

An Experience on Problem Based Learning in an Engineering Faculty

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Abstract

In 2001, Engineering Faculty of Dokuz Eylül University has started to change its undergraduate education in a radical way. As being among the first examples in the world, the Departments of Electrical and Electronics, Geological and Geophysics Engineering in 2002 and Mining Engineering Department in 2003 have adopted the so-called “modular-staged problem based active learning system”. The system is based on real engineering problems which values teamwork and the integration of information from different disciplines and it places the student at the center of the learning process. The faculty has learned many things and it needs to learn many other things on how to write a real world engineering scenario, to facilitate the construction of learning environment that the students must do by themselves, to assess students’ performances in a compatible way to the implemented education system, to evaluate educational programs for continuous improvement and to integrate educational activities with research done in the departments for mutual benefits of students and faculty staff.

1. Introduction

The faculty of engineering of Dokuz Eylül University (DEU), Turkey was founded 37 years ago within Aegean University, İzmir, and constituted a part of DEU by its foundation in 1982. The faculty has an innovative structure shaped with different education cultures carried by its staff % 27 of them having Ph.D. degrees from other universities in the country and % 28 from abroad.

Since 2002, the faculty has adopted Problem Based Learning (PBL) [1] in four pilot undergraduate programs: Electrical and Electronics, Geological, Geophysics, Mining Engineering. This has been in accordance with the new vision of DEU which aims to educate students as enterprising, creative, innovative and proficient graduates who will contribute to their community and will serve as good citizens in a universal sense. In designing new curricula, the departments have taken care of the facts: i) Not teaching but learning is fundamental in education [2], ii) Education programs should be designed based on an education strategy with considering the other strategies as complementary: For instance, learning as discovering is the main strategy in PBL while didactic, Socratic and inquiry processes taking place in modules are complementary [2], iii) Students have different learning styles, so the education system should include the implementation of different learning methods to reach every student [2]-[3], iv) The engineers are intended to solve engineering problems and to design products, so an engineering education system should be structured based on real

engineering problems and on design projects to meet these demands. v) Solving a real engineering problem and realizing a real engineering project needs to use, in an efficient manner, the integrated knowledge of mathematics, basic sciences and engineering disciplines, so curricula must be an integrated one [4]. In this period, the faculty has been influenced largely by the education reform within the university started in the faculty of medicine and by the progress of engineering education in the world [2].

The second important change in the education system of the faculty places the issue of quality of education on top of its agenda. Following self-assessments, the Departments of Environmental, Geological and Mechanical Engineering made their undergraduate programs available in 2004 for critical appraisal of the Engineering Evaluation Board MÜDEK which was founded in 2002 with the undertakings of Engineering Deans Council of Turkey. The other departments have followed them, thus, the Faculty entered a new phase on the way to perfection in engineering education as to be evaluated in a learning centered approach, namely an outcome based evaluation relies on Engineering Criteria 2000 (EC2000) introduced by Accreditation Board for Engineering and Technology Education (ABET) [5].

The outcome based evaluation of education programs, the implementation of problem based learning and the works on mutual recognition of study visits under the European student exchange programs (i.e. the calculation of credits based on the real loads of students) have taught the importance and some basic facts of a learning centered organization of education and why in absolute sense students must gain some predetermined educational outcomes. Calculating the course credits based on European Credit Transfer System (ECTS) [6] by considering the students' real loads in learning and defining the learning outcomes and objectives of the courses has been another event for the Faculty to face with learning centered approach.

The faculty now prepares a PBL curriculum which is common for all freshmen engineering students and mainly based on integration of physics, mathematics and computer basics. The faculty plans to reorganize the current PBL curricula, fourth years of which are already designed as project based learning, by embedding project based learning into the whole curricula. The faculty plans also to evaluate its research activities in an outcome based fashion [5] and to have a strategic plan for a 5 years period.

The paper is organized as follows. Section 2 is devoted to the implemented problem based learning education system and 3 years experiences. Section 3 presents some changes in the engineering education of the faculty during the outcome based self evaluation of the undergraduate programs.

