Fostering Students' Capability of Problem Solving Through Semester Projects in Fluid Mechanics

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Abstract

Both lecture and laboratory courses are essential and integral parts of engineering curriculum of all engineering programs. The classroom lectures nurture students to build a foundation on theories and principles of applied science which they experiment through hands-on laboratory activities, in-class and homework assignments. Design experiments in laboratory courses and similarly semester projects in classroom lectures are good learning tools for sophomore and junior undergraduate students to prepare for their senior design projects. Semester project is an effective pedagogical assignment that demands students to work on a specific topic of interests in order to achieve tangible outcomes and implementation of engineering principles on specific problem solving. ABET requires all engineering program to show successful students' skills and performance in 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.

Introduction

At WVU Tech mechanical and civil engineering programs, MAE331 Fluid Mechanics is a common course in thermos-fluid area that the both programs have its requirement to earn a BS degree. A traditional lecture course typically offers a number of learning outcomes especially based on textbook chapters. Such chapter topics are well explained in the textbook and are usually taught in the class that includes theories, equations with workout examples that are followed by homework, quizzes and tests. This traditional style of teaching does not typically provide opportunities for students to implement classroom learning in order to solve an open-ended case study or real world kind of problems. The ability of sophomore and junior undergraduate engineering students to design and complete their semester projects is relatively low compared to the ability of completing regularly assigned homework. It may be difficult for many undergraduate students to lay out systematic techniques to complete a semester project through a regular homework type solutions. Last semester Fall 2014, semester projects were assigned to the students of MAE 331 Fluid Mechanics course as a pilot study to see the effectiveness of project assignment in learning process. In this paper, we present this pilot study of semester project study with some of the findings that may be helpful for future implementation and evaluation. Students' accomplishments in project work somewhat prove that this tool can be very successful and an effective tool to achieve targeted Students' Learning objectives (SLO). Within the first week at the beginning of the semester, students were provided the information of project expectations and a general guidelines on project working plan and reporting (Exhibit A) along with the course syllabus.

Students were then advised to pick a topic related with "Fluid Mechanics" for their semester projects (Exhibit A). Topic for the project were not theme-based, that allows student to choose any fluid mechanics related topic. Timeline for the project work was divided in three folds; one, initial proposal and instructor's approval, two, project progress reporting and three, final project presentation and report submission. Two to three students were allowed to team up for the project work in order to complete the project in a collaborative environment. Project teams were facilitated with necessary suggestions and improvement comments through emails and face to face meetings in weekly basis. Collaborative work including group discussions through intergroup and intra-group fashions were encouraged to engage students in meaningful learning of the course contents relating their project work. At the end of the semester, students submit their written reports and did their PowerPoint presentations in the class.

ABET accreditation requirements for many common engineering programs (Exhibit B and Exhibit 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. Viewing on the ABET requirements and for course continuous improvement, students' project work and their presentations were evaluated according to a rubric for testing students' learning 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: Semester Projects

In this paper, a list of projects are presented of which students brought their topics and were approved to proceed the work for their semester projects. As it was mentioned earlier, students were encouraged to come up with their topic of interest for their semester project 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 inclined to civil engineering and mechanical engineering applications chosen by students from civil engineering and mechanical engineering majors.

Here are the project topics:

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*
5. *Pump selection for a basement sump pump system*

In this paper, two project topics of which both related to pump selection, topic 4: *Pump Selection for water supply in a multi-story building* and topic 5: *Pump selection for a basement sump pump system* are presented here. The materials given below are merely the presented materials by the two teams.

Topic 4: Pump Selection for water supply in a multi-story building

Topic 4 (a) Objectives and Overview

The objective for this project is to find the *Horse Power required to pump water to a roof tank on a six-story building with a basement story* (**Figure 1**) *at different flow rates and select a pump that best fits the geometric and fluid flow parameters*. Students involved in this project presented their work by PowerPoint slides:

- Introduction
- Procedure
- Results and Discussion
- Conclusion
- References

Students introduced the project with the use of roof tanks to ensure adequate water pressure in buildings, and especially in tall buildings with multiple floors. In tall buildings, the pressure from a city source does not provide an adequate flow rate at the top of the building and this may be due to the head loss proportional to the pipe length. With some realistic given data as shown in the free body diagram below (**Figure 1***: Pipe flow diagram with an enclosed a picture of multi-story building of WVU Tech Engineering Building*), students used basic fluid flow equations to come up into a conclusions for the selection of pumps.

