DEVELOPMENT AND APPLICATION OF A RUBRIC SPECIFIC FOR THE SENIOR-YEAR GRADUATION DESIGN PROJECTS FOR ASSESSING LEARNING OUTCOMES

Yangin-Gomec Cigdem, Kose-Mutlu Borte, Dulekgurgen Ebru, Ozturk Izzet, Tanik Aysegul

Istanbul Technical University, Istanbul, Turkey.

Abstract

This paper discusses the modifications in the "*Graduation Design Project*" -a senior-year course in Environmental Engineering Undergraduate Program (EEUP) of Istanbul Technical University (ITU)- which were implemented primarily for improving students' learning skills in environmental engineering design, and also for better assessment and evaluation (A&E) of the learning outcomes adopted from those set by ABET Engineering Accreditation Commission (EAC) in Program Criteria for Environmental and Similarly Named Engineering Programs. This paper also includes an extensive description of steps taken to ensure consistency among student team projects, detailed grading rubrics, and an overview of the overall grading system for Graduation Design Projects (GDPs). Comparative evaluation of outcome (OC) based assessment results from 8 semesters indicates that the senior-year GDP course falls short in achieving the targeted performance regarding OC1 and OC5 that addresses the freshman and sophomore/junior year levels, respectively. Assessment results from 8 semesters also indicates that the senior-year GDP course falls short in achieving the targeted performance regarding OC8 that addresses sophomore/junior/senior years. Hence, GDP course needs to be reviewed/improved with respect to those outcomes, yet it is distinctly successful in realizing the learning outcomes addressing junior and senior years (OC7&11), as well as those others addressing sophomore/junior/senior years (OC3&4).

Key words

Accreditation, Engineering Programs, Environmental Engineering, Graduation Design Project, Learning Outcomes, Rubric

1. Introduction

Since its foundation more than 200 years ago as the very first engineering school of the country and among the earliest examples at the region, Istanbul Technical University (ITU) has been one of the leading engineering higher education institutions of Turkey (1). Spread to 5 campuses in Istanbul and housing 12 engineering faculties, 29 engineering departments and a total of 39 undergraduate programs, ITU serves to more than 30,000 students, of which about 25,000 of them are undergrads. In addition to engineering education, high-quality scientific and technological research and development (R&D) are supported through the activities of several research centres including those of "National High Performance Computing, Satellite Communications and Remote Sensing, Molecular Biology-Biotechnology and Genetics

Research, Disaster Management, Materials Science and Manufacturing Technology Application and Research, Entrepreneurship and Innovation", etc. Furthermore, by the recent establishment of a new centre in 2015, called ITU-CE3 (Centre for Excellence in Engineering Education) it has been targeted to provide a collaborative and interactive teaching and learning ecosystem to enhance the learning abilities of the students and to support the development of the engineers and academics of tomorrow.

Another distinguishing feature of ITU is the importance it assigns to quality assurance in engineering education. There are various international bodies for quality assurance management and accreditation in higher education, such as the USA-based Accreditation Board for Engineering and Technology (ABET) accrediting higher education programs in USA, as well as in other countries world-wide (2) and the EU-based European Network for Accreditation of Engineering Education (ENAEE) authorising accreditation and quality assurance agencies to award the EUR-ACE® label to accredited engineering degree programmes in Europe (3). Moreover, there are national accreditation bodies as well, such as that in Turkey called Association for Evaluation and Accreditation of Engineering Programs (MUDEK), which has been a member of ENAEE since 2006 and thus is authorized to award the EUR-ACE® label to the applying Turkish national universities (4).

In accordance with its quality assurance strategies, ITU completed its preparative works for having its engineering undergraduate programs being accredited and a total of 23 engineering undergraduate programs offered by ITU have been accredited by the Engineering Accreditation Commission (EAC) of ABET (2).

