation system, and have the ability to solve complex engineering problems. This objective is designed to support DR-3 of GR-11.

The method to evaluate the achievement of course objectives will be discussed in next section.

3. Quality Assurance System

The members of the Education Steering Committee (ESC) is composed of deputy dean, department leader, discipline leaders, backbone faculty members and enterprise experts. In the continuous improvement process, ESC assumes a quality assurance role, which is illustrated by the flowchart in Fig. 2. The achievement of the program outcomes is evaluated periodically, and the whole process normally consists of the criteria formulation, data collection, results analysis, actions implementation and validity judgement.

Firstly, the tracking and feedback mechanism for new graduates is regarded as the inner loop, which is referred to a ''fast loop''. On the one hand, course instructors evaluate the teaching and studying

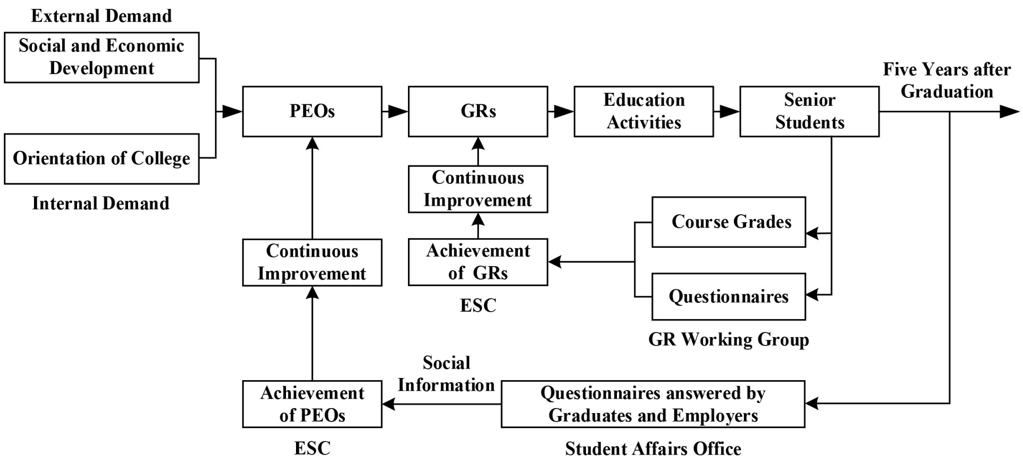

Fig. 2. The continuous improvement process.

qualities based on students' grades of all courses. On the other hand, the working group considers the qualitative achievement degree of GRs based on questionnaires collected at least once a year. After comparative analysis, the professional ESC issues the comprehensive assessment report about the accomplishment, as the basis for continuous improvement of GRs.

Secondly, the social evaluation mechanism is constructed as the outer loop, referred as a "slow loop" taking a relatively long time. National economic development needs and school professional orientation are main bases for formulating PEOs. Questionnaires answered by graduates and employers are collected by student affairs office five years after graduation. Then, the social information is fed back as the basis to evaluate and improve current PEOs. The final revision is completed by ESC and the process keeps continuous optimization though the survey experience.

3.1 Assessment Approach for the Achievement of PEOs

The evaluation of the achievement of PEOs is the need to improve and perfect the talent training process. It is known that the most common method is to connect with employers and track the career development of graduates. The achievement degree of PEOs of the program can be evaluated on a scale of 1 to 5. If the result is greater than 4 out of 5, the item is judged to be reasonable. The weighted average of two survey objects by graduates and industrial enterprises for each PEO is obtained as

$$S^i = W_G \frac{\sum_{j=1}^{N_G} GS_j^i}{N_G} + W_E \frac{\sum_{j=1}^{N_E} ES_j^i}{N_E}, \quad (1)$$

where $i \in \{1, 2, 3, 4, 5\}$ is the number of PEO; GS and ES are scores from graduates and enterprises; N_G and N_E are total amount of questionnaires fed back by graduates and enterprises, respectively. Here, W_G and W_E are weight factors for two kinds of data. Since the feedback information of employers are more reliable than data from graduates, W_E is always chosen as a constant which is larger than W_G. Actually, positions of graduates and main businesses of enterprises are also important effects. Hence, a correlation index module is purposefully designed and contained in every questionnaire, which should be checked by the respondent for the final decision of factors.

The social assessment on the quality of graduates in all aspects is the final test of whether PEOs are achieved. Firstly, the survey to students who have graduated for 5 years is implemented by head teachers and counselors in the student affairs office. The statistics of 53 online questionnaires

Table 4. The rationality evaluation of PEOs by graduates

			Percentage (%)				
PEOs	**AS**	**SD**	**5**	**4**	**3**	**2**	**1**
PEO-1	4.21	0.79	38.99	43.39	16.98	0.64	0
PEO-2	4.33	0.67	47.17	38.36	14.47	0	0
PEO-3	4.09	0.91	32.70	44.03	23.27	0	0
PEO-4	4.43	0.57	52.20	38.37	9.43	0	0
PEO-5	4.32	0.68	45.28	41.51	13.21	0	0

AS = Average Score, SD = Standard Deviation.

Table 5. The rationality evaluation of PEOs by enterprises

PEOs	AS	SD	Percentage (%)				
			5	4	3	2	1
PEO-1	4.19	0.81	0.32	0.55	0.13	0	0
PEO-2	4.29	0.71	0.39	0.52	0.09	0	0
PEO-3	4.20	0.80	0.36	0.48	0.16	0	0
PEO-4	4.44	0.56	0.45	0.53	0.02	0	0
PEO-5	4.44	0.56	0.48	0.48	0.04	0	0

AS = Average Score, SD = Standard Deviation.