2. Problem Based Learning in DEU Engineering Faculty

The faculty offering undergraduate, master's and doctoral degree programs in 11 different engineering disciplines, has always been aware of the need for monitoring the universal and local changes, the varying needs of the society and industry, the progress of sciences of education and engineering and thus, it has been tried to adapt itself in accordance with new demands and developments. Adopting PBL in the education system and evaluating the education programs would be considered in this general context. Poor problem solving skills, lacking of communication and team working skills, poor link between any course and real engineering world in the former education systems were other motivations for the departments in transition to PBL education system. The most important factor is perhaps the PBL practice started in 1997 in the faculty of medicine of DEU. The engineering faculty staff has been influenced by the presentations which had been done directly by the Rector Prof. Dr. Emin Alici and by the seminars given by the members of medical education unit of faculty of medicine. In that period, Electrical and Electronics, Geological, Geophysics, Mining Engineering Departments had redefined their institutional values, aims. The departments had

designed and then implemented new curricula based on PBL approach.

The implemented PBL systems are staged in a modular based. Since modular small group PBL is not common in engineering education, the departments have had some difficulties especially in designing new modular PBL curricula, writing real engineering scenario which motivates students and providing an efficient learning, and assessing and evaluating the students' performances [7] in a correct way in the new education system. The following subsections present approaches applied in DEÜ Engineering Faculty PBL practices.

2.1. Clusters of Learning Objectives as Skeletons of Modules

Modules of 2-3 weeks begin with a Problem Based Learning (PBL) session applied for small groups of 8-9 students. A module (see Figure 1) consists of 3-4 PBL sessions, presentations, laboratories, field studies, scientific consultation hours, engineering orientation, module discussion and examination [4].

The PBL session which is the heart of that educational system takes 2-4 hours provides a learning environment where the students attempt to define and then solve a real life problem introduced with a scenario. The scenarios are designed so that students are motivated for learning, supported for producing hypotheses and then eliminating them in the group discussion [1], [8]. At the beginning and at the end of each PBL session, students are asked to find the answers of the questions: What they know? What they need to learn? What they will find out? Between each pair of successive sessions, students search for information to solve the problem presented by the scenario using different sources of information. The roles of module components other than PBL sessions are just complementary to PBL sessions. The presentations given by lecturers provide information which the students could very hardly reach or understand. Students in PBL rooms have active roles in contrast to their classical "listen and take notes" roles in the classrooms. Faculty staff participated to a PBL session is involved with learning process as facilitator rather than lecturing.

Each module as a stage of the education program is intended to provide the students to have predetermined abilities called learning outcomes which are indeed the projections of the program outcomes [5] into the time period devoted to the module. Module objectives are learning objectives for students which are defined as observable actions of students. They are usually classified by using Bloom's taxonomy [9]. At the end of each PBL session, students determine learning objectives at six cognitive levels of Bloom's i.e. knowledge, comprehension, application, analysis, synthesis and evaluation.

A PBL curriculum is, by definition, integrated, so are the modules. Designing a PBL curriculum is a problem of identifying clusters of closely related learning objectives. The Electrical and Electronics, Geological, Geophysics, Mining Engineering Departments had designed modules as units of integrated learning objectives from different disciplines such as mathematics, physics, chemistry, computer basics and engineering sciences. In 2003, the faculty curriculum design committee whose members are from disciplines of mathematics, basic sciences and engineering sciences had constructed 14 clusters of learning objectives from mathematics, physics and chemistry for freshmen engineering curricula. The Electrical and Electronics, Geophysics and Mining Engineering Departments had redesigned their freshmen engineering modules as taking the clusters as basis and then integrating them with engineering learning objectives. The Electrical and Electronics Engineering Department has chosen to include material sciences learning objectives instead of chemistry learning objectives. The first cluster of learning objectives which constitutes the main body of the first module in freshmen curriculum of the department is depicted in Figure 2.