Topic 4 (b) Basic Fluid Flow Equations for the selection of pump
Following basic equations were used for the selection of pump:

Volumetric Flow Rate 'Q'

$$Q = V.\ A$$

Reynolds Number 'Re'

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

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

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

Calculation of Pump Head 'h_p'

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

Required Pump Power 'P'

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

Where symbols in equations have their usual meanings.

Here,

V denotes velocity (ft/s), D is pipe diameter (inch or ft),

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 (%).

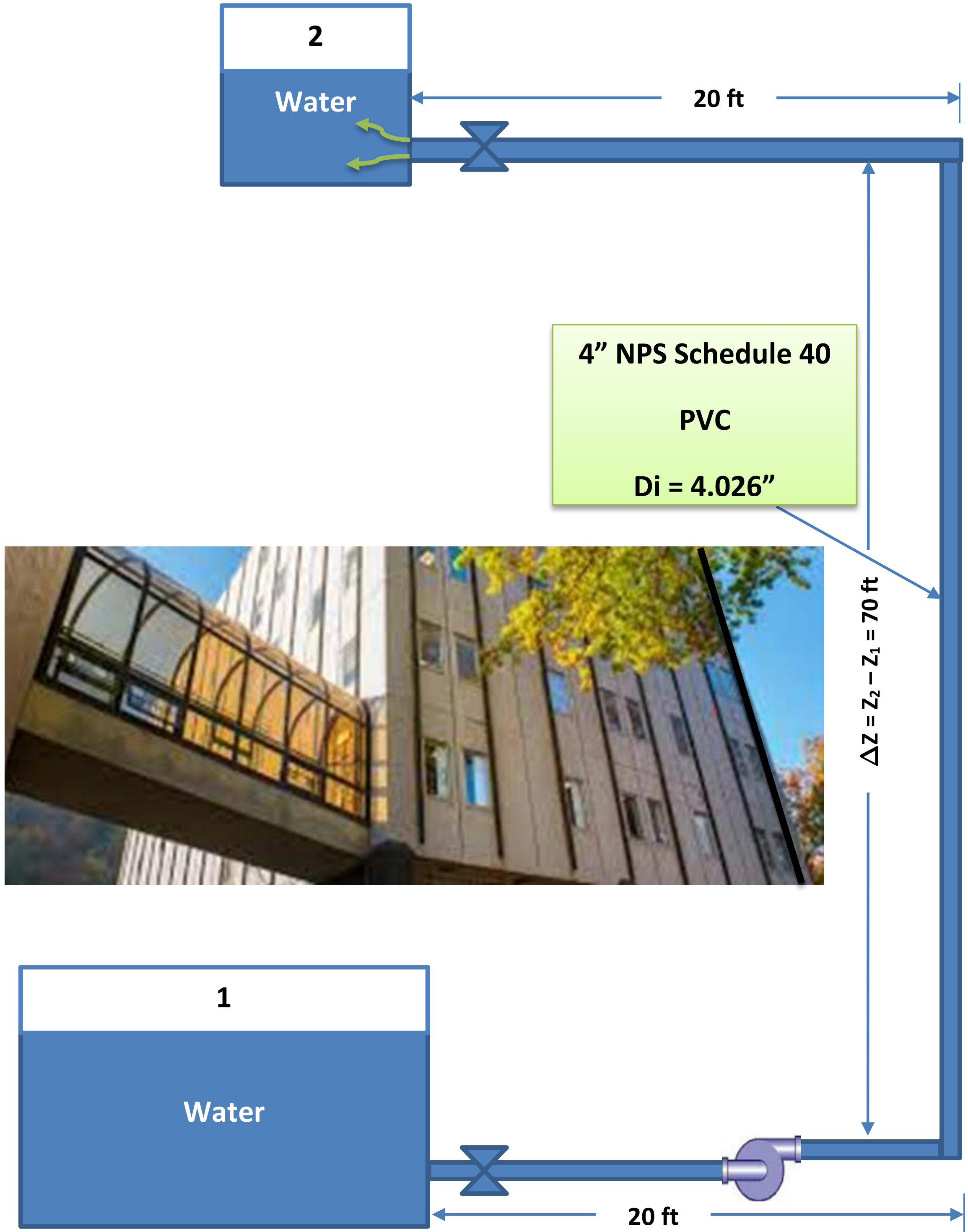

Figure 1 Pipe flow diagram for the selection of pump in a multi-story building water supply

Topic 4 (c) Procedure

The plan for selecting a pump was to determine the givens based on the situation and use the calculated variables to get a set of pump specification parameters to select the pump.