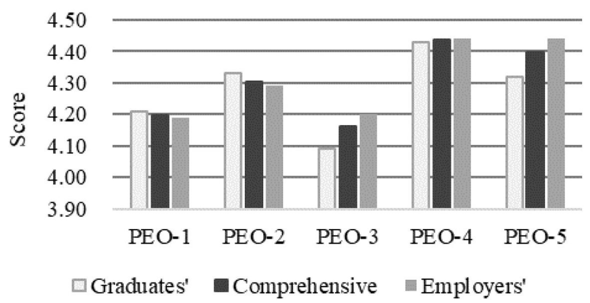

Fig. 3. The comprehensive evaluation of PEOs.

from graduates in same batch are listed in Table 4. The results show that the minimum value of the evaluation is 4.09 for PEO-3, which is larger than 4 and meets the rationality requirements of objectives. It can be concluded that graduates of EEA program think they are competent for works in related fields, but need to gradually improve their ability in the teamwork and project management through continual learning.

Besides alumni, questionnaires are also distributed to enterprises through campus job fairs, research seminars, E-mails and chat applications. For instance, items for evaluating communication and interpersonal skills of graduates are listed in Appendix 2. The results of 25 questionnaires from different employers are shown in Table 5. It can be seen that industry enterprises have high evaluation on graduates' lifelong learning, knowledge renewal and self-improvement ability. However, the lowest score is 4.19 for PEO-1, which indicate that employers hope graduates can improve the abilities to solve the complex engineering problem in manufacturing. Moreover, graduates are also expected to give a better performance in teamwork and enterprise operation, since the evaluation score is 4.20 for PEO-3.

Substituting two types of average scores into Eq. 1, the comprehensive evaluation results based on the feedback information of graduates and enterprises are illustrated in Fig. 3. By thoroughly considering the correlation situations of samples, weight factors are chosen by $W_G = 0.35$ and $W_E = 0.65$ in Eq. 1 this time. It can be seen that the minimum value is 4.16 for PEO-3. Thus, comprehensive scores of all PEOs are appropriate to standards. The result has been proved that current PEOs of the EEA program meet the needs of disciplinary orientation and industrial development. By analyzing the achievement degree, the PEOs are then revised by ESC in continuous improvement process.

3.2 Assessment Approach for the Achievement of GRs

The degree of achievement of GRs adopts a combination of quantitative and qualitative evaluation methods. The quantitative method is mainly based on the analysis of course-level grade, and the qualitative method is mainly based on the graduates' questionnaire results. Both methods take OBE as the core. The former reflects the quantitative support of teaching activities for the achievement of GRs, and the latter is a qualitative analysis of the actual ability of fresh graduates. The results obtained by the two methods can be used as a reference for continuous improvement of GRs.

The foothold of whether the GRs can be achieved is the curriculum syllabus. Therefore, the syllabus and teaching framework should be designed to support the measurable basis, which means that teaching objectives of every course need to correspond to DRs of related GRs. The direct performance of students to each course can be measured by quizzes, assignments, midterm exams, experiments, reports and final exams. Here, course ELEA3039 is still chosen as an example, and COs which support GRs have already been introduced in section 2. The comprehensive grades of students are composed of necessary items by 10% (quizzes), 20% (experiments), 10% (midterm exam) and 60% (final exam). The particular rules for the achievement evaluation are indicated in Table 6. Then, the course instructor evaluates achievement level by

$$Achievement = \frac{\sum_{i=1}^{N} AS_i * Pct_i}{\sum_{i=1}^{N} Scores_i * Pct_i}, \quad (2)$$

