Case study on rubric-based assessments for senior-year Graduation Design Project and recommendations for improving the assessment tools

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Abstract –The study presents the main features of the problem-based learning oriented Graduation Design Project (GDP) course of the Environmental Engineering Undergraduate Program (EEUP) of Istanbul Technical University (ITU), the specifically designed grading rubric, as well as the basic definitions and the required extend of the new "*environmental management considerations*" recently introduced to the course for continuous improvement purposes in agreement with the renewed definitions and requirements of EEUP curricula listed in ABET EAC 2015-2016 Program Criteria. The study also aims at rapid communication of recommendations outlined for improving the assessment and evaluation (A&E) process so as to continue with comprehensive and realistic assessment of the related learning outcomes and student performance about those new considerations, namely "*risk assessment, uncertainty and sustainability analyses, life cycle assessment, environmental impacts, project management*, and *application of advanced principles and practice relevant to the program objectives*". Accordingly, new query options related with each of those recently introduced considerations were identified, graded and incorporated to the specific-rubric to improve the assessment tool to be used in the next A&E cycle of the GDP assignments.

1. Introduction –Istanbul Technical University (ITU) is one of the top-ranked public universities in the country serving to more than 25,000 undergraduate students and among the higher education institutions in the world with the highest number of internationally accredited undergraduate programs. 23 engineering undergraduate programs offered by ITU have been accredited by ABET EAC (Accreditation Board for Engineering and Technology, Engineering Accreditation Commission) [1] and Environmental Engineering Undergraduate Program (EEUP) is among those [2]. Being one of the anchors of effective engineering education practices, "*problem-based learning* (PBL)" has been of great significance in the design and content of the EEUP of ITU. Accordingly, the curriculum includes several compulsory courses, offered mostly at the junior/senior years, designed and taught mainly with a specific focus on PBL. In addition to develop and improve the disciplinary and content-specific knowledge of the students, equally important other educational objectives of such PBL-oriented courses are to help students develop self-learning strategies, engage in active learning, enhance their problem-solving abilities, foster development of critical thinking skills and decision-making abilities, as well as to promote collaborative/cooperative learning and to sharpen communication skills through short- or long-term team works focused on real-life problems [3].

One of those PBL-based courses is the "*Graduation Design Project* (GDP)" offered at the senior-year. In fact, in its current structure and content, which underwent a major change and improvement in 2009-2010 as part of the continuous improvement and educational quality assurance practices in ITU and also to align with the accreditation requirements of ABET, this course has become one of the most powerful and comprehensive PBL-based educational tools of the EEUP curriculum. Apparently, it is required to run a continuous assessment and evaluation (A&E) process to determine the level of success in providing effective teaching environment/tools for development of relevant student abilities and learning attributes. Accordingly, a GDP-specific grading rubric [4] which was developed by the course coordinators has been in use for assessing the senior-year students' performances and the level of realization of the learning outcomes targeted by the GDP assignments.

Details about (i) the content and structure of the senior-year GDP course, (ii) the A&E process including the overall grading system and (iii) the A&E results for 8 consecutive semesters between 2010 and 2014 academic years are given elsewhere [5]. Brief information on the structure and content of the course as well as the main features of the specific grading rubric are provided below. Here, the environmental management considerations which have been recently introduced to the GDP course (2014-2015 Spring semester) will be explained in detail and recommendations on query alternatives to address those new considerations, as well as on how to incorporate those new entries to the A&E process to improve the rubric-based assessment will be given at the following sections.

2. Approach and Tools – As mentioned above, focal teaching strategy of the GDP course of the EEUP at ITU is the PBL approach and it also combines the merits of "design- and project-based learning". The driving force behind this strategy is the inevitable shift in perception of "student learning" from "*learning as knowledge acquisition*" resulting from the conventional "teacher-centered approach" to "*learning as knowledge construction*" shaped by the "student/learner-centered approach" [6]. Concurrently, the current structure and content of the senior-year GDP course include such features (i) to instigate students to look for a deeper comprehension of previously and/or newly delivered facts/concepts, (ii) to identify, connect, implement previous knowledge for comprehension and solution of newly introduced problems/cases, (iii) to promote students work collaboratively in teams to provide step-by-step solutions for complex and multi-stage real-world problems, (v) to motivate students in improving their time-management skills, (iv) to encourage students on building their own decision-making environment/mechanism while working on their assignments and develop skills in defending their decisions based on sound, realistic, and scientific grounds.

