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Freshman Engineering Majors gets Pumped up to Design Human Powered Water Pump at University of Maryland Eastern Shore

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Abstract

Engineering Criteria 2000 of the Accreditation Board of Engineering and Technology (ABET) is encouraging engineering programs to emphasize on both soft and technical skills in the engineering curriculum. Engineering graduates of the new millennium will not only have to be proficient in mathematics and sciences but will also have to learn to work well in teams to design and develop products to meet specified needs.

University of Maryland Eastern Shore (UMES) offers an ABET accredited engineering program in collaboration with University of Maryland College Park(UMCP). In response to the new criteria UMCP developed a team based design course for the freshman engineering majors. The course has been adopted with suitable modifications at UMES. The course is designed to introduce field of engineering and engineering design process to freshman engineering majors so as to enable them to realize how individual courses in an engineering curricula are integrated together under a common objective.

In this paper we describe the highlights of design efforts by the students in developing human powered water pumps with specified head and flow rate in the spring and fall semesters of year 2001. The project outcomes are elaborated from the perspective of Kolb's experiential learning cycle. The assessment techniques and their strengths and weaknesses are also discussed.

I. Introduction

Emerging trends in engineering education facilitated by the Engineering Criteria 2000(EC2000) developed by the Accreditation Board of Engineering and Technology (ABET) [1] is encouraging integration of design throughout engineering curricula including the freshman and sophomore years [2, 3]. It is also promoting a holistic integration of 'soft' and 'technical' skills encompassing academic knowledge and life skills consistent with the engineering profession.

The Introduction to Engineering Design course (ENES 100) has evolved over the last decade at University of Maryland, College Park (UMCP) and integrates ideas, opinions and experiences of many faculty members who have experimented with teaching design to freshman students. The course involves freshman students in a "hands on" product realization process. The product development project is assigned in teams of four or five. The typical product chosen, like many engineering products is synthesized from components and engineering principles that cover a spectrum of topics.

While developing the course at University of Maryland Eastern Shore (UMES) which offers an ABET accredited Engineering Degree in collaboration with Clark School of Engineering at University of Maryland, College Park to the residents of Eastern Shores of Delmarva peninsula, the basic structure and content have remained unaltered. However, suitable refinements have been incorporated such that all the four phases of "Experiential Learning Cycle" [4, 5] are emphasized.

The Introduction to Engineering Design (ENES 100) is a 3 credit course and is required for all freshman engineering majors at UMES. In this course the students are required to work in teams of four or five to design and manufacture an engineering product over the semester given a set of specifications and constraints. The course introduces freshman students to the field of engineering and the engineering design process that forms the backbone of real world engineering practice. The class lectures and design integration draws knowledge from several different courses/fields the students will be undertaking in subsequent years thereby avoiding compartmentalization of knowledge by rigid subject/disciplinary boundaries. The students learn project management, teamwork, engineering drawing, project presentation, data analysis, writing technical reports, and fundamentals of engineering science related to the design project assigned.

UMES student efforts pertaining to design and development of "Postal Scales" have been reported earlier [6, 7]. In order to provide variety as well as to develop an understanding of student "comfort level" and "achievement of desired learning outcomes" and its correlation with the nature of project assignment, it was decided that design of "Human Powered Water Pumps" will be used as an alternative design project. This article reports the results pertaining to "water pump design project" at UMES in the spring and fall semester of 2001. "Introduction to Engineering Design, Book 4: Human Powered Water Pump" [8] and "Engineering Design and Pro/Engineer" [9] are used as text-books.

As in the past efforts are made to engage students through all four phases of Kolb's "Experiential Learning Cycle", involving 'Concrete Experience', 'Reflective Observations', Abstract Conceptualization' and 'Active Experimentation' to provide a holistic learning experience which integrates knowledge from many different fields. The course has a clear set of outcomes consistent with the Engineering Criteria 2000 of ABET. Moreover, the course helps provide "engineering" flavor early in the curricula so that the mathematics and science components in the first two years of engineering curricula becomes less abstract and more relevant in the students mind.