where AS_i is average score of the corresponding

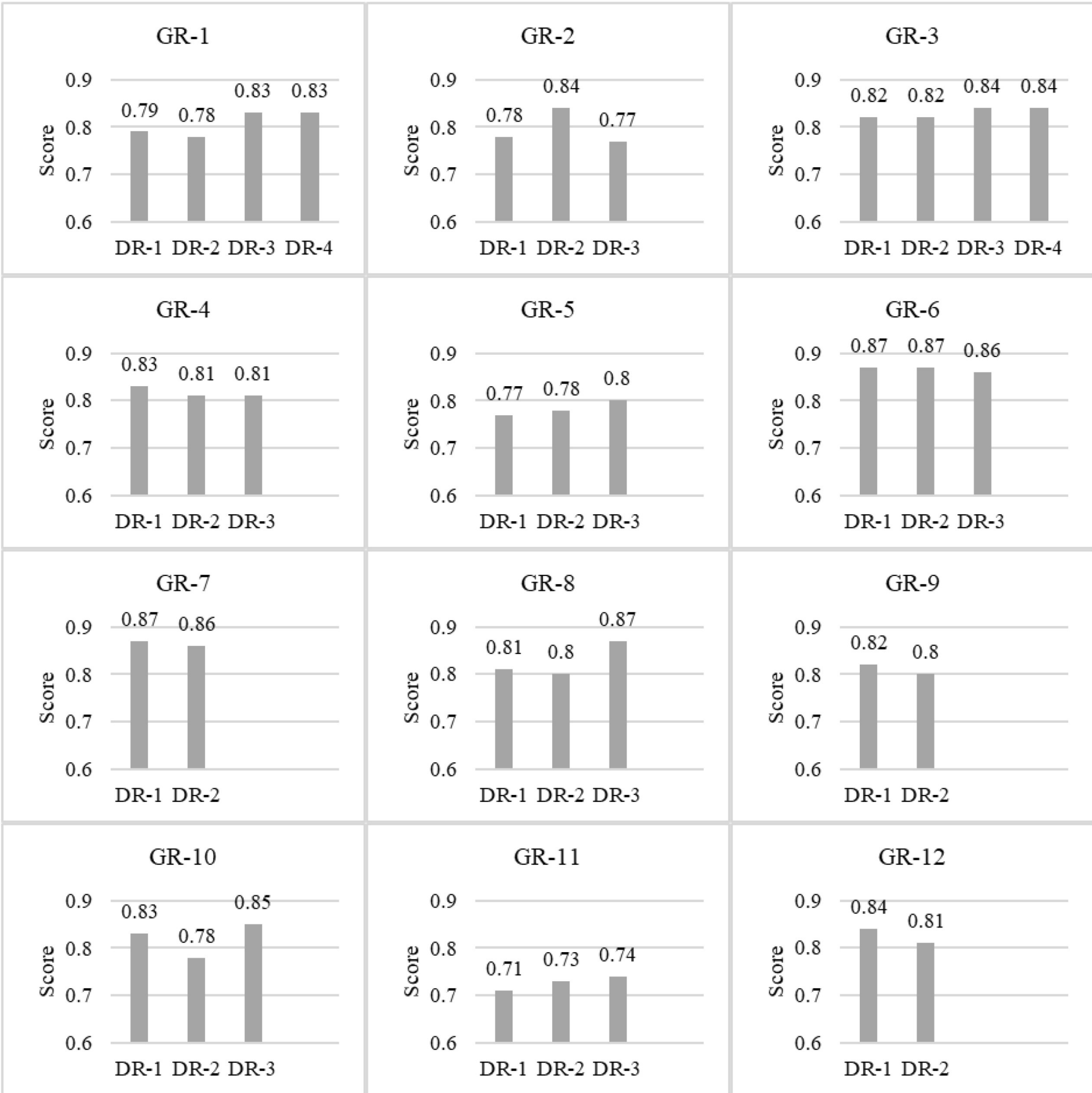

Fig. 4. Achievement of GRs based on courses.

item, N is the number of items for corresponding CO. Such specific rubrics are designed to contain more precise assessments instruments than previous approaches. The result is discussed and the achievement is concluded in the final course report by instructor every semester. Finally, the achievement of a detailed requirement rule is obtained by the weighted summation of all supportive courses in the last semester.

The results of quantitative analysis are shown in Fig. 4. By considering the threshold of 0.7, achievement levels of DRs belong to GR-11 perform weakest, which show that students lack the ability to apply engineering economic and management knowledge in a multidisciplinary environment. The reason is that teaching and studying activities in existing curriculum system have not achieved the expected effect. The improvement methods include adjusting the relevant curriculum and optimizing the syllabus of courses.

The questionnaire analysis method is concerned with the ability evaluation of fresh graduates. The content of questionnaire consists of items corresponding to GRs. As the survey basis, the score of each item is made into 5 grades (very good, good, general, poor, very poor). The average score and score distribution are counted by results of questionnaires answered by fresh graduates.

In Fig. 5, achieving degree of GRs judged by the survey of fresh graduates are illustrated. The low

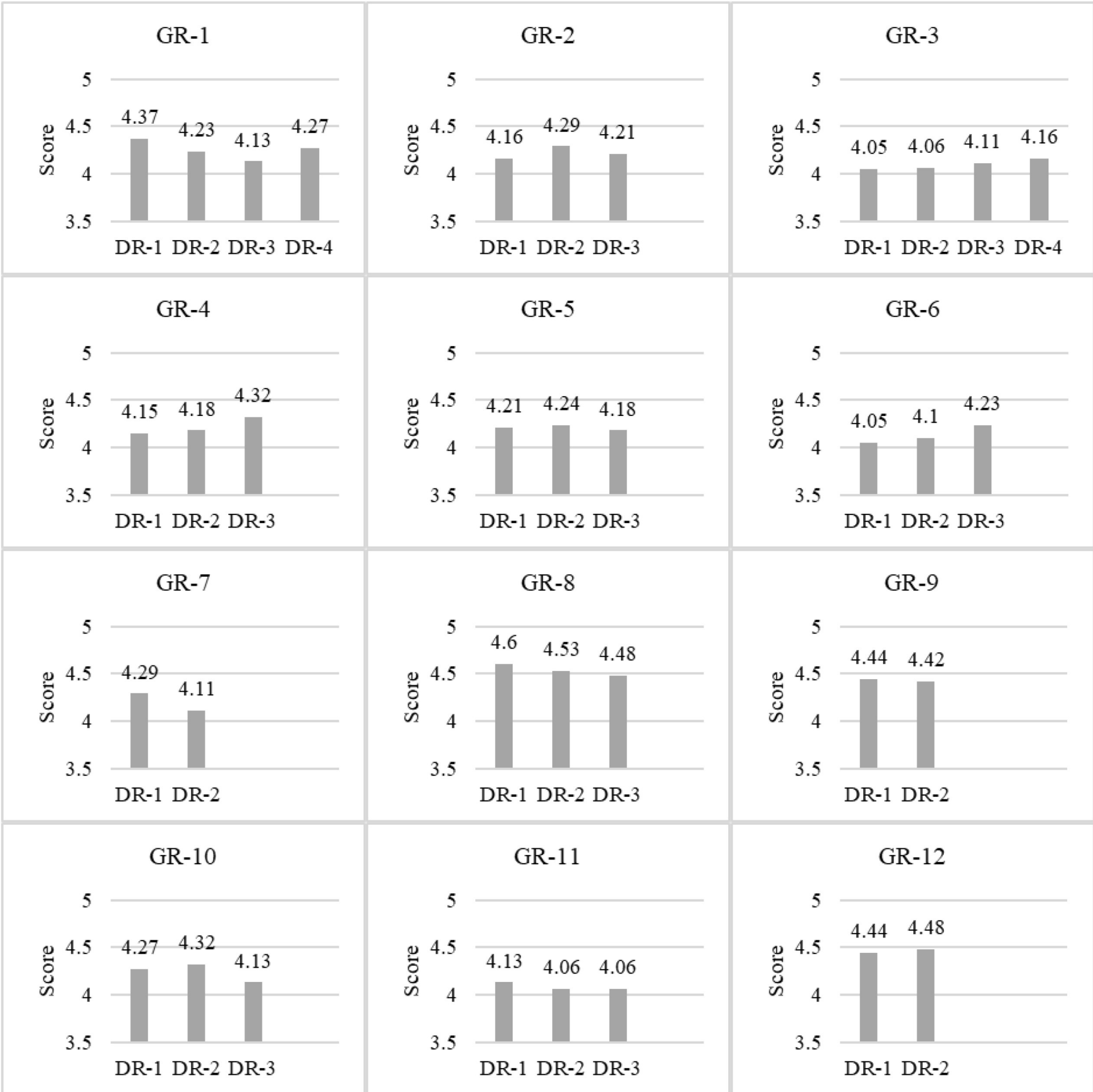

Fig. 5. Achievement of GRs based on questionnaires.