2.1 Brief description of the GDP

"Solid Waste Management" and "Industrial Wastewater Treatment" have also been included as project topics yet, "Biological Wastewater Treatment" has been the main topic for "designing an environmental system" within the frame of the GDPs since 2010-2011. All assignments were meant to motivate the students to provide engineering solutions to complex real-world environmental problems of selected regions in Turkey. In addition to the PBL-oriented content of the course, its structure has also differed from the teacher-centered, weekly in-classroom-lecturing style: after announcement of the overall framework of the project as an "*Open-Ended-Problem*" at the beginning of the semester, student teams (4-5 students per team) start working on their assignments which include the following project management steps: collection of field- and case-related information about the project area (population, demography, existing infrastructure-public services, etc.), technical site-visits, meetings with local authorities, conceptual design, comparative evaluation of process/system alternatives, selection of the most appropriate solution followed by detailed calculations and design of selected process/system, hydraulic- and architectural-design, selection of instruments and appurtenances, P&I diagram, brief risk assessment, financial analyses, feasibility report, detailed technical drawings, project final report, and defense in front of the jury and audience. Student teams working on those work-packages in a step-by-step manner are required to construct their own work schedules and self-define roles and responsibilities of each team member. Teams developing engineering solutions at each step of the project prepare mini-presentations for weekly team meetings where two instructors and two teaching assistants join them for guidance and support throughout the semester. Weekly seminars given by the invited experts on various features of environmental system design and project management provide a valuable contribution to the students regarding the real-world professional perspective.

2.2 Brief description of the GDP-specific grading rubric

Main features of the GDP-specific grading rubric are summarized in Table I. Project final reports of teams are evaluated according to that both by the supervisors of each team, the course coordinators and the jury. Percent (%) contributions of those separate evaluations to the final grade of each team member are 30% and 20%, respectively. Remaining half of the final grade of each student is assigned based on individual inputs like individual contributions to the project during the semester (10%), attendance to the weekly seminars (10%), points earned from a technical exam (OBEx: Outcome-Based-Exam) given at the end of the semester (20%), and presentation skills during defense (10%).

Table I. Main features of the current GDP-specific grading rubric for the project final report

Main Features	**Required Details**	**Points**
1. Mechanics and General Content	Grammar/technical writing skills; Statement of Purpose; Data Presentation Features (i.e., lists and formats of tables, figures, content, appendix); Literature review; Conclusions; Discussions; References	18
2. Design (Process/System)	Legal issues; Info on the project area; Basic design considerations of the process alternatives for the desired environmental system (incl., flow schemes, process calculations, general layouts, rough cost analysis); Preliminary conceptual design; Feasibility report and detailed design of the selected alternative (incl., system layout, pipping plan, detailed equipment selection, architectural drawings of each unit of the system, hydraulic profile, P&I diagram)	60
3. Time Management	Work-Time schedule (i.e., Gant chart); Responsibilities of each member	4
4. Cost Analyses	Bill of quantities, estimated cost and tender document; Capital cost; Operational cost; Total investment cost; Unit cost; End-user tariff option	18
TOTAL		*100*

As seen from Table I, the GDP-specific rubric which has been used for the last eight A&E terms, does not address the concepts of risk, uncertainty, sustainability, life-cycle principles, environmental impacts, which became a shortcoming after inclusion of those considerations in the GDPs as of 2014-2015 Spring semester.

3. Results and Discussion – ABET EAC 2015-2016 Program Criteria [7] suggest that "*the (environmental engineering) curriculum must prepare graduates to design environmental engineering systems that include considerations of risk, uncertainty, sustainability, life-cycle principles, and environmental impacts; and apply advanced principles and practice relevant to the program objectives*". Upon announcement of those new entries by ABET EAC by the end of 2014, they were rapidly incorporated to the ITU EEUP curriculum and included in the main requirements of the senior-year GDP course as of 2014-2015 Spring semester. One of the weekly seminars at the beginning of the semester was dedicated to instruct the students thoroughly on what those new considerations mean. The students were also informed about the expectations from them on to what extend they need to explore those new topics in their projects.

3.1. Environmental management considerations recently added to the GDP

- *Risk Assessment*: Even before the addition of "*consideration of risk*" to environmental system design by ABET, some GDP-teams preferred including basic risk assessment issues in their final reports. Those initial assessments were mostly in the form of an Emergency Action Plan (EAP). However, as of 2014-2015, more emphasis was put on this feature. Accordingly, "risk assessment" sections of the GDP final reports are expected not to be limited with EAPs, but also include some other features like compiling health and safety principles and regulations considering the current local issues, and including real-life health and safety problems/accidents encountered recently (i.e., in the last 5 years) in similar environmental systems (i.e., operating full-scale treatment plants). Since risks are likely to occur throughout the life-time of a project, risk management practices are expected to encompass some other risk factors including those in the areas of, i.e., conceptual design, project financing, construction, start-up, operation, and even decommissioning.

- *Uncertainty*: Minimum expectations about considering uncertainty in GDP works are identifying design and financial parameters prone to fluctuate, outlining necessary precautionary measures and proposing backup plans against unexpected/unpredictable circumstances due to i.e., natural disasters (earthquakes, floods, etc.). Use of certain safety factors/coefficients in environmental system design is a frequent practice which allows meeting the targeted standards even under conditions of uncertainty due to i.e., randomly and/or continuously fluctuating design inputs (e.g., oscillating influent flow rates, pollution loads [8].