Environmental Engineering Undergraduate Program (EEUP) is one of those accredited programs of ITU (5). As for all engineering programs in general, some of the most challenging tasks for the EEUP at ITU have also been designing an effective curriculum and structuring sound and effective ways of assessing and evaluating the outcomes. Accordingly and in compliance with ITU's quality assurance strategies, which are also in line with the ABET's accreditation criteria, 4-years EEUP curriculum has been reinforced by revision and improvement of several core courses, addition of several new courses to the program, inclusion of external partners like alumni and professionals to evaluation, etc., and also by implementation of an assessment and evaluation (A&E) process run each academic year so as to determine the level of achievement in realizing the pre-set learning outcomes of the curriculum. Among those, the outcome-based education/assessment, which has become a standard for the undergraduate programs accredited by ABET, has been a significantly useful approach/tool in providing solid data for the A&E of the knowledge and skills that students acquire from a given course and the level of achievement of realization of the OCs by various courses of the curriculum (6).

The aim of this paper is to discuss the modifications in the "*Graduation Design Project*" -a senior-year course in EEUP of ITU- which were implemented primarily for improving students' learning skills in environmental engineering design, and also for better A&E of the learning outcomes adopted from those set by ABET EAC in Program Criteria for Environmental and Similarly Named Engineering Programs. Moreover, an extensive description of steps taken to

ensure consistency among student team projects, detailed grading rubrics, and an overview of the overall grading system for GDPs is also presented.

2. Approach and Tools

The approach/tool proves to be more comprehensive and informative compared to the conventional weekly-lecture schedules, list of lecture topics and learning outcome statements, which may provide some indication as to the content that is covered in, yet not providing details on what is actually assessed, how it is assessed, and how it is graded (6).

2.1 ABET Criteria for Accrediting Engineering Programs

Since ABET sets the global standards for undergraduate programs in applied sciences, computing, engineering, and engineering technology; the primary purpose of the ABET Foundation is to advance, promote, and support the charitable, educational, and scientific purposes of ABET, Inc., by (2, 7);

(i) Creating, sustaining, and managing an endowment fund for ABET,
(ii) Organizing and operating an educational service for domestic and non-domestic institutions and programs aspiring to meet ABET standards,
(iii) Assisting other countries and non-domestic agencies in developing accreditation systems for scientific and technical education programs,
(iv) Supporting research activities related to the goals and activities of ABET, and
(v) Providing other services or engaging in activities that are closely related in purpose or function to ABET.

ABET criteria for accrediting engineering programs are divided into two sections:

1. General Criteria apply to all programs to be accredited by a specific ABET commission
2. Program Criteria provide discipline specific accreditation criteria

Each program to be accredited by an ABET commission must satisfy every criterion that is in the General Criteria for that commission. Moreover, programs must indicate that they satisfy all of the specific Program Criteria implied by the program title (2).

General Criteria for Baccalaureate Level Programs are as follows (2):

- Criterion 1. Students
- Criterion 2. Program Educational Objectives
- Criterion 3. Student Outcomes
- Criterion 4. Continuous Improvement
- Criterion 5. Curriculum
- Criterion 6. Faculty
- Criterion 7. Facilities
- Criterion 8. Institutional Support

In accordance with Criterion 5 (Curriculum) for the previous ABET accreditation cycle (2010-2011); an engineering undergraduate program *must prepare the students for engineering practice through a curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier coursework and incorporating appropriate engineering standards and multiple realistic constraints.* Accordingly, the following issues are required to be satisfied in the A&E Procedure of the Graduation Design Project (GDP) course (2, 8);

(i) Implementation of the review and assessment processes for Program Educational Objectives (PEOs) and ABET (a)-(k) learning outcomes;
(ii) Collection and assessment of students' works;
(iii) Demonstration of loop closing and continuous improvement;
(iv) Review and adaptation of the most up-to-date Accreditation Criteria, Policy and Procedures, and Questionnaire(s) on a regular basis.