scores 4.05 and 4.06 appears in GR-3, which indicate that graduates feel inadequate in system design of complex systems. Meanwhile, score 4.05 in GR-6 demonstrate that graduates think they have insufficient comprehension of relevant standards, rights, policies and regulations in electrical and automation fields. The result is slightly different from corresponding quantitative analysis, which reflects that graduates pay more attention to the cultivation of these abilities subjectively. In addition, two kinds of achievement evaluations to GR-11 give similar results in Fig. 4 and Fig. 5, which indicate the necessity to strengthen the capacity-building of engineering management and economic decision-making.

Based on qualitative and questionnaire results, the general assessment report is summarized annually by GR working group, which is composed of department leader, teaching-affair secretary, discipline leaders and backbone course instructors.

4. Continuous Improvement Process

The core concept of professional accreditation is to build a closed-loop continuous improvement framework with OBE, as shown in Fig. 2. The feedback loops mainly include:

(1) A closed-loop of education quality supervision.
(2) A closed-loop of the achievements of GRs.
(3) A closed-loop of the social assessment.

Firstly, through the supervisory control of teach-

Table 6. Evaluation rules for the achievement of COs

COs	Items	Content	Scores	Pct.
CO-1	Qs	1. Basic features and configurations of control system. 2. Schematic and functional block diagram	15	20%
	ME		30	20%
	FE		25	60%
CO-2	Qs	1. Mathematic model of system. 2. Laplace transform. 3. Block diagram reduction.	15	10%
	ME		50	10%
	FE		20	60%
	Es		20	20%
CO-3	Qs	1. Performance criteria in time-domain. 2. Routh-Hurwitz criterion 3. Root Locus 4. Bode plots. 5. Nyquist Diagram and stability.	40	10%
	ME		20	10%
	FE		40	60%
	Es		60	20%
CO-4	Qs	1. PID control. 2. Lag compensator. 3. Lead compensator. 4. Lag-Lead compensator.	30	20%
	FE		15	60%
	Es		20	20%

Qs = quizzes, ME = midterm exam, FE = final exam, Es = experiments, Pct. = percentage.

ing links and the quality evaluation of curriculum achievements, the continuous improvements of teaching activities, curriculum outline, teaching faculty and supporting conditions are realized. Fig. 6 can be regarded as the refinement and supplement to Fig. 2. The evaluation for the achievement of course objectives is based on the final report which is finished by course instructor every semester and reviewed by discipline leader. It is regarded as the basis for continuous improvement of teaching activities. Furthermore, every student should finish an online questionnaire before querying the grade. The statistic result covers ten aspects about the effectiveness, which would help the instructor to optimize the teaching procedure.

Secondly, through the evaluation of the achievement levels of senior students before graduation, the continuous improvements of GRs (including DRs of GRs) and curriculum outline are realized, see Fig. 2 or Fig. 6. The main task of this framework is the quantitative evaluation based on curriculum achievement and the qualitative evaluation based on graduates' questionnaire survey. Here, the latter work is implemented online and the analysis results are generated automatically.

Finally, through regular evaluation of the rationality and achievement, the continuous improvements of PEOs are realized. The main task of this framework is to conduct a questionnaire survey on alumni and their employers five years after graduation, which is previously illustrated in Fig. 2. The main purpose is to enhance the relevance of PEOs and the needs of industrial and technology development, as well as the school orientation and the trend of professional development. Since contact groups for graduates are established by chat applications, careers of alumni can be continuously tracked. Similarly, the communication groups of enterprises are also maintained by the responsible faculty. By this way, the social feedbacks of alumni are obtained. Meanwhile, the industry forum and campus recruitment can be organized annually.

From the perspective of cybernetics, the above three closed-loops constitute a cascade control system. According to the control and optimization theory, the improvement is implemented on the loop of education quality supervision. Each semester, the instructor of every course finishes the "Grade Analysis" and "Course Summary" based on the performance of students, and evaluates whether the course objectives have been achieved. After being reviewed by the discipline leader, it can be used as the basis for the continuous improvement of teaching activities. Then, the "tracking and feedback framework for fresh graduates" in the second loop evaluates the achievement levels of GRs. Based on the comparative analysis of quantitative and qualitative results from GR Working Group, the ESC issues the "Comprehensive Evaluation Report on Achievement Performance of Graduation Requirements", as the basis for continuous improvement of GRs every year. The "social evaluation framework" is in the outermost loop and economic needs and professional orientation are the main basis for improving PEOs. The student affairs office of SU organized to collect the "feedback questionnaires for graduates" and "feedback questionnaires for employers".