The students have reflected that the design efforts have helped them in realizing the "role" of the customer in engineering design, development of a clear perception of constraints in space, time and budget while implementing projects. Other life skills pertaining to improvement in communication skills, ability to work in teams and resolve conflicts etc. have also been favorably impacted. The course has provided the students with a better appreciation of the role of engineering in society. Finally and perhaps most importantly the students reflect that the experience have allowed them to comprehend more effectively the philosophy behind the engineering curricula and its emphasis on the language, general education, mathematics, science and engineering components.

II. Project Overview, Highlights and Pitfalls

Following the text the students were introduced to historical development of pump design. The students were assigned to reverse engineer a garden water pump, a centrifugal pump and an automobile fuel injection pump. The class lectures provided elaborate discussion on design specifications; engineering fundamentals of piston, diaphragm and centrifugal pumps with emphasis on piston pumps; test facility for testing the pumps manufactured by the students and conducting performance evaluation with respect to design specifications. In the spring of 2001 all three teams in the class decided to develop piston pumps. In the fall of 2001 four of the six teams decided to develop piston pumps while the remaining two attempted to develop centrifugal pumps. Figure [1] shows students of the fall 2001 ENES 100 class gathered together with their pumps prior to testing. Figures 2 thru 4 are examples of completed pumps designed by student teams. Figure [2] shows a completed piston pump and the team that built it. Figure [3] shows a double acting dual piston pump that one of the teams designed. Figure [4] shows a centrifugal pump and its drive system which has been developed using a discarded bicycle.

Besides feasible budget and space constraints the students were also provided with the following specifications- a flow rate of 5 – 15 Gallons per minute with a head of 8 ft. with a flooded suction. It was expected that the drive mechanism would provide enough mechanical advantage so as to allow the weakest member of the team to operate the device effectively. The dimensions of the fittings for the inlet and outlet piping to the pump were also provided to the students. A simple test set-up was provided with an 8 feet long vertical pipe that would connect to the outlet of the pump and pour the water into a calibrated bucket. The flow rate was to be measured with a stop-watch using observations of the water level in the calibrated bucket during testing. The testing arrangement, consisting of the source water drum, the long delivery pipe and calibrated bucket are visible in Figure [5] along with a student team and the piston pump built by them. Figure [6] shows one of the student teams getting ready for pump-testing at the end of spring semester of 2001.

Besides attending class lectures the ENES 100 students used the Computer Aided Engineering (CAE) Laboratory and the Workshop facilities at UMES extensively during the project. The 3 credit hours of the course include 2 lecture hours and 2 Laboratory hours per week. The two lab hours were utilized for software skills development, manufacturing efforts in Carpentry and Machine Shop, as well as teamwork. The first two weeks of lab time was utilized for introduction to Microsoft Word, Excel and PowerPoint, followed by 7 /8 weeks of demonstration and training using ProEngineer. The remaining lab hours were left at the discretion of the student project leaders for manufacturing efforts in the workshop, technical report, final presentation and completion of engineering drawings of the designed product on ProEngineer. Appropriate supervision and instruction on safety precautions were provided to the students when they used the "Wood Shop" or "Machine Shop". Figure [7] shows students working in the "Wood Shop" at UMES on their pump project.

After the 5th week of classes the students were required to give a presentation using Microsoft Power-point which included a Gantt chart for their team project. In this presentation they were also required to provide a design alternative analysis to justify their selection of the design project using Pugh Matrix (See Fig [8]). They also provided an overview of the design concept they decided to pursue.

During the next phase of the project the students learned to use Microsoft Excel to perform design analysis (particularly those that decided to build piston pumps). It was pointed out unlike mathematical problems the students have solved in high school that typically yielded one answer, a typical design problem will have more than one mathematically feasible solution. Engineering judgment with due regard to cost, space, manufacturing, time and performance constraints will need to be applied to choose the optimal solution. Figure [9] shows the analysis using EXCEL to choose the stroke length and diameter for a piston pump performed by a particular student team using the design specifications. The chosen design parameters are highlighted. Students also developed engineering drawings, product structure diagram and bill of materials/parts list prior to purchasing components and manufacturing the pumps corresponding to their own teams. Figures [10a] and [10b] show the Pro/E solid model of one of the pumps built by the students and the corresponding completed pump, respectively.