2.2 Rubric for the senior-year GDPs for assessing learning outcomes

A specific rubric has been developed and continuously updated at each of 8-semester cycles at EEUP of ITU (9) in line with the Continuous Improvement Process (CIP) by Environmental Engineering Department (EED) in compliance with ITU's quality assurance strategies as well as with ABET's accreditation criteria. In this context, EED of ITU significantly modified its approach for the assessment of program outcomes (POs) in Spring 2010 in lieu of ABET (a)-(k) learning outcomes (5). Accordingly, the related POs and the level of contribution for each PO were determined for the senior-year GDP course.

The objectives of this course are;

(i) to design a system or a process for gaining knowledge and experience at the preliminary project level performed by using previous knowledge obtained from their bachelor education, in the framework of a partially open-ended projects and preferentially within a team of students,
(ii) to provide the opportunity for the students to gain experience on all aspects and phases of a design work within the framework of an engineering problem,
(iii) to develop the creativity of the students and promote teamwork, and
(iv) to improve the oral and written communication skills of the students.

On the other hand, course learning outcomes for students who satisfactorily passed the course will be as follows;

(i) Have knowledge and experience on conceptual design approach and methodology,
(ii) Gain experience on problem definition, searching and using information, developing alternative solutions, selection and improvement of the most appropriate alternative, design work on the chosen alternative, presenting results for the open-ended design project,
(iii) Gain teamwork experience by working in groups of 4-6 students,
(iv) Gain experience on preparing a detailed feasibility report including the technical and financial analysis, which is close to EU standards, and
(v) Have the skills to draw the system in the level and detail of a preliminary design project, including the features of architectural, civil, mechanical (process, piping & instrumentation, hydraulic profile, etc.), and electrical disciplines.

3. Results and Discussion

The existing senior-year "*Graduation Design Project*" course has been modified and given since 2010–2011 Spring Semester coded as CEV492/E with 10 ECTS credits. The content of this course has been prepared so as to specify the topics appropriate to engineering capstone design work taking into consideration the global engineering standards, and realistic physical constraints such as economics, environmental, social, political, ethical concerns, health and safety issues, manufacturability and sustainability of the work done. With this design course, topics of project management, project flow diagrams, and process management are also covered and as such, the students become well prepared to their professional lives. By this course, students participate in the projects devoted to engineering practice and use their already gained theoretical knowledge through an integrated approach prior to completing their environmental engineering education. Besides, they also improve their knowledge in selecting materials and mechanical equipment which will be useful in their professional life. Moreover with this course, each student have the ability to design an engineering system including Conceptual Design, Preliminary Feasibility Analysis, System Selection, Feasibility Report, and Draft Project which are prepared in a professional format similar to those prepared for the real-world field-scale environmental systems. The GDPs have been primarily about designing full-scale systems for 'Wastewater Treatment' or 'Integrated Solid Waste Management' according to student's choice.

This GDP course has been also supported by weekly lectures/presentations that are given by several invited professionals (i.e. external constituents outside of EED that are experts in their professions) from different disciplines on the related topic. With the support of these invited professionals giving seminars on different aspects of system design at each week all throughout the semester, the senior-year students have the opportunity to sharpen their design skills by grasping the professional perspective at first-hand. Also they have the chance to increase their self-confidence by communicating with their future employees. The distinctive feature of the GDP is that it is an "*Open- Ended Project*" where students are encouraged to discover the most applicable engineering solution for a given task. The project basically includes the detailed analysis of the project area, necessary calculations for present and future situations, wastewater collection system, transportation, conceptual plant design, discharge and reuse options together with sludge treatment and management alternatives for wastewater treatment. For the integrated solid waste management; students are asked to design the landfill site, Recycling Disposal Facility (RDF), and leachate treatment facilities. The final step is the economic analysis for the selected option so as to comply with realistic engineering practices. This GDP course has been conducted for the last 8 semesters (2 terms in an academic year) starting from the semester of Spring 2010-2011, and up to now more than 200 senior students had been benefitted from this design experience realized in teams. Scope of the work has not been limited and the students have been promoted to generate their own environmental solutions for the given provinces of Turkey that are selected close to Istanbul for ease in conducting field trips, on-site data collection, and meetings with local authorities. The projects were original and applicable in the sense that the selected provinces currently do not have any wastewater/solid waste collection/treatment/management infrastructures. The selected projects were evaluated on the basis of options suggested together with the detailed engineering drawings.