The results in Fig. 4 and Fig. 5 can be considered together for deep analysis by

$$CSocre_j^i = \sqrt{\left(\tilde{S}_j^i\right)^2 + \left(\bar{S}_j^i\right)^2}, \qquad (3)$$

where $CSocre_j^i$ is the comprehensive achievement of GR-i (DR-j), $\tilde{S}_j^i$ and $\bar{S}_j^i$ are corresponding

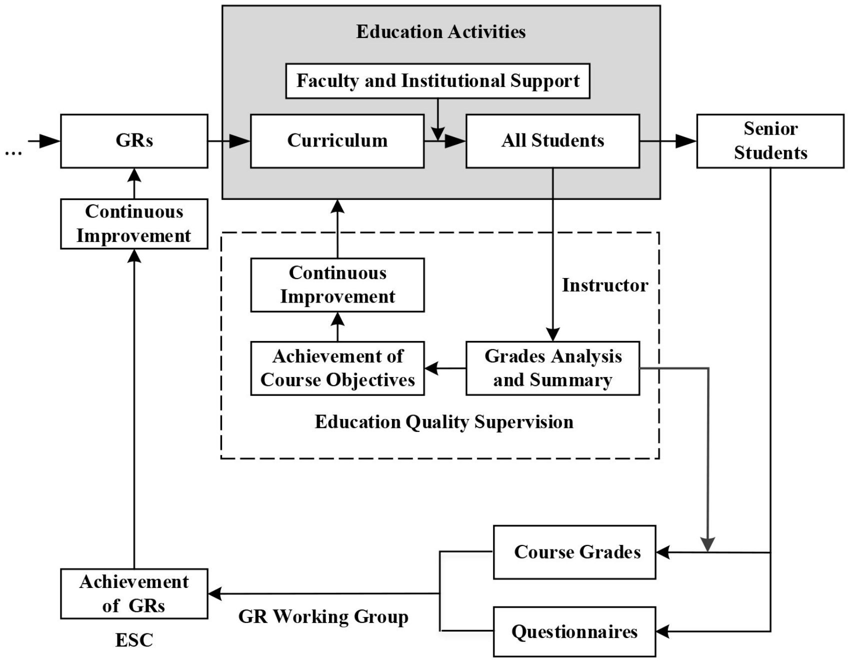

Fig. 6. Education quality assurance system.

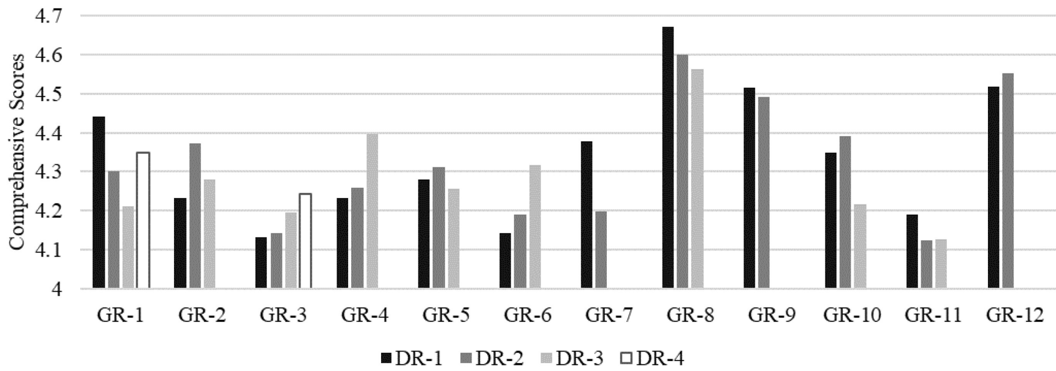

Fig. 7. Comprehensive achievement of GRs.

scores in Fig. 4 and Fig. 5, respectively. By inspecting the final results illustrated in Fig. 7, the ESC concluded that GR-3, GR-6, GR-7 and GR-11 were seemed to be in need of improvement. Based on the conclusion, major common changes for courses of the curriculum system are the following.

(1) In Jan. 2018, it was decided to introduce a new course "Introduction of Automation" in second semester. The course objectives supported GR-6, GR-7 and GR-11. The primary teaching objective of the course is to develop the ability to solve the complex industrial problem under the consideration of various external factors, and then, understand engineering management principles.
(2) In Feb. 2018, it was decided to revise the outline of "Principle of control engineering". The knowledge about performance index in frequency domain and feedforward correction were deleted. More knowledge about the PID method for system correction was added into the teaching content, which was expected to support GR-11. In addition, two new experimental modules were added to simulate complex systems, which were expected to support GR-3 deeply.
(3) In Feb. 2019, it was decided to revise the outline of "Computer control system". The knowledge of modern control theory was replaced by the introduction of intelligent control for perturbation system, which was expected to support GR-3.
(4) In Feb. 2019, it was decided to introduce a new course "Research & Innovation Practice" in third semester. The course objectives supported

GR-6, GR-7, GR-8, GR-11 and GR-12. In this course, students are expected to master the software and hardware knowledge about localization, mapping, navigation and auto driving. The module of a competitive tender simulation is designed to develop the abilities about teamwork, commercial competition and intellectual property protection.

(5) In Feb. 2020, it was decided to revise the outline of "English for Academic Purposes". Increase the proportion of the peacetime grade in the final result. Every student's performance of English presentation was mainly considered. It was developed to support GR-10 about the training of international communication abilities.

(6) In Feb. 2020, it was decided to introduce a new course "Philosophy and Ethics of Engineering" in seventh semester. The course objectives supported GR-6, GR-7, GR-8 and GR-9. The primary objective is to develop the abilities to evaluate the rationality of industrial project and its effects to human, society and environment.

(7) In Sep. 2021, it was decided to revise the outline of "Fundamentals of Electric Technology". New experiments about the medium scale integrated counter and the construction of frequency divider were introduced to improve the achievement of GR-1.

(8) In Sep. 2021, it was decided to introduce a new course "Professional labor education practice" in second semester. The course objectives supported GR-3, GR-6 and GR-9. In this course, students need to complete a vegetable planting experiment in the smart farm with multi-sensor monitor and control system. The primary objective is to develop the abilities to design the process and solve relevant problems by the consideration of various effects.

Above improvements to the curriculum make the GRs more fully supported, and new courses focus on cultivating students' practical abilities. Furthermore, the continuous optimization of GRs was discussed at a symposium organized by GR Working Group. By considering opinions of experts from enterprises and other universities, improvements for detail rules of GRs were implemented as follows:

(1) The DR-3 of GR-6 was revised as:
Consider the comprehensive solution for a complex engineering problem, and intensify the protection of intellectual property though legal means.