All the piston pumps developed by the students performed satisfactorily, some better than others. However, despite significant effort by the students in developing drive mechanisms, impellers and volute section, the centrifugal pumps failed to work adequately due to sealing and other associated problems.

On the final day of classes the teams were required to give a final presentation highlighting the design process, the product performance, possible improvements, learning outcomes as well as how to improve effectiveness of teamwork.

III. Assessment and Learning Outcomes

Assessment of courses that incorporate teamwork and cooperative learning poses a significant challenge both with regard to grading student performance and evaluation of the desired learning outcomes. Criteria 2000 of ABET and associated outcome evaluation process have challenged engineering educators and have set into motion an ongoing dialogue to improve the instruction and assessment methods [10-12].

The assessment of student performance is performed in the ENES 100 course by both conventional approach using scores from mid term, final examination and homework assignments as well as peer evaluation for teamwork. Appropriate forms developed for the purpose are provided to the students to be filled by the team members and team leaders. Also significant importance is provided to the first and final presentations of the project which are evaluated by a group of invited faculty members and administrators using appropriate forms. The peer evaluations and instructor perception are utilized to provide a token award / certificate to the “Best Team Leader”, “Best Team Member”,
“Most Improved Team Player”, and the “Best Team Project”.

The grading scheme used in the class may be summarized as follows:

Grading :

Attendance, Class participation and Examination	30 %
Team Grade (on Product development)	40 % *
Homeworks (individual and team)	15 %
Application software skills	15 %

***Team Grade :**

Preliminary Design Evaluation , Report and Oral Presentation	30 %
Final Design Package, Report, Web Page and Oral Presentation	40 %
Product performance and teamwork	30 %

The desired learning outcomes which are elaborated to the students on the first day of classes include efforts to develop skills consistent with engineering profession. “Life-skills” and “Civic Responsibility” outcomes are emphasized along with “Academic Outcomes”. The student perception of “Learning Outcomes” are evaluated by way of a bonus question in final examination which requires the students to fill in an outcome evaluation form similar to the one shown in Figure [11]. Figure [11] also shows the compilation of data corresponding to student perception of learning outcomes for the ENES 100 class at UMES for the spring and fall semester of 2001.

IV. Conclusion

The student perception indicates the desired learning outcomes have been achieved in the Introduction to Engineering Design (ENES 100) course. Feedback also indicates students are more comfortable with the requisite technical knowledge which primarily spans over algebra, trigonometry, mechanism design, high school physics for “Pump Design”, and fundamentals of fluid mechanics, as opposed to mechanics, strength of materials, D.C. circuits and basic electronics for “Postal Scale” design. Since the objective of the course is to introduce students to all facets of the design process, engineering drawing, manufacturing and quality evaluations as well as to nurture their creativity while keeping them involved in all four phases of the “Experiential Learning Cycle” it seems the “Human Powered Pump” design project is more suitable compared to the “Postal Scale” design project for engineering freshmen.

The Pro-Engineer component of the course needs to be integrated better. Students struggled in the initial phases of the instruction using this popular solid modeling package. With time they began to realize the capabilities of the software and utilizing the same more effectively. However, it appears some students feel that not enough time is available to master the software during the course due to other demands pertaining to teamwork and project completion.

V. Acknowledgement

The authors wish to acknowledge the efforts of the freshman engineering majors of the spring and fall of 2001. In the spring 2001 semester 12 students participated in the course in three teams where as in fall semester of 2001, 23 students participated in the project in six teams. Mr. Ron Spencer, the Carpentry shop supervisor and Dr. Emin Yilmaz who is

in charge of the Machine Shop at UMES, provided full support to the students. The co-author of this article not only worked with the students in the "Machine Shop" and "Wood Shop" but allowed access to the students to the facilities at inconvenient hours so that they could complete their projects.