Givens:

- Elevation for water, z (ft)
- Length of pipe, L (ft)
- Flow Rate, Q (gal/min, i.e. GPM)
- Cross section-area of pipe, A (ft^2)
- Pipe diameter, D (ft)
- Pump efficiency, η (%)

Calculations:

- Head of Pump, h_p, (ft)
- Velocity of water in pipe, V (ft/s)
- Reynolds Number, Re
- Pipe friction factor, f
- Pump Power, P (Horse Power, HP)

Topic 4 (d) Results and Discussions:

- Estimated amount of fixtures to be 156 based on the number of bathrooms and water fountains
- Based on our research 156 fixtures at peak demand produces a flowrate of 36.5GPM (**Table 1**)
- After calculating the head of the pump for various flow rates, we graphed a system curve
- We researched various pumps based on their performance curves. Multiple systems curves are shown above for various models of a specific pump that fits our situation (**Table 2** and **Table 3**)

Table 1 Fixture unit values for some common plumbing fixtures

Fixture	Fixture units
Bath or shower	2
Bidet	2
Clothes washer (automatic)	3
Drinking fountain	3
Kitchen sink	1.5
Urinal or water closet (with flush tank)	3
Urinal or water closet (with flush valve)	6
Washbasin	1

Source: Taylor & Wood 1982 (p. 153).

Table 2 Calculation of required pump horsepower based on the given flow rates

Q (GPM)	Q(ft^3/s)	V (ft/s)	Re	h_p (ft)	W (ftlb/s)	W (HP)
50	11401	1.260124	34371.67	70.1405	609.469	1.108125
100	22802	2.520247	68743.34	70.5234	1225.592	2.228349
150	34202	3.780371	103115	71.13533	1854.34	3.371527
200	45603	5.040495	137486.7	71.97049	2501.481	4.548147
250	57004	6.300619	171858.3	73.02523	3172.676	5.768501
300	68405	7.560742	206230	90.17145	4701.138	8.547524
350	79805	8.820866	240601.7	75.78341	4609.512	8.38093
400	91206	10.08099	274973.3	77.48313	5386.168	9.793033
450	02607	11.34111	309345	79.39467	6208.927	11.28896
500	114008	12.60124	343716.7	81.51683	7083.208	12.87856

Table 3 Calculation of pump horsepower based on chosen diameters and elevations

D (ft.)	Q (gpm)	Z_1 (ft)	Z_2 (ft)	Q(ft^3/s)	V (ft/s)	Re	υ (ft^2/s)	f	hp (ft.)	γ	η	W, ft. lb./s	W, hp	Area, A
0.3355	36.5227	0	70	0.081373	0.92046	25106.92	1.23E-05	0.0244	70.07774	62.4	0.8	444.7907	0.80871	0.08840
0.3355	57.784	0	70	0.128744	1.4563	39722.65	1.23E-05	0.02188	70.1847	62.4	0.8	704.795	1.281445	0.08840