(2) The DR-2 of GR-7 was revised as:
Formulate safety precautions in solving complex engineering problems and judge the possible harm to people in the process.

(3) The DR-3 was added in GR-7 as:
Reasonably solve complex engineering problems by applying relevant theories of environmental protection and sustainable development.

The effectiveness of improvements will be confirmed by feedback information from the evaluation system.

5. Conclusion

The reform of engineering education in China was promoted by introducing the OBE concept. The educational model is expected to transform from curriculum orientation to outcome orientation, teacher-centered to student-centered, and quality supervision to continuous improvement. To realize these three transformations, higher education institutions will know the key of professional accreditation, which assists in academic program quality by effecting changes in the curricular content, educational plan, teaching methodologies, practices activities, and result assessment.

In this paper, measurement approaches for outcomes achievement, especially by students' performances and social judgements, are very effective tools for program assessment and evaluation. Then, the achievement results are analyzed and corresponding actions are proposed as changing plans implemented for continuous improvement. Encouragingly, the EEA program passed the accreditation by CEEAA in 2018. However, some challenges are encountered during the process, involving the efficient applications of new educational concepts and criteria in all courses by instructors. The others include the workload of the faculty members, the close contact with enterprises, and the functional management mechanism. Further, strategies and methodologies adopted in this research can be applied to many different programs seeking the engineering education accreditation.

References

1. A. C. D. N. Gomes, F. S. Madani, J. E. B. Maia, M. C. Pereira and M. H. D. Queiroz, Contributions of ENADE to the Assessment of Control and Automation Engineering in Brazil, *IEEE Transactions on Education*, **64**(2), pp. 124–132, 2021.
2. D. W. Parent, Improvements to an Electrical Engineering Skill Audit Exam to Improve Student Mastery of Core EE Concepts, *IEEE Transactions on Education*, **54**(2), pp. 184–187, 2011.

3. J. E. Froyd, P. C. Wankat and K. A. Smith, Five major shifts in 100 years of engineering education, *Proceedings of the IEEE*, **100**, pp. 1344–1360, 2012.
4. C. R. Smaill, G. B. Rowe, E. Godfrey and R. O. Paton, An Investigation Into the Understanding and Skills of First-Year Electrical Engineering Students, *IEEE Transactions on Education*, **55**(1), pp. 29–35, 2012.
5. F. Gider, B. Likar, T. Kern and D. Miklavcic, Implementation of a Multidisciplinary Professional Skills Course at an Electrical Engineering School, *IEEE Transactions on Education*, **55**(3), pp. 332–340, 2012.
6. J. Uziak, M. T. Oladiran, M. Walczak, J. Vergara and M. M. Ilabaca, Requirements, Challenges and Consequences in Accreditation of Engineering Programmes, *International Journal of Engineering Education*, **33**(1), pp. 187–202, 2017.
7. L. S. Lee, H. M. Ko and M. T. Wang, Quality of Accreditation Services for Engineering Programs, *International Journal of Engineering Education*, **33**(4), pp. 1335–1344, 2017.
8. About ABET, http://www.abet.org/about-abet/, Accessed 1 January 2022.
9. A. F. Almarshoud, Developing a Rubric-Based Framework for Measuring the ABET Outcomes Achieved by Students of Electric Machinery Courses, *International Journal of Engineering Education*, **27**(4), pp. 859–866, 2011.
10. H. A. Al-Twaijry, M. C. Mekhallalati, H. R. Abachi and G. Muhammad, A Rubrics Based Quality Improvement Methodology for ABET Accreditation, *International Journal of Engineering Education*, **28**(6), pp. 1266–1273, 2012.
11. J. C. McNeil and M. W. Ohland, The Influence of ABET Accreditation Practices on Faculty Approaches to Teaching, *International Journal of Engineering Education*, **32**(3), pp. 1151–1159, 2016.
12. M. Rashid, A Systematic Approach of Data Preparation for ABET Accreditation, *International Journal of Engineering Education*, **37**(1), pp. 172–184, 2021.
13. M. T. Oladiran, G. Pezzota, J. Uziak and M. Gizejowski, Aligning an Engineering Education Program to the Washington Accord Requirements: Example of the University of Botswana, *International Journal of Engineering Education*, **29**(6), pp. 1591–1603, 2013.
14. C. Turhan, G. Sengul and M. Koyuncu, A Comprehensive Assessment Plan for Accreditation in Engineering Education: A Case Study in Turkey, *International Journal of Engineering Education*, **31**(5), pp. 1270–1281, 2015.
15. E. Matemba and N. Lloyd, Internationalisation of Professional Engineers: A Review of Globalisation of Engineering Education and Accreditation-Challenges from an African Perspective, *International Journal of Engineering Education*, **33**(6), pp. 2083–2097, 2017.
16. S. A. Al-Yahya and M. A. Abdel-halim, A Successful Experience of ABET Accreditation of an Electrical Engineering Program, *IEEE Transactions on Education*, **56**(2), pp. 165–173, 2013.
17. W. Rashideh, O. A. Alshathry, S. Atawneh, H. A. Bazar and M. S. AbualRub, A Successful Framework for the ABET Accreditation of an Information System Program, *Intelligent Automation and Soft Computing*, **26**(6), pp. 1285–1307, 2020.
18. M. G. Aparicio, J. R. Reséndiz, G. M. Bobadilla and S. Thenozhi, A Multidisciplinary Industrial Robot Approach for Teaching Mechatronics-Related Courses, *IEEE Transactions on Education*, **61**(1), pp. 55–62, 2018.
19. M. I. Khan, S. M. Mourad and W. M. Zahid, Developing and qualifying Civil Engineering Programs for ABET accreditation, *Journal of King Saud University Science*, **28**, pp. 1–11, 2016.
20. S. Wang, F. Zhang, Q. Tang, X. G. Zhang and R. X. Zhao, A Take-Home Motor Control Teaching Experiment Platform for Control Engineering-Related Courses, *IEEE Transactions on Education*, **65**(2), pp. 115–123, 2022.
21. K. J. Min, J. Jackman and D. Gemmill, Assessment and Evaluation of Objectives and Outcomes for Continuous Improvement of an Industrial Engineering Program, *International Journal of Engineering Education*, **29**(3), pp. 520–532, 2013.
22. A. Shafi, S. Saeed, Y. A. Bamarouf, S. Z. Iqbal, N. M. Allah and M. A. Alqahtani, Student Outcomes Assessment Methodology for ABET Accreditation: A Case Study of Computer Science and Computer Information Systems Programs, *IEEE Access*, **7**, pp. 13653–13667, 2019.
23. M. Saleem, A. U. Zaman, M. Aman and F. Albatati, A Proposed Roadmap of Transition to the New EAC-ABET Student Outcomes, *International Journal of Engineering Education*, **37**(3), pp. 761–768, 2021.
24. Criteria for Accrediting Engineering Programs, 2020–2021, Available: https://www.abet.org/accreditation/accreditation-criteria/, Accessed 1 January 2021.
25. R. M. Harden, Developments in outcome-based education, *Medical Teacher*, **24**(2), pp. 117–120, 2002.
26. R. M. Harden, Outcome-based education: The future is today, *Medical Teacher*, **29**(7), pp. 625–629, 2007.
27. M. Z. Zamir, M. I. Abid, M. R. Fazal, M. A. A. R. Qazi and M. Kamran, Switching to Outcome-Based Education (OBE) System, a Paradigm Shift in Engineering Education, *IEEE Transactions on Education*, **65**(4), pp. 695–702, 2022.
28. J. S. Cicek, S. Ingram and N. Sepehri, Outcomes-Based Assessment in Action: Engineering Faculty Examine Graduate Attributes in their Courses, *International Journal of Engineering Education*, **30**(4), pp. 788–805, 2014.
29. I. Damaj and J. Yousafzai, Effective Assessment of Student Outcomes in Computer Engineering Programs using a Minimalistic Framework, *International Journal of Engineering Education*, **35**(1), pp. 59–75, 2019.
30. I. Damaj and A. A. Kranov, Sustainable Practices in Technical Education: A Quality Assurance Framework, *International Journal of Engineering Education*, **33**(5), pp. 1627–1642, 2017.
31. D. Dustegor, Analytical Tool for the Modelling and Simulation of Curriculum: Towards Automated Design, Assessment, and Improvement, *International Journal of Engineering Education*, **35**(2), pp. 645–657, 2019.
32. M. Danaher, A. Rhodes and A. A. Kranov, Applying the Computing Professional Skills Assessment Method to ESL Students in a Computing Program, *International Journal of Engineering Education*, **37**(5), pp. 1429–1440, 2021.
33. B. K. Jesiek and L. H. Jamieson, The Expansive (Dis) Integration of Electrical Engineering Education, *IEEE Access*, **5**, pp. 4561–4573, 2017.
34. A. Valentine, I. Belski, M. Hamilton and S. Adams, Creativity in Electrical Engineering Degree Programs: Where Is the Content?, *IEEE Transactions on Education*, **62**(4), pp. 288–296, 2019.
35. P. Shekhar and M. Borrego, After the Workshop: A Case Study of Post-Workshop Implementation of Active Learning in an Electrical Engineering Course, *IEEE Transactions on Education*, **60**(1), pp. 1–7, 2017.
36. L. L. Zhang and Y. Z. Lei, Dissemination of the Phasor Method in Electrical Engineering in China, *IEEE Transactions on Education*, **57**(1), pp. 20–24, 2014.
37. G. Naveh and D. Bykhovsky, Online Peer Assessment in Undergraduate Electrical Engineering Course, *IEEE Transactions on Education*, **64**(1), pp. 58–65, 2021.

