Comparative Study of Students' Problem Based Learning Over Two Years through Semester Projects in Fluid Mechanics

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Abstract

Compared to traditional lecture style teaching, visualization and/or demonstration based teaching, project and/or problem based learning (PBL) are becoming increasingly popular in many US Universities as these teaching techniques are found to be more collaborative, integrative and effective in engaging learners and instructors. The in-class engineering lectures develops students' foundations on theories and principles of applied science which they experiment through hands-on laboratory activities, in-class and homework assignments. Similar to design experiments in laboratory courses, semester projects in theoretical courses enhances students' knowledge on practical applications. This can also be a gateway learning for sophomore and junior undergraduate students to prepare for their senior design projects This study compares the PBL performance data over two years from students' outcomes, students' learning objectives and course evaluation in MAE 331 Fluid Mechanics, a junior level civil cum mechanical engineering course. The analysis dictates that there is a clear relation between students' outcomes (measured by students' direct performance), learning objectives and course evaluation (measured by students' indirect survey. The implementation results of PBL provide valuable inputs to fulfill for ABET outcomes including (a) Engineering Science: apply knowledge of mathematics, science, and engineering, (d) Teamwork: ability to function on multidisciplinary teams, (e) Problem Solving: ability to identify, formulate, and solve engineering problems, and (g) Effective Communication: ability to communicate effectively. Study suggests to implement semester project and/or problem as an effective pedagogical assignment that demands students to work on a specific sub-topic of that specific course in order to achieve tangible outcomes and implementation of engineering principles on specific problem solving methods. This study is presented here as a continuation of last year's conference paper.

Introduction

At WVU Tech mechanical and civil engineering programs, both programs share several common courses including a course "MAE331 Fluid Mechanics," a junior level course in thermos-fluid area. A traditional lecture course typically outlines a number of learning outcomes especially based on a specific textbook contents. Such chapter topics are well explained in the textbook and are usually followed in the class to enrich students with necessary theories, equations, problem solving with practical examples. Students are normally assessed by homework, quizzes and tests. This traditional style of teaching does not typically offer opportunities for students to solve real world projects through classroom environment. However, junior undergraduate engineering students' project solving skills may be limited compared to the ability of completing regularly assigned homework, this allows them to solve real world problems through classroom environment. Over the last two semesters of Fall 2014 and Spring 2015, semester projects were assigned to the students of “MAE 331 Fluid Mechanics” course. The effectiveness of project based learning (PBL) in students' learning is comparatively studied. In last year's paper, we presented a pilot study of project based learning in Fall 2014 semester. Some of the past findings are helpful for PBL in Spring 2015 for the implementation and evaluation of semester projects. Comparative study of students' PBL over two years, students' learning through project assignment clearly prove that this tool is a very successful and an effective tool to achieve targeted Students' Learning Objectives (SLO). By the second week of the semester, students were supplemented with the information of project expectations and general guidelines of semester project (Exhibit A) along with the course syllabus.

Students were then advised to choose a topic related with “Fluid Mechanics” for their semester projects (Exhibit A). Topic for the project were open-ended, that allows students to choose any fluid mechanics related topic. Timeline for the project work was divided in three folds; initial project proposal, interim project progress report and final project report in a technical paper format. Two to three students were allowed to team up for the project work in a collaborative environment. Project teams were facilitated with necessary instructions and improvement comments through emails and one-on-one meetings in weekly to biweekly basis. Collaborative work including group discussions through intergroup and intra-group fashions were encouraged to engage students.

ABET accreditation requirements for many common engineering programs (Exhibits B and C) are to show successful students' skills and performance for a number of outcomes including (a) Engineering Science: apply knowledge of mathematics, science, and engineering, (d) Teamwork: ability to function on multidisciplinary teams, (e) Problem Solving: ability to identify, formulate, and solve engineering problems, and (g) Effective Communication: ability to communicate effectively. Students' project work and their presentations were evaluated based on a rubric for testing students' learning and accomplishments mainly based on ABET outcomes (a), (d), (e), and (g). Initial project proposal, collaborative team work, formulating a plan for project completion and final project communication were carefully evaluated.

Methods: Assignment of Semester Projects

In this paper, a list of projects from Fall 2014 and Spring 2015 semesters are shown. Some of which students brought their topics and/or instructor provided topics for their semester projects. As it was mentioned earlier, students were encouraged to come up with their topic of interest for their semester projects as long as the topic is relevant within the scope of fluid mechanics. Since the course is common to both civil and mechanical engineering majors, there were project topics in civil engineering and mechanical engineering applications chosen by students from civil engineering and mechanical engineering majors respectively.