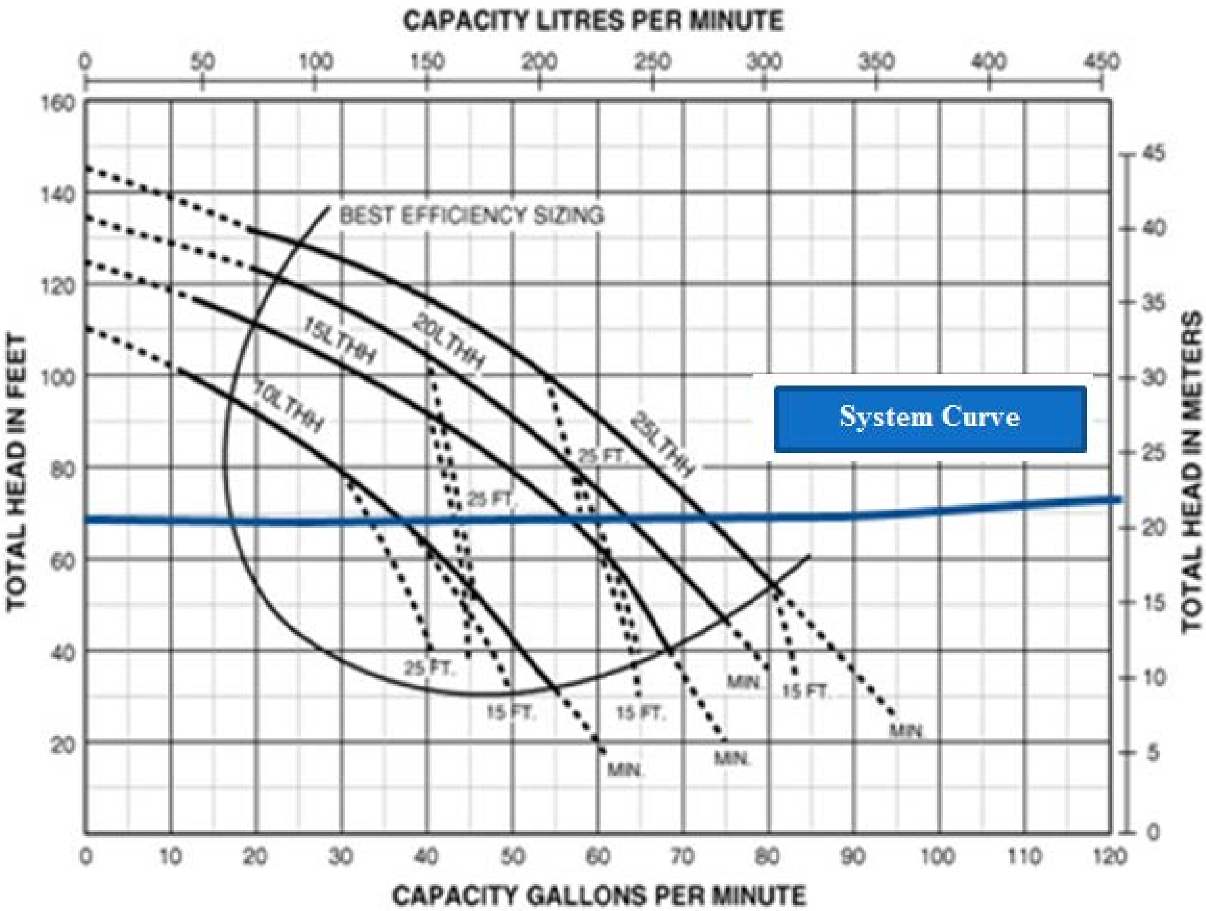

Figure 2 Centrifugal pump performance curve (*Figure 14.5-Elger et al*) with system curve

Topic 4 (e) Conclusion

- Our selection was based on the overlaying of the systems and performance curves and then choosing the pump that would supply our maximum flow rate at our required head.
- The 15LTHH version of the pump has 1 ½ HP which provides a 55.7 GPM rate at our required head. (**Figure 2**)
- This provides a Factor of Safety (FS) = 1.5 in terms of gaining maximum flow rate.
- In conclusion we selected the 15LTHH Self-Priming Centrifugal Pump as shown below from a Berkeley manufacturer (**Figure 3**).

Figure 3 15LTHH Self-Priming Centrifugal Pump manufactured by Berkeley Manufacturer.

Topic 5: Pump selection for a basement sump pump system

Topic 5(a) Problem Statement

Homeowners at Kanawha County wants to find the solution for their basement flooding problem by a heavy rainfall overnight. Immediate action is needed and the homeowners want to choose a sump pump system that will efficiently pump out the basement water with a cost effective way. Being engineering students, we are taking this project to help the homeowners with the recommendation of an appropriate pump (**Figure 4**).

Topic 5(b) Solution Plan

- Calculate volume of water collected from rainfall.
- Pick a water flowrate at which the homeowners want the basement water to empty.
- Use the pump head equation to find the pump head needed.
- Plug into the power equation for the selection of pump.
- Analyze results and provide the information with a recommendation.

Based on a typical house roof measurement, following assumptions were made in order to accurately calculate the water accumulation in two hours by the overnight rainfall.