38. J. Kittur, Measuring the Programming Self-Efficacy of Electrical and Electronics Engineering Students, *IEEE Transactions on Education*, **63**(3), pp. 216–223, 2020.
39. F. Martinez-Rodrigo, L. C. H. D. Lucas, S. D. Pablo and A. B. Rey-Boue, Using PBL to Improve Educational Outcomes and Student Satisfaction in the Teaching of DC/DC and DC/AC Converters, *IEEE Transactions on Education*, **60**(3), pp. 229–237, 2017.
40. V. Vodovozov and Z. Raud, Concept Maps for Teaching, Learning, and Assessment in Electronics, *Education Research International*, pp. 1–9, 2015.
41. A. Canedo, P. Goyal, D. Huang, A. Pandey and G. Quiros, ArduCode: Predictive Framework for Automation Engineering, *IEEE Transactions on Automation Science and Engineering*, **18**(3), pp. 1417–1428, 2021.
42. W. Hussain, W. G. Spady, M. T. Naqash, S. Z. Khan, B. A. Khawaja and L. Conner, "ABET Accreditation During and After COVID19–Navigating the Digital Age," *IEEE Access*, **8**, pp. 218997–219046, Dec. 2020.
43. N. E. Kadhi and M. M. Bunagan, Assessment Methodologies for Abet Accreditation: Success Factors and Challenges, *International Conference on Frontiers in Education: Computer Science and Computer Engineering*, pp. 116–122, 2015.