Here are project topics from Fall 2014 and Spring 2015 semesters:

Fall 2014

1. Analysis and redesign of flow pipelines for natural gas supply,
2. Analysis of hydrostatic forces on a rectangular gate submerged in the WVU Tech swimming pool,
3. Fluid flow analysis on water dams,
4. Pump Selection for water supply in a multi-story building, and
5. Pump selection for a basement sump pump system.

Spring 2015

1. Water Pressure Comparison in different floors of WVU Tech Campus Engineering Building,
2. Hydroelectric Power Plant,
3. Demand of Water for Montgomery,
4. Buoyancy and Recovery,
5. Pump selection for a Water Supply Tank,
6. River Flow Reduction, and
7. Aerodynamic Forces.

Students involved in projects presented their work in a technical report format and through PowerPoint slides using the following format:

- Introduction
- Procedures/Methods
- Results and Discussion
- Conclusion
- References
- Appendix

As typical example project topics related to pump selection are as follows; Topic 4 (Fall 2014): Pump Selection for water supply in a multi-story building, Topic 5 (Fall 2014): Pump selection for a basement sump pump system, and Topic 5 (Spring 2015): Pump selection for a Water Supply Tank. The materials given below are merely the presented materials by the two teams.

For example, basic fluid flow equations for the selection of pump, following equations were used (considering water is incompressible, and the density "ρ" is constant) for the topics related to pump selection.

Volumetric Flow Rate 'Q' (Pumping rate of volume or mass)

$Q = V.\ A$, and

$V_{inlet}\ .\ A_{inlet} = V_{outlet}\ .\ A_{outlet}$

Reynolds Number 'Re' (Laminar or Turbulent flow)

$Re = V.\ D\ /\ \upsilon$

Calculation of Friction Factor 'f' (Assuming negligible pipe surface roughness, ks =0)

$f = 0.25\ /\ [\log_{10}(5.74/Re^{0.9})]^2$

Calculation of Pump Head 'hp'

$h_p = (z_2 - z_1) + (1 + f\ L/D) V^2/2g$

Required Pump Power 'P' for the selection of appropriate pump

$P = (Q*h_p*\gamma)\ /\ \eta$, 1 horse power (HP) = 550 ft . lbf/s

Where the symbols in equations have their usual meanings.

Here, V denotes average velocity in a pipe (ft/s),
V_{inlet}, A_{inlet}, V_{outlet}, and A_{outlet} are inlet velocity, inlet cross sectional area, outlet velocity, and outlet cross sectional area respectively.

D is pipe diameter (inch or ft),

D is pipe diameter (inch or ft),

μ is dynamic viscosity of water (Pa.s),

υ is kinematic viscosity of water (m^2/s),

L is pipe length (ft),

h_p is pump head required (ft),

$(z_2 - z_1)$ is differential elevation for fluid pumping (ft),

γ is specific weight (lbf/ft^3),

Re is Reynolds number (dimensionless number), and

η is pump efficiency (%).

Below are centrifugal pump performance curve and a snapshot of a centrifugal pump used in the project.