Week 1

	Monday	Tuesday	Wednesday	Thursday	Friday
08:30	PBL I. Session	Presentation (Math)	PC Lab Group A	PBL II. Session	Engineering Orientation
09:30					
10:30		Consultation	PC Lab Group B		
11:30					
13:00	Presentation (Physics)	PC Lab Group A	Turkish	Presentation (Materials)	
14:00					
15:00	Physics Lab. A	PC Lab Group B	Presentation (Math)	Non-Technical Elective Course	
16:00					

Week 2

	Monday	Tuesday	Wednesday	Thursday	Friday
08:30	PBL III. Session	Presentation (Math)	PC Lab Group A	Discussion	Module 4 Exam
09:30					
10:30		Consultation	PC Lab Group B		
11:30					Module Discussion
13:00		PC Lab Group A	Turkish	Presentation (Materials)	
14:00					
15:00	Physics Lab. B	PC Lab Group B	Presentation (Math)	Non-Technical Elective Course	
16:00					

Figure 1. The time table for the module of measurement of physical quantities.

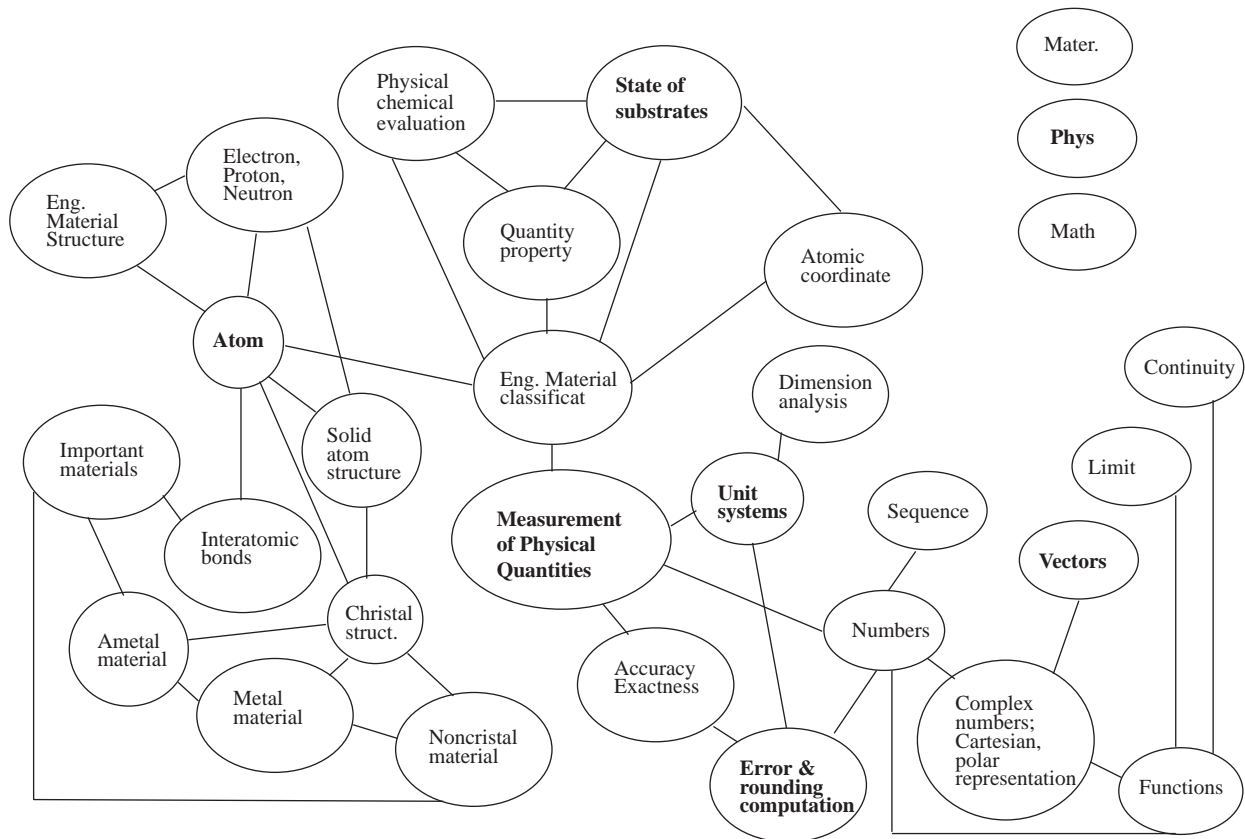


Figure 2. Learning objectives and their interconnections of the module of measurement of physical quantities.