A specific grading system (Table 1) has also been developed for the GDP course in order to provide that all the students conduct the GDP using the same format and hence, the quality of the projects will not vary significantly between the teams. With this grading system, the individual contribution of each student is also considered. Moreover, working and presentation performances as well as the fundamental environmental engineering knowledge of each student and the project reports of the teams are evaluated. The examination committee is expanded by including the advisory committee to the evaluation process. Team supervisors (Advisory Team), course coordinators and advisory committee (both from and out of EED) are invited to the final presentations and they altogether form the examination committee. The content of the GDP course should satisfy various ABET (a)-(k) learning OCs either partially or fully as shown in Table 2.

Table 1: Grading system of the GDP.

Academic Year	Examination Committee	Mean	Used Tool	Midterm %	Final %	Total
2010-2011 Spring	Advisory Team	Project report	Rubric[a]	60		100
	Advisory Committee[*] and Course Coordinators	Project report	Rubric		40	
2011-2012 Fall to 2014-2015 Fall	Advisory Team	Individual working performance	Rubric of OC4[b]	10		100
	Advisory Team	Project report	Rubric	40		
	Course Coordinators	Technical exam	OBEx[c]		20	
	Advisory Committee and Course Coordinators	Project report	Rubric		20	
		Individual oral presentation performance	Rubric of OC7[d]		10	

[*]External constituents from and out of Environmental Engineering Department (EED); [a]Scores of the project reports using the rubric specific for the senior-year Graduation Design Projects (GDPs); [b]Scores given to each student individually according to the performance criteria (PC) in the rubric prepared specific for Outcome 4 (OC4); [c]Outcome Based Exam; [d]Scores of individual oral presentation performances of each student using the specific evaluation form prepared according to the performance criteria (PC) of the rubric specific for Outcome 7 (OC7).

Table 2: Learning outcomes of EEUP of ITU and the level of contribution of GDP course.

OC#	Learning Outcomes	Level of Contribution		
		1	2	3
1	An ability to apply knowledge of mathematics, science and engineering			**X**
2	An ability to design and conduct experiments along with data interpretation and analysis	**X**		
3	An ability to design an environmental system, component or process with an integrated approach considering the multi-realistic constraints			**X**
4	An ability to work individually, in team and to participate in multi-disciplinary working groups			**X**
5	An ability to identify, formulate and solve problems in the field of environmental engineering			**X**
6	An understanding of professional and ethical responsibility		**X**	
7	An ability to communicate effectively			**X**
8	An understanding of the impact of environmental engineering solutions in a global and societal context within the framework of sustainability and environmental policy			**X**
9	A recognition of the need for, and an ability to engage in life-long learning		**X**	
10	A knowledge of contemporary issues		**X**	
11	An ability to use the techniques, skills, and modern engineering tools required for Environmental Engineering practice			**X**

1: Little, **2:** Partial, **3:** Full

As seen from Table 2, the learning outcomes that should be satisfied fully by the GDP course are OC1, OC3, OC4, OC5, OC7, OC8, and OC11 and the level of achievement in realization of those outcomes are to be shown by some assessment tools. In this respect, initially a specific rubric has been developed and continuously updated at each of 8-semester cycles for the senior-year GDPs for assessing learning outcomes. Achievement levels of the learning OCs and the tools used in A&E Process in addition to specific rubric are presented in Table 3. For the first three semesters, realization of the OCs was above the "≥50% Satisfactory" threshold; whereas for the following three semesters, it was above the "≥60% Satisfactory" threshold set by the faculty in order to assess continuous improvement in the senior-year GDPs at the ITU-EED. As an example, for 2012-2013 Spring Semester; outcome based assessment results (Table 3) indicated that out of seven learning OCs to be satisfied by the course, four of them (OC3, 4, 7, and 11) were realized above the "≥60% Satisfactory" threshold; whereas realization of the other two (OC1 & 5) was far below this threshold (i.e. realization of OC1 and OC5 was 35% and 6%, respectively) set by the faculty of the ITU-EED. On the other hand, realization of OC8 could be barely achieved above the "≥60% Satisfactory" threshold value (Figure 1a-b).