Assuming total roof length (L) 70 ft., width (W) of 30 ft and rainfall thickness (t) of 2 inch in an hour. Total water accumulation,

Volume, ∀ = L * W * t = 70 ft * 30 ft * 2/12 ft = 350 ft^3 = 2618.4 GALLONS (∵ 1 ft^3 = 7.481 gallons)

Assuming the rain fall was lasted for two hours that had filled the basement, then the total water accumulation,∀' = 2 * ∀ = 5237 gallons (We used 5300 GAL/HR i.e. 88.33 GPM)

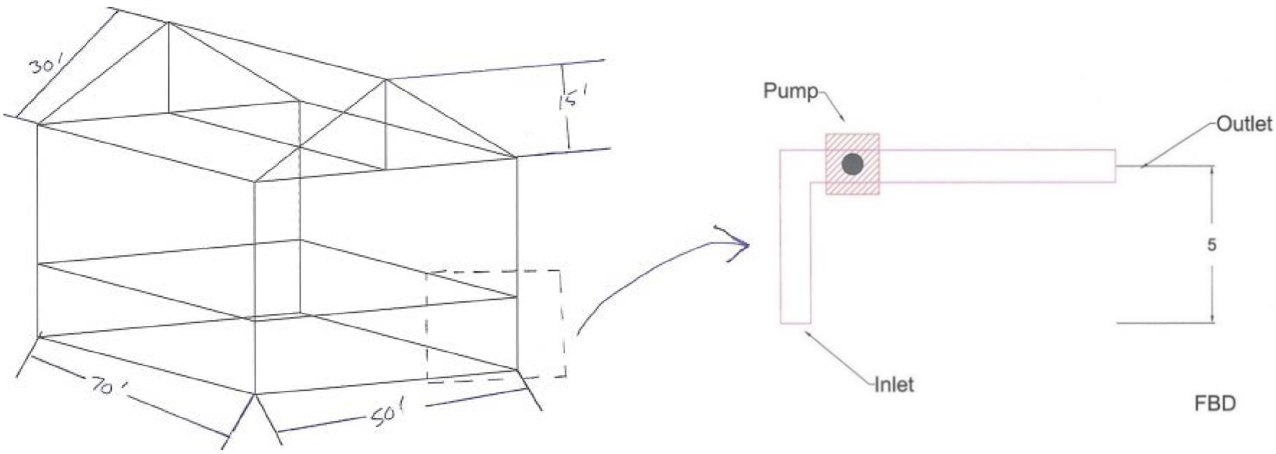

Figure 4 Sump Pump System used in the basement of the house

Topic 5(c) Equations used

Pump head equation for 'h_p', followed by pipe head loss for 'h_L', friction factor 'f', Reynold's number for 'Re' and pump power for the calculation of 'P' equations are shown below:

$$\frac{P_1}{\rho}+\frac{V_1^2}{2g}+\mathbf{z}_1+h_p=\frac{P_2}{\rho}+\frac{V_2^2}{2g}+\mathbf{z}_2+h_L$$

$$h_L=(f\frac{L}{D}+\sum K)\frac{V_2^2}{2g}$$

$$f=\frac{64}{R_\mathbf{e}}$$

$$R_\mathbf{e}=\frac{DV_2}{\nu}$$

P = (Q*hp*γ) / η

1 HP = 550 ft . lbf/s

Topic 5(d) Assumption of two design choices

Choice 1: Move 5300 GAL/HR and empty the basement in 1 hour.

Choice 2: Move 2650 GAL/HR and empty the basement in 2 hours.

Topic 5(e) System Components:

30' PVC pipe

2" Diameter

Friction factor, $f = 0.001$ (Standard Table for friction factor for the PVC pipe)

Minor Loss coefficient for inlet $K_L = 0.5$

Minor Loss coefficient for outlet $K_L = 1.0$

Minor Loss coefficient for elbow, $K_L = 1.5$

Differential elevation, $\Delta Z = Z_2 - Z_1 = 5$ ft.

Topic 5(f) Results

Using the equations, following results were obtained for design choices 1 and 2 (**Table 4)**:

Table 4 Calculation results for Design Choices 1 and 2

Results for Design Choice 1	**Results for Design Choice 2**
Choice 1: Move 5300 GAL/HR (88.33 GPM) and empty the basement in 1 hour.	Choice 2: Move 2650 GAL/HR. (44.17 GPM) and empty the basement in 2 hours.
Velocity, V = 115.63 ft/s,	Velocity, V = 57.81 ft/s,
Pump head, h_P = 665.21 ft,	Pump head, h_P = 170.02 ft,
Horsepower, P = 8185.16 ft-lbf/s =14.88 HP ≈ 15 HP	Horsepower, P = 1031.22 ft-lbf/s = 1.87 HP ≈ 2 HP
Pump Model : Berkeley B54504	Pump Model : Utilitech UTP20P1
Total Market Cost = $1,997.00	Total Market Cost = $348.00