The department of geology engineering has preferred to choose a different way of integration: Mathematics and basic science learning objectives are spread over the entire modules of 4 years. The core learning objectives of a module are from geology. The other learning objectives are embedded to the modules whenever related. This approach has been observed having some positive outcomes. Students have been motivated by introducing geology discipline and its real world problems from the beginning. The department had evaluated its education program according to ABET/MÜDEK criteria and made the program available in 2004 for critical appraisal of the Engineering Evaluation Board MÜDEK. Considering feedbacks from MÜDEK evaluators, the department is now preparing a new curriculum.

2.2. Designing a Freshmen Engineering PBL Curriculum

After having 3 years experience, the faculty has converged to the idea of designing a PBL curriculum common for first year students in all engineering disciplines. Physics, mathematics and computer basics are identified as common disciplines for all engineering programs. So, freshmen engineering PBL curriculum has been planned to be structured based on the integration of physics, mathematics and computer basics. For many reasons including interrelated historical progresses of physics and mathematics, numerical and logical basis of computer sciences, learning objectives from physics, mathematics and computer basics are closely related and easy to be integrated in a real world scenario. Scenarios, which are now written by the collaboration of instructors formerly responsible for teaching physics, mathematics or computer basics, are not necessarily about an engineering problem but must be chosen on a real world physics problem.

As a new feature, scenarios are coupled with the physics laboratory experiments. In the physics

laboratory, students will perform an experiment as a part of the scenario. In the laboratory, they will collect data and then analyze the data, so they learn by doing the mechanisms on which the scenario has been built up.

Another feature added to the new freshmen engineering PBL curriculum, which is planned to be applied as the first time in 2005-2006 academic year, is the project based learning in a format same with the Pittsburgh University example [10]. 2 hours per week in all modules of both semesters of the first year are devoted to the project based learning. In the first week, students will be informed about the aims, learning outcomes and learning objectives, and about the implementation of project based learning. Teams of 3-4 students will be asked for proposing, realizing and presenting a project on the topics specified in the first call for projects announced in the first week. The projects will be supposed to be original and to have an integration feature. The topics must be on basically physics, mathematics and computer basics, but the topics on related engineering sciences and other basic sciences such as chemistry or material sciences may also take place based on the thematic area(s) of the semester. Teams will take feedbacks from the instructors along 14 weeks and eventually submit a final report which will be in a conference paper format. They will present the poster form of their paper in a poster gallery which will be held in the last week of the semester and they will present their projects also in a 5 minute oral communication along with a power point presentation in front of a jury. It is expected that such a project based learning component embedded to a PBL curriculum helps students to integrate knowledge from different modules in the same semester, so the lack of interconnection of different modules in modular staged PBL education systems is overcome. The other benefits might be to enhance team working skills, life long learning skills, written and oral communication skills, and to foster design concept.

2.3. Project Based Learning in a PBL Education System

In the departments implementing PBL education system, fourth years only have been devoted to project based learning from the beginning of PBL implementation. Now, the departments plan to embed project based learning into all of four years of their PBL curricula. The projects in the first year aim to integrate the knowledge of mathematics, basic sciences and computer basics. The second year and third year projects are planned to be designed to integrate the knowledge of the core and professional engineering sciences. They support students to gain the competency in team working, independent study, communicating as professionals and to develop engineering design skills. As also planned in designing the first PBL curricula in 2002, the fourth years' projects are capstone engineering design projects. Gaining professional design skills and knowledge about professionalism, engineering management and innovation are core learning objectives in the fourth years' projects which are assigned to teams of 3-4 students like former years' projects. In addition to team projects, the departments plan to continue to assign individual graduation projects in the fourth years.