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FIGURE 1

FIGURE 2

FIGURE 3

FIGURE 4

FIGURE 5

FIGURE 6

FIGURE 7

CRITERIA	Gear	Centrifugal	Diaphragm	Piston
Cost of Materials	-	S	S	DATUM
Availability of Material	+	+	+	
Simplicity	_	-	S	
Manufacturing ease	_	S	S	
Ease of assembly	_	-	S	
Ease of disassembly	_	-	S	
Impact on Environment	S	S	S	
Weight	S	+	-	
Power requirements	S	-	S	
Friction effects	+	S	-	

FIGURE 8

Lever d	radius	stroke	RPM	qvolume	gpm	qweight	pressure	force	work(in)	work (ft)	P(ft-lb/min)	HP	Pin=Pout	Force piston
8	2	18	30	6782.4	29.361	244.871	3.466	43.5279	783.503	65.291904	1958.757	0.0593563	0.118713	43.52794
10	2	18	15	3391.2	14.6805	122.436	4.332	54.4099	979.379	81.61488	1224.223	0.0370977	0.074195	54.40992
15	2	18	15	3391.2	14.6805	122.436	6.498	81.6149	1469.07	122.42232	1836.335	0.0556465	0.111293	81.61488
12	2	16	30	6028.8	26.0987	217.663	5.198	65.2919	1044.67	87.055872	2611.676	0.0791417	0.158283	65.2919
13	2	12	15	2260.8	9.78701	81.6237	5.632	70.7329	848.795	70.732896	1060.993	0.0321513	0.064303	70.7329
12	2	20	30	7536	32.6234	272.079	5.198	65.2919	1305.84	108.81984	3264.595	0.0989271	0.197854	65.2919
7	2	12	15	2260.8	9.78701	81.6237	3.032	38.0869	457.043	38.086944	571.3042	0.0173122	0.034624	38.08694
5	2	10	10	1256	5.43723	45.3465	2.166	27.205	272.05	22.6708	226.708	0.0068699	0.01374	27.20496
9	2	15	20	3768	16.3117	136.039	3.899	48.9689	734.534	61.21116	1224.223	0.0370977	0.074195	48.96893
13	2	18	11	2486.88	10.7657	89.7861	5.632	70.7329	1273.19	106.09934	1167.093	0.0353664	0.070733	70.7329

FIGURE 9

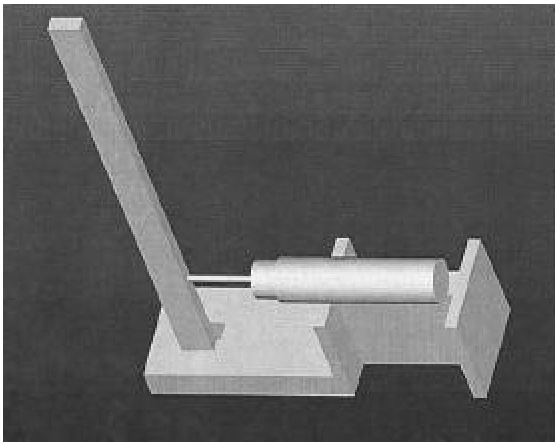

FIGURE 10a

FIGURE 10b

0 – Not Influenced at all; 1 - Influenced Little; 2 -Moderately Influenced; 3 – Strongly Influenced

LEARNING OUTCOMES	**0**	**1**	**2**	**3**
Academic Outcomes Desired				
Assimilation of "learning inputs" provided by the instructor to be able to apply the theory to design an engineering product (Water Pump) within specifications and constraints arising due to size, capacity and budget.	0	0	7	28
Experience with engineering design from start to finish including project definition, planning, risk assessment, design alternative analysis,software use, prototyping , testing, evaluation etc.	0	0	10	25
Development of communication skills.	0	0	10	25
Better appreciation of the role of customer in engg. design	0	3	17	15
Improved study habits and interaction with faculty	2	15	8	10
Ability to integrate knowledge from many different fields.	2	12	13	8
Life Skills Outcome Desired				
Critical thinking ability	2	12	11	10
Interpersonal and conflict resolution skills to successfully cooperate in a team.	0	2	14	17
Appreciation of role of community service in society.	4	6	19	6
Civic Responsibility Outcomes Desired				
Appreciation of "Code of Ethics" for engineers and development of professional ethics.	0	8	12	15
Desire to serve the community in the future.	8	14	5	8
Better appreciation of engineering and its socioeconomic impact.	0	4	12	19

FIGURE 11