Topic 5(g) Conclusion

- For these conditions we have chosen **Design Choice 2** by which money is saved and not much performance is sacrificed.
- By using the appropriate equations we were able to effectively design a pump system to remove the water from the flooded basement (**Figure 5**).
- Ways to improve our findings
  - Requires much deeper study in Pump Performance Curve
  - Find efficiency of pump throughout the performance curve for even better choice.

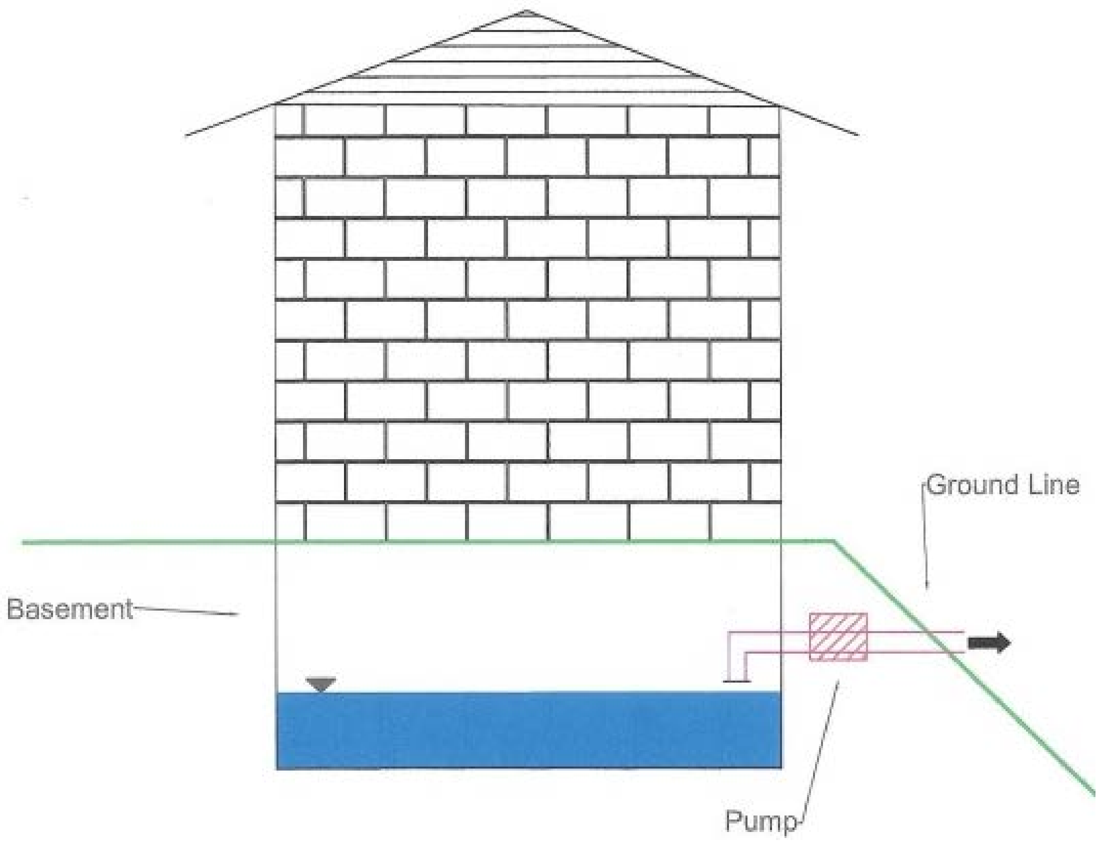

Figure 5 Pump installment for the Sump Pump System used in the basement

Assessment of semester project and continuous improvement

The final reports and/or 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. 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 compared with their overall course grade. The table also showed each team performance for four different ABET outcomes (a), (d), (e) and (g). For each team, last row represents the average for ABET outcomes and the last column represent the average for teams. Except the first two teams, other teams performed well. A survey was conducted in the class to know the feedback of students about the project. Eight out of eleven students agreed that semester project was substantially effective for their learning.