Appendix 1

Graduation Requirements

GRs	Description	
GR-1	Apply the knowledge of mathematics, natural science and engineering fundamentals to solve complex engineering problems of electrical systems and industrial automation systems.	
	DR-1	Acquire the mathematical knowledge which can be used for studying, modeling, analyzing and solving the engineering problem.
	DR-2	Apply the knowledge of automation, computer, detection and instrument technology to solve the control problem.
	DR-3	Master the basic knowledge of circuit principle and electronic technology, and have the ability to analyze and design the electrical system.
	DR-4	Be familiar with a programming language and use it to realize the algorithm to solve the complex engineering problem.
GR-2	Identify and analyze problems of complex electrical systems and industrial automation systems, and draw valid conclusions.	
	DR-1	Use mathematical and engineering knowledge to identify and analyze complex engineering problems in professional fields.
	DR-2	Through literature retrieval, acquire various solutions of a complex engineering problem.
	DR-3	Analyze the influencing factors and key links of a complex engineering problem, and verify the rationality of the solution.
GR-3	Design particular processes of complex electrical systems and industrial automation systems to meet specified needs with appropriate consideration of society, health, security, law, culture and environment.	
	DR-1	Complete software and hardware requirements analysis of complex electrical and automation systems.
	DR-2	Design algorithms and programs according to requirements, and validate the correctness.
	DR-3	Optimize the design scheme of software and hardware by innovation concept.
	DR-4	For engineering problems, identify factors referred to society, health, security, legal, culture and environment issues, and analyze the effectiveness of setting.
GR-4	Based on scientific principles and methods, study problems of complex electrical systems and industrial automation systems to provide valid conclusions by designing experiments, analyzing data and integrating information.	
	DR-1	Propose research plans and design experimental schemes based on the expertise of electrical and automation domains.
	DR-2	Construct experimental devices or simulation systems, and use scientific methods to carry out experiments safely.
	DR-3	Collect and analyze experimental data, and draw valid conclusions.
GR-5	Develop, select and apply appropriate modern tools for complex engineering problems to realize predictions and simulations.	
	DR-1	Properly use computer software to complete the simulation of electrical and automation engineering projects.
	DR-2	Use electronic instruments and other devices to determine key parameters of electrical and automation systems.
	DR-3	Use modern tools to verify, analyze and predict the performance of electrical and automation systems.
GR-6	Evaluate the rationality of the solution to a complex engineering problem and understand the impact on health, culture, legal, society and security issues.	
	DR-1	Understand relevant technical standards, intellectual property rights, industrial policies, laws and regulations in the field of electrical engineering and automation.
	DR-2	Understand the impact of electrical engineering on industrial automation, intelligent manufacturing and social progress.
	DR-3	Have experiences in engineering practice and understand the corresponding social responsibility.

GR-7	Understand the impact of professional engineering practice to environmental and social sustainable development.	
	DR-1	Understand the specific connotation and significance of environmental protection and social sustainability, and be familiar with corresponding guidelines, policies, laws and regulations.
	DR-2	Evaluate the efficiency of an automation project, and formulate safety precautions to prevent possible harm to human beings.
GR-8	Have scientific literacy and social responsibility, and understand professional ethics and norms in engineering practice.	
	DR-1	Have humanistic knowledge, critical thought, and scientific spirit.
	DR-2	Have correct outlook on life and the world.
	DR-3	Understand responsibilities of an electrical engineer, and abide by professional ethics and norms in engineering practice.
GR-9	Function effectively in a teamwork as the core member or leader in order to accomplish the common goal.	
	DR-1	Play a personal role and assume responsibilities in the team.
	DR-2	Have the ability of organization, and complete tasks by cooperating with team members.
GR-10	Have a global outlook in order to effectively communicate and exchange ideas with industry peers and the public.	
	DR-1	Be able to express key technologies and difficulties of engineering problems orally or in writing, and effectively communicate with the public and peers.
	DR-2	Have a good command of foreign language, and skillfully read and write materials related to engineering technology.
	DR-3	Have an international vision to achieve cross-cultural communication, technical exchange and project cooperation.
GR-11	Understand engineering management principles and master economic decision-making methodologies, which can be applied in a multidisciplinary environment.	
	DR-1	Master the management knowledge of industrial enterprise and electrical engineering project.
	DR-2	Understand the economic and managerial factors involved in engineering activities, and analyze the specific problems.
	DR-3	Apply the knowledge, principles and methods of economics and mathematics in the planning, design and research of automation system.
GR-12	Have the awareness of independent and lifelong learning for the adaption to society development.	
	DR-1	Understand the necessity of continuous exploration, and have the awareness of autonomous and lifelong learning.
	DR-2	According to personal or professional development needs, adopt appropriate methods to continuously improve and expand learning ability.

Appendix 2

Items for Evaluating Communication and Interpersonal Skills

• Friendly cooperate with team members to solve complex engineering problems.	□ 5 □ 4 □ 3 □ 2 □ 1
• Have abilities of oral presentation and written description for a team work.	□ 5 □ 4 □ 3 □ 2 □ 1
• Accept good advices with an open mind and be brave to face mistakes.	□ 5 □ 4 □ 3 □ 2 □ 1
• Be thoughtful and give the help to colleagues at appropriate time.	□ 5 □ 4 □ 3 □ 2 □ 1
• Be patient and responsible when having conflicts with colleagues.	□ 5 □ 4 □ 3 □ 2 □ 1
• Smoothly communicate with technicians of foreign companies for projects.	□ 5 □ 4 □ 3 □ 2 □ 1
• Proficient in reading and writing for technical documents by a foreign language.	□ 5 □ 4 □ 3 □ 2 □ 1

Yu Gao received his PhD degree in electronics engineering from Chonbuk National University, Korea, in 2012. He is a lecturer in the School of Mechanical and Electrical Engineering, Soochow University. His research interests include model predictive control, optimal control, and robust control.

Lei Yu received the PhD degree from the College of Automation, Southeast University, Nanjing, China, in 2011. He is currently a Professor with the School of Mechanical and Electric Engineering, Soochow University, Suzhou, China. His current research interests include human-computer interaction, filter systems, robust control, and so on.

Liang Chen received his PhD degree in control engineering from a joint PhD program at Zhejiang University & TU Berlin in 2009. He is now a Professor and the Assistant Dean of the School of Mechanical and Electric Engineering, Soochow University. His research interests include intelligent robots and deep learning based intelligent control.