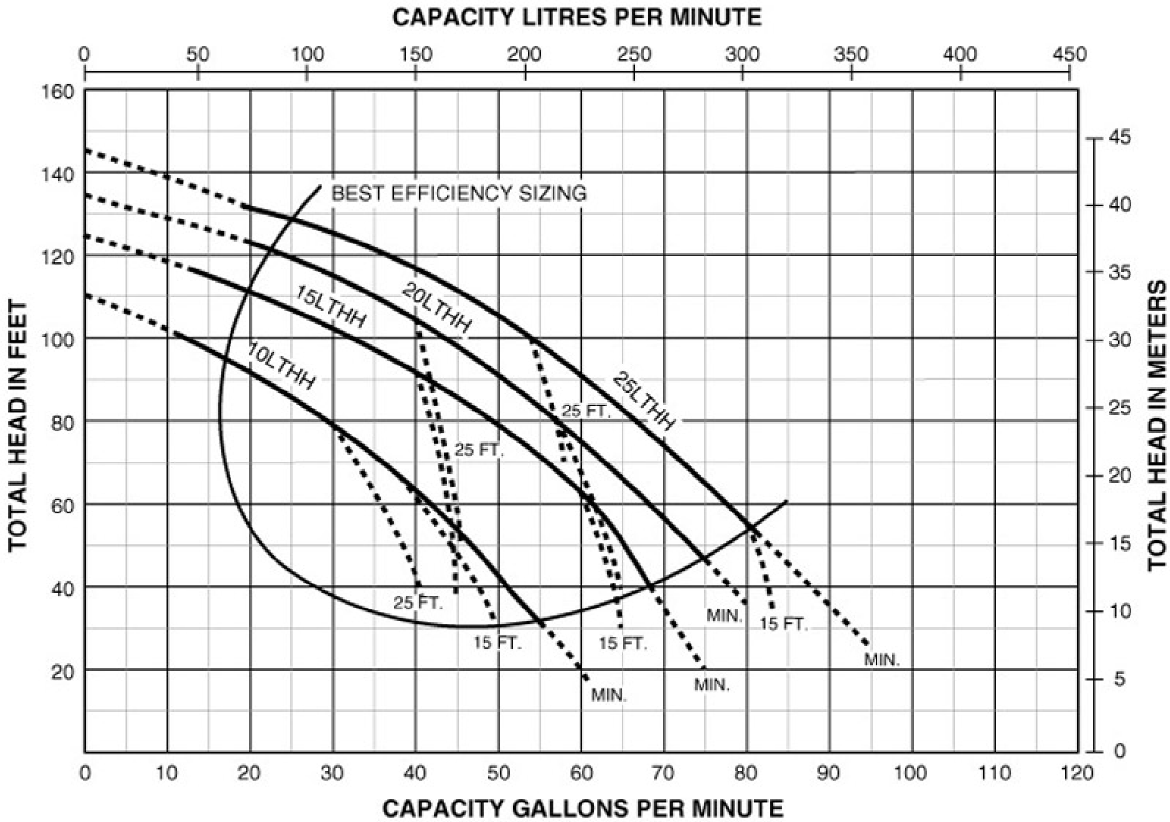

Figure 1 Centrifugal pump performance curve (*Figure 14.5-Elger et al*, and *http://www.berkeleypumps.com/ResidentialProduct_Series_LTHH.aspx*)

Figure 2 15LTHH Self-Priming Centrifugal Pump manufactured by Berkeley Manufacturer.

Assessment of semester project and continuous improvement

The final reports and presentations were evaluated according to the assessment rubric shown in **Table 5** for four different ABET outcomes (a), (d), (e) and (g). The evaluation results showed that the overall project performance of the students met the students' learning in both years. However, the evaluation of project completely depends on one specific project topic for each group and therefore could not be concluded overall advances of students' learning and performance for the course. The table also showed each team performance for four different ABET outcomes (a), (d), (e) and (g) in two years. For each team, last row represents the average score for ABET outcomes and the last column represent the average score for teams. Except the first two teams, other teams performed well in Fall 2014 (Refer to Table 1). Similarly, last four teams performed well (Refer to Table 2). A survey was conducted in the class to know the feedback of students about the project. Eight out of eleven students in Fall 2014 and fourteen out of seventeen students in Spring 2015 agreed that semester project was substantially effective for their learning.

Table 1 Assessment Summary for Fall 2014 - MAE331 Fluid Mechanics for ABET Outcomes (a), (d), (e), and (g).

(a) Engineering Science: apply knowledge of mathematics, science, and engineering,
(d) Teamwork: ability to function on multidisciplinary teams,
(e) Problem Solving: ability to identify, formulate, and solve engineering problems, and
(g) Effective Communication: ability to communicate effectively.

ABET Outcomes	(a) Engineering Science: apply knowledge of mathematics, science, and engineering,	(d) Teamwork: ability to function on multidisciplinary teams,	(e) Problem Solving: ability to identify, formulate, and solve	(g) Effective Communication: ability to communicate effectively	Average Points
Full Points *Teams and their Topics*	*5*	*5*	*5*	*5*	*5*
Team 1: Pipelines for Natural Gas Supply	4	3.5	3.5	4	3.750
Team 2: Hydrostatic Forces on a gate submerged in swimming pool	4	4	4	3.5	3.875
Team 3: Fluid Flow Analysis on Water Dams	4	3.5	4	4.5	4.000
Team 4: Pump for a Basement Sump Pump System	4.5	5	4.5	4.5	4.625
Team 5: Pump in Multi-Story Water Supply	4.5	5	4.5	5	4.750
Average Points	4.200	4.200	4.100	4.300	**4.200**

Table 2 Assessment Summary for Spring 2015- MAE331 Fluid Mechanics for ABET Outcomes (a), (d), (e), and (g).