The faculty does actually have some previous experience on project based learning which takes different forms from one department to another. Field study which is common in earth sciences, individual graduation projects and midterm projects assigned to along the courses are of examples which exist since the first implementation of undergraduate programs. All of eleven departments organize engineering days where fourth years students present their individual graduation projects in a poster gallery open to all students, all members of the faculty and public. Industry representatives, former graduates and emeritus faculty are invited to the poster gallery. All participants evaluate the presented projects, so their evaluations are considered in the evaluations done by the jury members. The engineering days also play a role of getting together all stakeholders of the faculty. Of course, the mentioned experiences on the use of project assignment

in the undergraduate education do not mean that the education system is based on project. The project assignments are rather used for fostering design concept and providing a learning environment close to real engineering world.

In the newly planned PBL curricula, problem based learning is still the main education strategy. However, project based learning that the faculty considers it as one of the forms of PBL suitable to engineering education takes place as the co-strategy. One of the motivations for progressing in this direction is to provide a vertical integration of learning objectives of the modules of the same semester, so enhancing the efficiency of PBL practice. A second motivation comes from the fact that most of the real world engineering problems to be solved by engineers can be formulated as projects that engineers propose and then realize them if found feasible. Designing or developing a product, a system, a process, a software or an hardware; building up a construction; managing an organization; monitoring a system or a process; measuring signals or collecting data and then analyzing them for making decisions or for producing solutions; or producing services for replying engineering demands are some examples for the tasks that engineers are supposed to be performed. These tasks may be considered as problems for engineers to solve and they may be performed by posing them as formal projects.

Basic and especially applied research done by the faculty members are usually realized as a part of a research project. So, problem based learning applied in undergraduate education may provide to the students a chance for sharing research experiences of the faculty staff and also may provide to the faculty staff a chance for rethinking about basics of the research they done.

On the other hand, engineers may face with an accident, a failure or a case along their engineering practice. Such problems are very suitable for creating a real world engineering scenario. To collect stories that engineers in Turkey tell their experience on solving real engineering problems, the faculty had put an initiative via internet in 2003. Unfortunately, very small number of responses had been taken. Now, there are some attempts by the faculty staff to contact engineers individually and to obtain their written stories which may constitute the backbone of the scenario [11].

2.4. Evaluation of a PBL Engineering Education Program Based on EC2000

The determination of the quality of educational programs of the faculty is a need for accountability. The continuous improvement of the quality of the educational programs requires as systems to have a well established assessment and evaluation mechanism for their educational activities. Such mechanisms only could provide the possibility of meeting predetermined educational outcomes and educational goals, and having a desirable long term impact on the society. Assessment and evaluation of an educational program should take into account feedbacks from students, faculty staff, graduates, employers, governmental and nongovernmental institutions, in short from all persons and institutions affected by the outcomes of the educational program.

Environmental, Geological and Mechanical Engineering Departments of the Faculty have evaluated their programs and then applied to Engineering Evaluation Board MÜDEK in 2004 for critical appraisal. The faculty has been very recently informed by the Engineering Dean Council of Turkey that all of the three departments applied have been accredited by MÜDEK.

Accreditation studies of the departments can be summarized under different stages as preparation, carrying out the activities, evaluation (finally reflected in the self study reports) and making changes in the education.

Preparation stage constitutes the understanding “what accreditation and evaluation are” and “what

MÜDEK is seeking for” and to determine what we need to do. Therefore, the activities carried out in accreditation were initiated with the seminars in the departments to learn MÜDEK evaluation and ABET accreditation. After that, the commissions were formed and the responsibilities of each one were defined. The missions of the departments which are suitable to the mission and vision of the faculty was stated and announced via internet. The program educational objectives and aims of the departments were determined and then the questionnaires for students, graduates, alumni, courses, employees and employers, have been prepared in accordance to MÜDEK 3.a-k program outcomes [5]. Advisory boards made up of graduates, academicians, employers and employees were gathered to discuss the past and the present situation of environmental, geological and mechanical engineering education and to determine future needs of graduates.