Assessment rubric needs to be more inclusive and revised in order to predict and improve the students' learning objectives in correlation with the overall course grades. Assessment will provide valuable information for continuous improvement of the course.

Table 5 Assessment Summary for Fall 2014- MAE331 Fluid Mechanics for 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 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 engineering problems,	(g) Effective Communication: ability to communicate effectively	Average
Teams and their Topics *Points*	*5*	*5*	*5*	*5*	
Team 1: Pipelines for Natural Gas Supply	4	3.5	3.5	4	3.75
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
Team 4: Pump in Multi-Story Water Supply	4.5	5	4.5	5	4.75
Team 5: Pump for a Basement Sump Pump System	4.5	5	4.5	4.5	4.875
Average	4.2	4.2	4.1	4.3	

Conclusions

The projects were designed to improve student learning in the course. Since this pilot study was implemented for the first time at WVU Tech, we do not have a comparison of student performance in this course with the project to student performance in previous offering of fluid mechanics courses. We are only comparing the learning effectiveness with semester project comparing to without the project. Assigning semester project was seemed to produce positive results for students' learning effectiveness, however, there is also a need to create a new assessment tools to incorporate ABET requirements and correlate with the individual SLOs. Students were found strengthening their ability of formulating a problem statement, ability to function on multidisciplinary teams, and problem solving 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 helped students acquire in-depth knowledge for their project completion. 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 for the implementation of class taught theories and principles. Given the careful time management, proper project topic and guidance, students will become more engaged and students' learning objectives may be better achieved.

Acknowledgements

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Bibliography

World Health Organization, "Design of Plumbing Systems for Multi-storey Buildings.". Addressing http://www.who.int/water_sanitation_health/hygiene/plumbing14.pdf accessed on Feb. 10, 2015.

Elger, Donald, Barbara Williams, Clayton Crowe, John Roberson, “Engineering Fluid Mechanics”, 10th Edition, John Wiley & Sons, 2013.

LTHH Self-Priming Centrifugal Pumps Series, " LTHH Series Self-Priming Centrifugal Pumps” addressing http://item.waterpumpsnow.com/categories/berkeley-other-water-pumps/berkeley-15lthh-pump.html accessed on Feb. 10, 2015.

Norgaard, Jens, and Anders Nielsen, "Water Supply in Tall Buildings: Roof Tanks vs. Pressurised Systems" Grundfos Water Boosting. Addressing the website Grundfos accessed on Feb. 10, 2015.

Addressing the website www.kirkwoodplumbing.com accessed on Feb. 10, 2015.

Berkeley B54504. Addressing the website http://www.rainfloirrigation.com/water-pumps/water-pumps.php accessed on Feb. 10, 2015.

Utilitech UTP20P1. Addressing the website http://www.lowes.com/pd_313834-57366-UTP20P1_0__?productId=3087295 accessed on Feb. 10, 2015

“ABET Engineering Accreditation Alert”, Executive Committee, EAC, March, 2011

Hyun W Kim, Yogendra Pana, “Fostering Students’ Capability of Designing Experiments through Theme-Specific Laboratory Design Projects”, ASEE Annual Conference, San Antonio, Texas, June 2012.

ABET Engineering Accreditation Alert”, Executive Committee, EAC, March, 2011

Fox, RW, McDonald, AT, Pritchard, PJ, “Introduction to Fluid Mechanics”, 8th Edition, Wiley, 2011.

ABET Engineering accreditation, addressing http://www.abet.org on 01/15/2015.

Young, J., and Lasher, W., “Use of Computational Fluid Dynamics in an Undergraduate ME Curriculum”, ASME

Proceedings Fluid Dynamics Division Summer Meeting, Forum on Instructional Fluid Dynamics, 1995.

West Virginia University Institute of Technology Undergraduate Catalog, 2014-2015.

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.

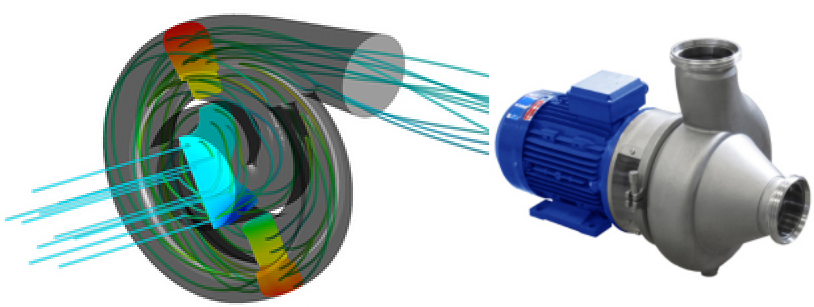
Sample Project Topic

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.