- *Sustainability*: This concept is simply defined as "*meeting todays' demands without compromising the needs of next generations*". It is not only the regulatory principle for proper management of resources but also forms the baseline for consistent functioning of infrastructures and public services, which eventually serve for the prosperity of a resilient society. Accordingly, the GDP-teams are expected to implement the "sustainability" concept in their works so to cover the practices like reduction of resource/raw material consumption along with waste minimization, recycling/reuse, proper waste handling/disposal, and generation of value-added side-products if possible. Integrated sustainability perspective comprised of environmental, economic and social dimensions is expected to have an overarching role throughout the entire project.

- *Life-cycle assessment (LCA)*: This is a tool to estimate the overall impact of environmental systems while avoiding shift of environmental impacts from one place to another [9]. Accordingly, student teams are expected to follow a "*cradle-to-grave*" or even a "*cradle-to-cradle*" approach in environmental system design and address the environmental impacts to water, air and soil for a simple yet fundamental LCA analysis. For that, the bare minimum is identification of system boundaries. Next basic and crucial step is evaluation of different impact categories and selection of an appropriate one. Both of those LCA phases are also check points to evaluate whether the student teams are running decision making processes during LCA.

- *Environmental impact*: although "consideration of environmental impact" has been recently mentioned in the ABET EAC 2015-2016 Program Criteria for EEUP [7], it was not considered and handled as a new entry for the GDP course, since "Environmental Impact Assessment (EIA)" has been among the main work-packages required to be completed within the framework of the GDP assignments of the EEUP at ITU.

3.2. Improvement of the GDP-specific grading rubric

Several rubrics designed by the ITU EEUP faculty are available to assess the achievement levels of ABET's Student Learning Outcomes (OCs) targeted by the GDP course (namely OC1, 3, 4, 5, 7, 8, 11). Additionally, the specifically developed grading rubric has been in use for assessment of student learning outcomes through project final reports since 2010-2011 [4]. Yet, even though the GDP-specific rubric was initially designed as comprehensive as possible to meet the needs of the period between 2010 and 2014, incorporation of new environmental management considerations to the GDP course in 2014-2015 calls for inclusion of those new considerations in the A&E process. Thus, new query options related with each of those new curriculum entries are identified, graded, and the rubric is improved accordingly as summarized in Table II so that it will be available for the next round of the GDP assignments.

Table II. GDP-specific rubric modifications and proposed new queries in relation to new curriculum entries

Modified modules and points [current→future]	**Recommended NEW QUERY**	***Related to new curriculum entries of;***
2. DESIGN: **[60 → 45]**		
2.5. Feasibility Report	Originality (novelty, and if applicable innovative) aspects of the selected treatment process and technology	"*application of advanced principles and practice*"*
5. ENVIRONMENTAL MANAGEMENT: [00 → 20]		
5.1 Risk Assessment	Emergency action plan (EAP) outlined/ Risk factors identified, their impacts forecasted	*"risk assessment"*
5.2 Uncertainty	Uncertainties for designed system specified	*"uncertainty analyses"*
5.3 Sustainability	Economic sustainability/ Social impacts explored	*"sustainability"*
5.4 Life-cycle assessment	System boundaries/ Impact categories determined	*"life-cycle assessment"*
5.5 Resilience (optional)	*Interdependencies/ Extra measures (+ to EAP) presented*	-

*although this entry is not related with the new "environmental management considerations", it is incorporated here since it has also been announced as a new addition to the EEUP curriculum (under ABET EAC 2015-2016 Program Criteria).

Two of the student outcomes that the GDP course aims to meet at the highest level are "OC3: *an ability to design a(n environmental) system, component or process with an integrated approach considering the multi-realistic constraints (such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability)*" and "OC8: *an understanding of the impact of (environmental) engineering solutions in a global and societal context (within the framework of sustainability and environmental policy)".* As apparent from those definitions, both OCs are directly related with the new curriculum entries. Thus, it is recommended here to run future A&E processes for those learning outcomes by combining the results of the relevant parts of the Outcome-Based Exams (OBEx) and those of the improved GDP-specific rubric currently suggested in Table II for a better, comprehensive and more realistic evaluation.

4. Conclusions – Abovementioned re-organization of the A&E tools of the GDP course will avoid overlooking students' performances related with the new curriculum entries, and will also prevent underestimation of overall achievement levels through the GDP assignments. Accordingly, the specific rubric to be amended by addition of several new queries, some recommended in this study, addressing the newly incorporated aspects of the EEUP curriculum will continue to serve as an inclusive A&E tool for a comprehensive and realistic evaluation, and as a meaningful instrument to measure achievement level of several student learning outcomes through the GDP course. Such remediates will not only help sharpen the GDP course-related A&E, but also are expected to contribute to continuous improvement of the GDP assignments, and thus to problem-based learning and design-based engineering education.

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