Table 3: Achievement levels of "Learning OCs" and tools used in A&E Process.

Semester (Number of Students)	OC	Percentages (%) of the Categories Meeting the Related OC*				Assessment Tool(s)
		Outstanding	Satisfactory	Developing	Unsatisfactory	
2010-2011 Spring (30)	1	-	-	-	-	None[a]
	3	45	45	10	0	Rubric[b]
	4	-	-	-	-	None
	5	55	45	0	0	Rubric
	7	60	25	15	0	Rubric
	8	-	-	-	-	None
	11	50	45	5	0	Drawing[c]
2011-2012 Fall (12)	1	-	-	-	-	None
	3	8	84	8	0	OBEx[d]
	4	91	0	9	0	OC4[e]
	5	60	32	8	0	OBEx
	7	59	41	0	0	OC7[f]
	8	0	9	82	9	OBEx
	11	67	33	0	0	Drawing
2011-2012 Spring (51)	1	10	12	24	55	OBEx
	3	55	33	10	2	OBEx
	4	84	14	2	0	OC4
	5	10	12	24	55	OBEx
	7	78	22	0	0	OC7
	8	-	-	-	-	None
	11	86	14	0	0	Drawing
2012-2013 Fall (14)	1	36	50	14	0	OBEx
	3	43	29	21	7	OBEx
	4	86	7	7	0	OC4
	5	14	43	43	0	OBEx
	7	100	0	0	0	OC7
	8	14	43	43	0	OBEx
	11	71	29	0	0	Drawing
2012-2013 Spring (48)	1	10	25	13	52	OBEx
	3	40	38	15	8	OBEx
	4	87	13	0	0	OC4
	5	2	4	17	77	OBEx
	7	89	11	0	0	OC7
	8	21	40	35	4	OBEx
	11	100	0	0	0	Drawing

Table 3 (continued): Achievement levels of "Learning OCs" and tools used in A&E Process.

Semester (Number of Students)	OC	Percentages (%) of the Categories Meeting the Related OC*				Assessment Tool(s)
		Outstanding	Satisfactory	Developing	Unsatisfactory	
2013-2014 Fall (18)	1	7	79	14	0	OBEx
	3	100	0	0	0	Rubric
	4	100	0	0	0	OC4
	5	7	79	14	0	OBEx
	7	100	0	0	0	OC7
	8	7	79	14	0	OBEx
	11	100	0	0	0	Drawing
2013-2014 Spring (34)	1	15	38	47	0	OBEx
	3	88	12	0	0	Rubric
	4	88	12	0	0	OC4
	5	9	41	47	3	OBEx
	7	91	9	0	0	OC7
	8	6	24	65	6	OBEx
	11	88	12	0	0	Drawing
2014-2015 Fall (18)	1	11	61	28	0	OBEx
	3	78	22	0	0	Rubric
	4	78	22	0	0	OC4
	5	11	61	28	0	OBEx
	7	83	11	5	0	OC7
	8	11	61	28	0	OBEx
	11	78	22	0	0	Drawing

*Outstanding: 100-75; Satisfactory: 74-50; Developing: 49-25; Unsatisfactory: 24-0; [a]No evaluation has been done for this outcome in this semester; [b]Scores of the project reports using the rubric specific for the senior-year Graduation Design Projects (GDPs); [c]Scores of only the drawing part of the projects in the rubric specific for the senior-year GDPs; [d]Scores of the question specific for this outcome in the 'Outcome Based Exam (OBEx)'; [e]Scores given to each student individually according to the performance criteria (PC) in the rubric prepared specific for Outcome 4 (OC4); [f]Scores of individual oral presentation performances of each student using the specific evaluation form prepared according to the performance criteria (PC) of the rubric specific for Outcome 7 (OC7).