Meetings with advisory boards were organized to take feedbacks. Course/module contents, objectives, assessment methods and student learning outcomes were determined by the instructors of the courses. Their evaluation stages were basically on the questionnaires. They were carried out at the end of each term and statistical analyses were done on the collected data. Making changes in the education programs are determined based on the results of questionnaires and conclusions obtained from meetings with advisory boards.

In conclusion, the environmental, geological and mechanical engineering departments have decided to form new curricula considering feedbacks provided by the MÜDEK evaluators and their stakeholders.

The departments now try to substitute design projects and some new non-technical electives. In order to graduate engineers enriched with social conscious and activities; the departments include at least four non-technical elective courses from a pool of non technical electives constituted by the faculty. These courses are selected from the groups classified as: “environment and the problems of the age”, “communication and team study”, “engineering ethics and life-long learning” and “general social-cultural”. Some new technical elective courses with considerable applications in industry are also included.

The faculty has recently given a great attention to student advisory system which is available from the establishment of the faculty. A new guide for students, faculty staff and administration has been prepared for explaining what they must do in a timely manner for having an efficient advisory system. An advisor which monitors and guides the students assigned to him/her has been selected by the department head. Forms to be filled by the students and advisors have been made available in the University web based automation system by the faculty. In addition to that advisory system, the faculty has established a new external advisory system for the students. Beginning by the fall semester of academic year 2005-2006, an external advisor who will be assigned in a voluntary based among the members of a pool including the departments’ external advisory board members will be assigned to each student. It is expected that external advisory system will enhance faculty-industry and faculty-society collaborations not in education issues but also in research issues.

Geological engineering department had been the only department which is under evaluation and implementing a PBL curriculum. The department has observed during the self evaluation of its PBL education program that the outcomes of PBL and the existence of feedback mechanisms for considering the views of students and faculty staff in continuous improvement of the PBL education program almost coincide with ABET/MÜDEK criteria e.g. EC2000 criteria. To see this fact, it may be compared the ABET EC2000 program outcomes 3 a-k [5] to the most important outcomes of PBL curriculum of geological engineering department given as:

- A) An ability to identify and then solve real engineering problems,
- B) An integrated knowledge of mathematics, basic sciences, geological engineering sciences and other

disciplines and the ability of using them,

- C) An ability to function on multidisciplinary and team study, and
- D) Skills of independent study and lifelong learning.

Herein, the ABET program outcomes constitute criteria that engineering programs must demonstrate that their graduates have:

- (a) An ability to apply knowledge of mathematics, science, and engineering.
- (b) An ability to design and conduct experiments, as well as to analyze and interpret data.
- (c) An ability to design a system, component, or process to meet desired needs.
- (d) An ability to function on multi-disciplinary teams.
- (e) An ability to identify, formulate and solve engineering problems.
- (f) An understanding of professional and ethical responsibility.
- (g) An ability to communicate effectively
- (h) The broad education necessary to understand the impact of engineering solutions in a global and societal context.
- (i) Recognition of the need for, and an ability to engage in life-long learning.
- (j) Knowledge of contemporary issues.
- (k) An ability to use the techniques, skills and modern engineering tools necessary for engineering practice.

The accreditation of PBL education program of geological engineering department that has very recently been announced by the Engineering Dean Council demonstrates the competency of the department in undergraduate education. It also makes clear that a PBL engineering education program can be accredited based on ABET EC2000 criteria. An increase in the department's article production in the journals cited by SCI-Exp and an increase in the department's research project production as indicated by the increased number of research projects supported by Turkish Scientific and Technical Research Council may be interpreted, at least for that department, as: Heavy load implied by small group PBL implementation may not weaken and even may enhance basic and applied research activities of faculty staff.

3. Conclusion

The faculty as a living organization has learned about which educational objectives respond to demands of the society and which kind of assessment, evaluation, grading and educational strategy would be used to meet these objectives and it plans to integrate teaching and research activities and to apply the outcome based approach also for evaluating its research activities.

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