(a) Engineering Science: apply knowledge of mathematics, science, and engineering,
(d) Teamwork: ability to function on multidisciplinary teams,
(e) Problem Solving: ability to identify, formulate, and solve engineering problems, and
(g) Effective Communication: ability to communicate effectively.

ABET Outcomes	(a) Engineering Science: apply knowledge of mathematics, science, and engineering,	(d) Teamwork: ability to function on multidisciplinary teams,	(e) Problem Solving: ability to identify, formulate, and solve	(g) Effective Communication: ability to communicate effectively	Average Points
Full Points *Teams and their Topics*	*5*	*5*	*5*	*5*	*5*
Team 1: River Flow Reduction,	3.5	4	4	3.5	3.750
Team 2: Aerodynamic Forces,	3.5	4	3.5	4	3.750
Team 3: Demand of Water Supply for the city of Montgomery,WV,	4	4	3.5	4	3.875
Team 4: Water Pressure Comparison in different floors of WVU Tech Campus Engineering Building,	4	4	4	4	4.000
Team 5: Hydroelectric Power Plant,	4.5	3	4	4.5	4.000
Team 6: Pump selection for a Water Supply Tank, and	4	5	4	4	4.250
Team 7: Buoyancy of a Boat.	4.5	5	4.5	5	4.750
Average Points	4.000	4.143	3.929	4.143	**4.054**

The data analysis from two years project results (Tables 1 & 2) shows that the average points are greater than 4 (Outcome (e) i.e. one exception in Spring 2015, Table 2) out of 5 full points for ABET outcomes (a), (d), (e), and (g). Team dynamics, communication between team members, difficulty of the specific topic chosen, and the problem layouts are some of the elements are factors affecting team scoring points. Also, we experienced that the assessment rubric needs to be more inclusive and to be revised to improve the students' learning. Assessment will then provide even more valuable information for continuous improvement of the course.

Conclusions

The projects were designed to maximize students' learning and therefore achieving ABET outcomes. Since both pilot studies were implemented for the first time at WVU Tech, we do not have student performances from other courses. However, two years project experience in the same course "MAE331 Fluid Mechanics" proves the effectiveness of PBL in students' learning. Assignment of semester projects motivates students' more into the course contents and their practical applications and seemed to produce positive results for students' learning effectiveness, however, there is also a need to create a more detailed project rubrics to incorporate ABET requirements and correlate with the individual SLOs. Students were found strengthening their ability of formulating a problem statement, ability to well-function in team, and problem solving by collaboration through project work. They also get an opportunity of developing their oral and written communication skills. Well planned project assignments, good communication between the instructor and students, continuous progress reporting can help students acquire in-depth knowledge to complete their projects on time. Thus, semester project approach, yet more to improve, proved to be an effective pedagogical tool allowing students to work on a specific topic of interests to enrich class materials and see practical applications. Given the careful time management, proper project topic and guidance, students will become more engaged and students' learning objectives may be better achieved.

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Exhibit A: Semester Project Guidelines

Department of Mechanical Engineering

Fluid Mechanics Semester Project Report/Presentation

The objective of projects is to become familiar with real world projects/problems that require fluid mechanics related problem/project analysis. Following is a basic format to write a report on your semester project. You can either submit a written report in 'Word' format or can make a presentation in 'PPT' format. If you happen to choose PPT, your group will get 5-7 minutes to present. Presentation may be arranged in a different time than our usual class time.

'Word' Format for Report (Approximately 4-6 pages):

1. **Title page:** This page has the course title, project title, your name, and date (1 page).
2. **Abstract:** This includes summary of your work and findings. (1/2 page)
3. **Introduction:** This section contains brief description of the project, objective and literature review with figures. (1 page)
4. **Procedure/Plan:** This section contains your approach to complete your project work. This includes necessary equations and their proper sequences (11/2 page).
5. **Results and Discussion:** Based on your methodologies and results from your calculations (using excel spreadsheet if needed), you should sufficiently discuss your figures/plots/tables**.** Compare and discuss the results obtained (*see 4 above*). (2 pages with figures)
6. **Conclusion:** This includes your comments and future work about the project (1/2 page)

Acknowledgements: *Mention your colleagues, advisor's names where appropriate (1/2 page)*
References: *List all cited references including journals, text book, internet resources (1/2 page)*
Appendix *(2-3 pages)****:***
Figures: *One or more Free Body Diagrams (2D and 3D) and Pictures*
Sample Calculations: *Include your sample calculations.*