Figure 2a-d indicates the percent meetings for OC1, 3, 5, and 8 between 2010-2011 Spring to 2014-2015 Fall semesters. Since OC3 is mainly related with the senior-year "*Graduation Design Project*" course and it defines *an ability to design an environmental system, component or process with an integrated approach considering the multi-realistic constraints*; it was observed that realization of this OC could be achieved above the "≥60% Satisfactory" threshold set for all semesters (Figure 2b).

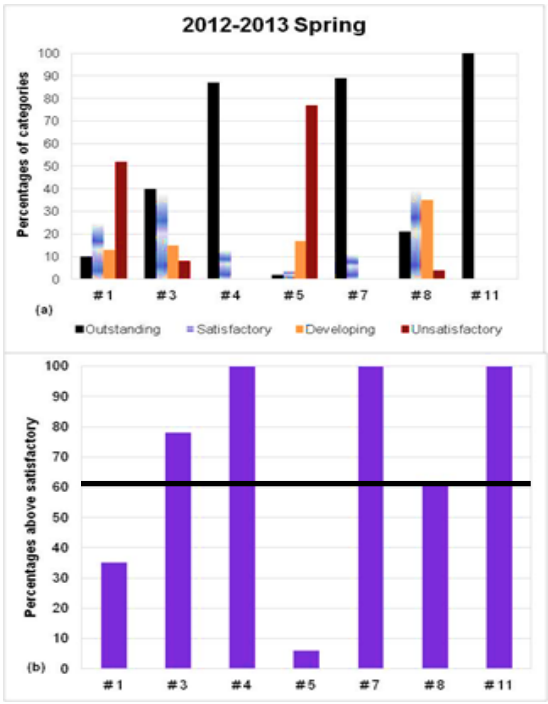

Figure 1: Distribution (a) of categories meeting the related outcomes; (b) above satisfactory.

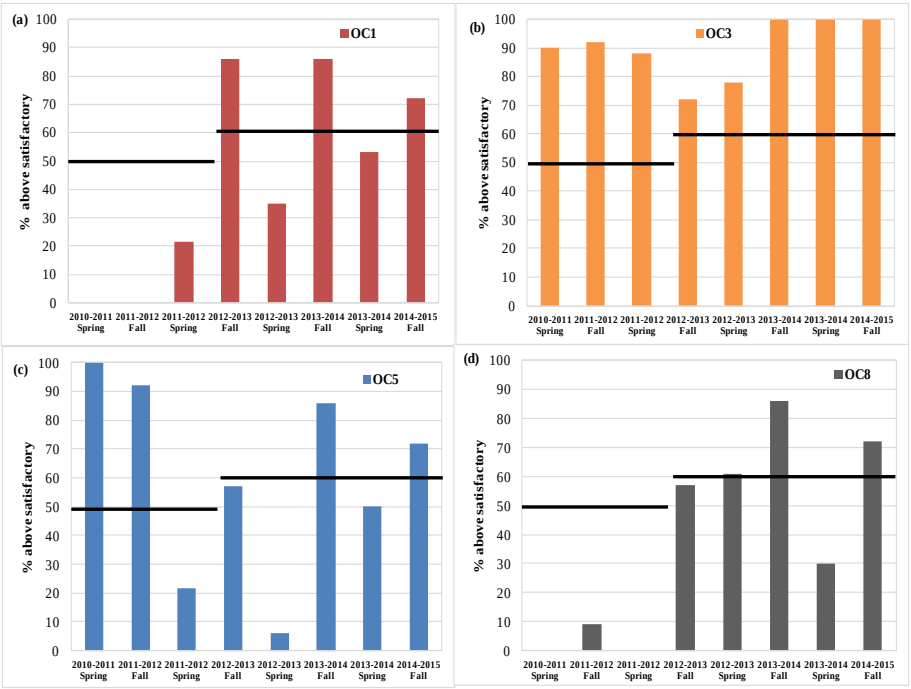

Figure 2: Percent meeting (a) OC1; (b) OC3; (c) OC5; and (d) OC8 between 2010-2011 Spring to 2014-2015 Fall semesters