<u>**FIND THE FOLLOWING**</u>

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: 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

A. 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.

B. 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.

C. Assessment

1. ATTENDANCE AND PARTICIPATION

In order to successfully complete this course, you must attend the class meetings. All of the class meetings will be critically important to sequentially learn the course materials, therefore attendance and participation in classwork (multiple choice quizzes) contribute to your final grade. Not only will class participation cut down on out-of-class study time, but can also clear up misunderstanding of concepts more quickly upfront. This course deals with material that requires highly analytical approach and reasoning processes that will lead to a successful solution. It also covers a great deal of problems that must depend on the solution process relying on good engineering judgment. Therefore, previewing the contents is very important. Please read the material and understand the theory and principles before you come to class so that you can actively participate in class discussions and problem solving process. Please inform your instructor if you are unable to attend due to an institutional excuse. It is your own responsibility to make arrangements for any planned or unplanned class absences (i.e. interviews, illnesses, personal emergencies, etc.). However, you are also welcomed to see the instructor.

2. HOMEWORK

Home works are considered very important for the understanding of the course materials presented in the class. They will be assigned based on the materials presented in the class and/or in the textbook. You are encouraged to discuss homework with your classmates, whenever possible, in groups for better understanding of the material. HOWEVER, YOU ARE REQUIRED TO COMPLETE THESE ASSIGNMENTS INDIVIDUALLY ON YOUR OWN. IDENTICAL HOMEWORK SOLUTIONS WILL BE CONSIDERED COPIED WORK UNLESS PROVED OTHERWISE BY THE STUDENTS. A ZERO GRADE MAY BE GIVEN TO ALL SUCH DUPLICATES IRRESPECTIVE OF THE REASONS.

3. CLASSWORK

Class works will be done together with the instructor that is based on the materials presented in the class and/or provided handouts. YOU ARE REQUIRED TO COMPLETE THESE ASSIGNMENTS INDIVIDUALLY ON YOUR OWN. IDENTICAL SOLUTIONS WILL BE CONSIDERED COPIED WORK UNLESS PROVED OTHERWISE BY THE STUDENTS. A ZERO GRADE MAY BE GIVEN TO ALL SUCH DUPLICATES IRRESPECTIVE OF THE REASONS.

4. QUIZZES

Quizzes may be given whenever it is found necessary. Makeup quizzes may be given for legitimate excuses only for emergency circumstances. You should contact the instructor as soon as possible to make such arrangements.

In addition, instructor expects you to read the textbook, devote extra time outside of class, use your best effort to complete the assignments and seek help with instructor when needed. You may contact the instructor by stopping by in the office hours, or by phone, email and/or by emailing for special appointment if you need additional help. I would be glad to help you; however, you have to make serious efforts t to complete the assigned tasks. Do not wait until the due date to see the instructor if you need assistance. Please consult the instructor before the deadline in order to successfully correct the assignment and resubmit your work if asked. Homework and project deadlines will be provided at the time of distribution.

5. 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.

6. TESTS AND FINAL EXAM

Each test date will be announced approximately at least one week before the date. There will be a review class for each test. The final exam will take place as scheduled by the institution. There will be NO make-up exams unless arrangements with approved excuses have been made in advance with the instructor. During any exam, no collaboration or sharing of any kind is allowed. Zero-tolerance is set against transgressions. Any electronic devices (e.g., cell phone, IPad, IPod, etc.) except an authorized calculator need to be turned off during the exam. Use of such

7. MODIFICATION OF COURSE POLICIES

Course policies may be modified during the semester if such circumstances arise. You will be notified via email or in the class if this happens. These changes will be made only after discussion of such changes in the class.

9. GRADING

Your final grade will be computed based on the deliverance and grading scale as shown in the following tables.

Course Deliverables (100%)	
Homework	15%
Classwork	15%
Quizzes (3)=1st Quiz: 1%; 2nd&3rd Quizzes: 2% each	5%
Project (1)	10%
Midterm Tests (3)=10% each	30%
Final Comprehensive Exam	25%

Grading Scale	
A	90-100%
B	80-90%
C	70-80%
D	60-70%
F	< 60%

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.