‘PPT’ Format for Presentation (Approximately 10-15 PPT Slides):

1. **Front Slide (Slide-1):** This slide should contain the course title, project title, your name, and date of your presentation.
2. **Overview (Slide 2):** This slide includes overview of your presentation that may include a bulleted listing of **Introduction, Procedure, Results and Discussion, Conclusions, References and Appendix**.
3. **Introduction (Slides 3-4):** This slide contains brief description of the project, objective and literature review with some Figures and numbers. Introduction may take 2-3 slides.
4. **Procedure/Plan (Slides 4-5):** This slide contains your approach to complete your project work. This includes necessary equations and their proper sequences. Methodologies may take 1-2 slides.
5. **Results and Discussion (Slides 6-8):** Based on your methodologies and results from your calculations (show excel spreadsheet if applies), you should sufficiently discuss your figures/plots/tables**.** Compare and discuss the results obtained (*see 4 above*). This section may take 2-3 slides with figures.
6. **Conclusion (Slide 9):** This includes your comments and future work about the project. Methodologies may take 1 slide.

Acknowledgements (Slide 10):
Mention your colleagues, advisor’s names where appropriate

References (Slide 11):
List all cited references including journals, text book, internet resources

Appendix (Slide 12-15):
Figures: One or more Free Body Diagrams (2D and 3D) and Pictures
Calculations: Include your sample calculations.

POSSIBLE TOPICS & IMPORTANT NOTES:

- Civil Engineering Dams/Swimming Pools/Basement Water/Hydrostatic Forces on Submerged Bodies, etc.
- Mechanical Engineering Applications/Machines/Automobiles/Aerospace/Marines/Energy including turbomachinery, pumps, turbines, fans, valves, pipe flow, viscosity, pipe losses, etc.
- *Form your group and come up with your group name, captain and a topic of interest for my approval.*
- Project work continues until the 2nd last week of the semester and its progress should be informed by email biweekly. Report or presentation is due by the last week of the semester.

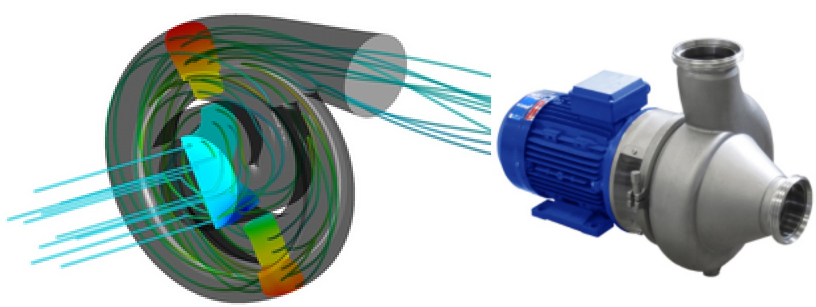
Sample Project Topic

Topic: Pump Performance Characteristics

Objectives This design experiment should relate the head and the efficiency of a centrifugal pump vs. the volumetric flow rate of water for the selection of a pump.

Materials Provided

Problem Statement: Use of Pump Performance Curve- In a chemical drug processing company, water is to be pumped from one large, open tank to a second large, open tank as shown in the Figure. The pipe diameter throughout is 6 in., and the total length of the pipe between the pipe entrance and exit is 200 ft. Minor loss coefficients for the entrance, exit, and the elbow are shown, and the friction factor for the pipe can be assumed constant and equal to 0.02. A certain centrifugal pump (as shown in the Figure) having performance characteristics shown in Figure is suggested as a good pump for this flow system.



FIND THE FOLLOWING

Evaluate the flow rate between the tanks.
Do you think this pump would be a good choice?
What would be the efficiency of the pump?
What would be the total head of the pump?

References: Munson et al, Fundamental of Fluid Mechanics, 7th edition, John Wiley and Sons, 2013.
http://www.mtiholland.com/research-development/computational-fluid-dynamics.html

Exhibit B: Brief Course Syllabus- MAE 331 Fluid Mechanics

College Catalog

Properties of fluids, fluid statics, fluid kinematics, thermodynamic principles, momentum and energy principles, similitude and dimensional analysis, laminar and turbulent flow, viscous effects, flow in pressure conduits.
Prerequisites: MATH 156 Calculus 2 and MAE 242 Dynamics

Course Objectives

The primary goal of this course is to introduce the students to the introduction on statics and dynamics of compressible and incompressible fluid flows. Topics covered include fundamental principles of fluid mechanics: hydrostatics, the conservation of energy and momentum. Additional topics are the solution of problems in fluid mechanics using the principles of dimensional analysis and similitude, the determination of energy losses due to viscous dissipation in pressure conduits and the differences between flow regimes such as compressible/incompressible and laminar/turbulent.
Computer usage may also be anticipated for aid in the understanding of these principles.