4. Conclusions

A Continuous Improvement Process (CIP) has been implemented by the Department of Environmental Engineering in compliance with ITU's quality assurance strategies, which are also in line with the ABET's accreditation criteria. This paper presents an extensive description of steps taken to ensure consistency among student team projects, detailed grading rubrics, and an overview of the overall grading system for GDPs in Environmental Engineering Undergraduate Program. By this way, the entire students take the graduation project at the same level and in the same design format and hence, the quality of the projects does not vary significantly and becomes more consistent among the different teams formed. The rubric specifically structured for this senior-year GDP course has proven to be an ample assessment and evaluation (A&E) tool serving for comprehensive and realistic evaluation of the course and as a basis for continuous improvement. The technical drawings are at an acceptable level, but still need further improvement. On the other hand, the recently submitted GDPs have indicated that the engineering solutions exhibited great diversity. Thus, the teams seem to adopt the idea of applying multi-realistic solutions by generating various unique tailor-made solutions for the wastewater collection system, reuse, discharge options, energy and sludge management methods.

Comparative outcome-based assessment of 8 semesters indicates that the senior-year GDP course falls short in achieving the targeted performance regarding OC1 and OC5 that addresses the freshman and sophomore/junior year levels, respectively. The lowest achievement levels of the "Learning Outcomes" are observed when the related outcome has been measured by Outcome Based Exam (OBEx) as the tool in assessment and evaluation (A&E) process. In this respect, for more reliable assessment, other assessment tools should be also used in order to evaluate the achievement in the targeted performance in future Continuous Improvement Process (CIP). Results of the outcome-based assessment for 8 semesters also indicate that the senior-year GDP course falls short in achieving the targeted performance regarding OC8 that addresses sophomore/junior/senior years. Hence, GDP course needs to be reviewed/improved with respect to those, yet it is distinctly successful in realization of the learning OCs addressing junior and senior years (OC7&11), as well as those others addressing sophomore/junior/senior years (OC3&4).

Acknowledgement

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6. Correspondence

Cigdem Yangin-Gomec (Corresponding Author), Istanbul Technical University (ITU), Environmental Engineering Department, 34469, Maslak, Istanbul, Turkey, +90 212 2853787, +90 212 2856545, yanginci@itu.edu.tr and www.akademi.itu.edu.tr/yanginci.

Borte Kose-Mutlu, Istanbul Technical University (ITU), Environmental Engineering Department, 34469, Maslak, Istanbul, Turkey, +90 212 2856785, +90 212 2856545, kosebo@itu.edu.tr and www.akademi.itu.edu.tr/kosebo.

Ebru Dulekgurgen, Istanbul Technical University (ITU), Environmental Engineering Department, 34469, Maslak, Istanbul, Turkey, +90 212 2857419, +90 212 2856545, dulekgurgen@itu.edu.tr and www.akademi.itu.edu.tr/dulekgurgen.

Izzet Ozturk, Istanbul Technical University (ITU), Environmental Engineering Department, 34469, Maslak, Istanbul, Turkey, +90 212 2853790, +90 212 2856545, ozturkiz@itu.edu.tr and www.akademi.itu.edu.tr/ozturkiz.

Aysegul Tanik, Istanbul Technical University (ITU), Environmental Engineering Department, 34469, Maslak, Istanbul, Turkey, +90 212 2856884, +90 212 2856545, tanika@itu.edu.tr and www.akademi.itu.edu.tr/tanika.