Learning Outcomes

Upon successful completion of this course, students are expected to:

1) Understand and apply basic concepts and terminology associated with the properties of fluids, including density, specific weight, vapor pressure, viscosity, compressibility and surface tension.
2) Understand and apply basic theoretical concepts associated with fluid flow, including the Reynolds transport theorem, continuity and flow classifications (ideal vs. real, steady vs. unsteady, laminar vs. turbulent, compressible vs. incompressible, etc.).
3) Analyze and solve problems in fluid statics: buoyancy, center of pressure, hydrostatic forces, and fluid pressure.
4) Analyze and solve problems in fluid dynamics: Integral analysis of fluid flow such as continuity, momentum, energy, and Bernoulli's principle.
5) Analyze problems involving steady incompressible flow in pressure conduits with friction including the calculation of pressure loss and flow rate.
6) Analyze internal flows such as flow through pipes in series and parallel based on Reynolds number, loss coefficients, friction factor, and pumping requirements.
7) Apply the concept of energy conservation for real and ideal fluids.
8) Understand, derive and sketch the energy and hydraulic grade lines for flow in conduits.
9) Select a pump for a simple piping system.
10) Understand and apply the concepts of dynamic similarity and dimensional analysis through the use of dimensionless parameters such as the Reynolds number.
11) Understand the lift & drag characteristics of streamlines/ bluff bodies exposed to external flow.
12) Understand Flow Measurements.

Projects

There will be a multi-week, team project that will bind together several relevant course topics for a significant, open-ended problem solution. Not only to the specific problem solution, development of effective team work skills, and effective communication will be emphasized. Project report writing and instructor/peer evaluation(s) of each team member's contributions will be used for grading of the projects.

Exhibit C: Bachelor of Science in Mechanical Engineering Program

First Semester

WVUE	191	First Year Seminar	1
ENGL	101	Composition & Rhetoric	3
CHEM	115	Fund of Chemistry I	4
MATH	155	Calculus I	4
DRET	120	Drafting I	2
GEC	3	The Past and Its Traditions[(1)]	3
			17

Second Semester

ENGL	102	Composition & Rhetoric	3
ENGR	111	Software Tools for Engineers	3
MAE	241	Statics	3
MATH	156	Calculus II	4
GEC	5	Artistic Expression Elective	3
			16

Third Semester

MAE	242	Dynamics	3
MAE	243	Mechanics of Materials	3
MAE	240	Manufacturing Processes	3
MATH	251	Multivariable Calculus	4
PHYS	111	General Physics I	4
			17

Fourth Semester

PHYS	112	General Physics II	4
MAE	331	Fluid Mechanics	3
MAE	201	Applied Engineering Analysis	3
MAE	320	Thermodynamics	3
MATH	261	Elementary Differential Equations	4
			17

Fifth Semester

MAE	342	Dynamics of Machines	3
MAE	333	Mechanical Measurements	1
MAE	321	Applied Thermodynamics	3
EE	221	Introduction Electrical Engineering	3
EE	222	Intro Electrical Engineering Lab	1
MAE	454	Machine Design & Manufacturing	3
GEC	8	Western Culture Elective	3
			17

Sixth Semester

MAE	332	Experimental Methods	1
MAE	423	Heat Transfer	3
MAE	419	Heat Transfer Lab	1
MAE	340	Vibrations	3
ENGL	305	Technical Writing	3
ECON	401	Managerial Economics (GEC 4)	3
GEC	6	The Individual in Society Elective	3
			17

Seventh Semester

MAE	405	Sr. Mechanical Engineering Lab	1
MAE	455	CADD-Comp Aided Des & Draft	3
MAE	480	ME Systems Design I	3
GEC	7	American Culture Elective	3
GEC	9	Non-Western Culture Elective	3
		Technical Elective(s)	3
			16

Eighth Semester

ENGR	401	Sr. Engineering Seminar	1
MAE	410	Materials Science	4
MAE	460	Auto Controls	3
MAE	481	ME Systems Design II	3
MAE	456	Finite Element Method	3
		Technical Elective(s)	3
			17

[(1)]Refer to GEC Matrix for available GEC Courses.
All Technical Electives must be approved by the M.E. Department Advisors.