Using “Conceptual” and “Assessment” Problems to Enhance Student Learning of Fundamental Concepts Taught in an Undergraduate Thermo-Fluid Mechanics Class

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Outline

• Genesis of idea
• Project Objectives
• Methodology
• Assessment Results
• Final Thoughts
• Acknowledgement
Genesis of Idea

Good grades on HW’s but still failing class.
Some students are not able to solve problems on exam that are same/similar to the ones assigned on homework.
Genesis of Idea

Fewer students seek help during regular office hours.

DUE FRIDAY?

DO FRIDAY

Procrastinator? No. I save all of my homework until the last minute because then I'll be older, therefore more wise.
Genesis of Idea

Textbook/Reference Book Reading???
Project Objectives

To enhance student learning and develop their problem solving skills using “conceptual” and “assessment” problems. This could possibly lead to achievement of following objectives:


Getting stuck is an important part of learning.
Project Objectives

To enhance student learning and develop their problem solving skills using “conceptual” and “assessment” problems. This could possibly lead to achievement of following objectives:


Although the perfect textbook may not exist but it is an important tool for students to gather more information and clear concept.
Project Objectives

To enhance student learning and develop their problem solving skills using “conceptual” and “assessment” problems. This could possibly lead to achievement of following objectives:

3). Effectively compel students to engage and to put in more effort to do assignments leading to increase in office traffic during regular/virtual office hours.
Project Objectives

To enhance student learning and develop their problem solving skills using conceptual and assessment problems. This could possibly lead to achievement of following objectives:

4). To develop a deeper understanding of fluid mechanics that could lead to better performance in a) class; b) exit assessment exam; c) FE exam.

A good understanding of the subject will also prepare them for advance level fluid mechanics course.
My belief: The more they do real-world problems, the better they get at setting up the problem, analyzing it and solving it. Must develop “problem solving skills”.

Idea was to give them few “never seen before” problems on assignment. I call these problems as “assessment problems”.

To solve these assessment problems, they will first need to solve “concept problems” which were carefully written/designed by me.
Methodology

- Picked few topics from each chapter.
- Summer 2013 : Spent time designing/ working on new problems on selected topics.
- Post a set of “Concept Problems” for each chapter on BlackBoard in the beginning of the semester.

- Each chapter has 10-15 concept problems.
- Each problem will be different from other but will provide additional reinforcement of concepts already discussed/taught in class.
- The question set and the completely worked out solution set were posted as two separate files on BlackBoard.
- Sample concept problems are shown in the next few slides.
Sample Concept Problem

Multiple-Choice Problems

*Problem #2: The quantity 2.36 x 10^{-8} \text{ Pa} (\text{Pa} \rightarrow \text{Pascal}) can be written as:
23.6 \text{ nPa}; (b) 0.0236 \mu \text{Pa}; (c) 236 \times 10^{-3} \text{ cPa}; (d) 2.36E-5 \text{ mPa}; (Refer table 1.3)
Answer: (a), (b) and (d)

*From Concept-Problems Set # 1

Problems with statements only (no figure)

*Problem #2: A farmer needs to fill a 5 acre field with water to a depth of 3 in. in less than 1 hour. How many 6 in. diameter supply pipes are needed if the average velocity in each cannot exceed 10 \text{ ft/s}. 1 \text{ acre} = 43,560 \text{ ft}^2.
Answer: n = 8

*From Concept-Problems Set # 3
Problem # 6: A long vertical wall separates seawater (S.G. = 1.03) from fresh water. If the seawater has a depth of 7 ft, what depth of fresh water, \( h \), is required so that the net force on the wall is zero? Also, in which direction the wall will rotate when the net force is zero. \( \gamma_{\text{water}} = 62.4 \text{ lbf/ft}^3 \); Answer: a) \( h = 7.104 \text{ ft} \); b) CCW

*From Concept-Problems Set # 2
Problem 3: **Reading Pump Performance Curve:** The pump characteristic curve of a centrifugal pump having impeller speed of 710 rpm is shown below for three impeller diameter size. $1 \text{ gpm} = 0.00222 \text{ ft}^3/\text{s}$

If $Q = 16 \times 10^3 \text{ gpm}$; find a) $H$; b) $\eta$; c) bhp; d) NPSHR; for impeller having 35-in. diameter.

If $Q = 24 \times 10^3 \text{ gpm}$; find a) $H$; b) $\eta$; c) bhp; d) NPSHR; for impeller having 38-in. diameter.

*From Concept-Problems Set # 7*
- On each assignment, students were given few “assessment problems”.
- The assessment problems will assess a student’s level of understanding of a) concept problems; b) fundamentals of topics covered in class and c) his/her ability to think logically and solve problems.
- Assessment problems are designed in such a way that minor changes in the problem statement (or figure) make it an entirely different problem. i.e., same set of problems can be used for next few semester.
- Some figures were taken from textbook/reference books and modified using MS-paint.
- Sample assessment problems is shown in the next slide.
Sample Assessment Problem

Original figure taken from fluid mechanics book by Cengel and Cimbala (chapter - 14).

Figure is modified with new components added in the pipe-system.
Sample Assessment Problem

Water ($\rho = 1.94$ slugs/ft$^3$; $v = 1.1 \times 10^{-5}$ ft$^2$/s) at 0.2 ft$^3$/s flows from a reservoir through new wrought iron pipe and various components and exits as free jet as shown in the figure below. Find the major head losses from (1)$\rightarrow$(2). The pipe system comprises of 390-ft of straight sections of pipe having uniform diameter, $D = 2$ in. followed by a sudden contraction of 10-ft of straight sections of pipe having uniform diameter, $d = 1.4$ in. Ignore kinetic energy correction factor.

a) If the pump is 70% efficient, find the pump power required to maintain the flowrate. Ignore minor losses.

b) Find the pressure drop across the thin plate orifice.

c) If water is at 60ºF and the pump inlet lies 20-ft below reservoir free surface, will there be cavitation. Take, $(NPSH)_R = 30$ ft.

d). Find minor head loss.

e). Ignore all the components and pump of the pipe system. Assume the flow to be frictionless and that the free jet exits 60-ft below reservoir free surface, find exit velocity at (2).

f). If the thin plate orifice is replaced by a long radius nozzle having same throat diameter as orifice, find the % increase/decrease of pressure drop across the device.
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Sample assessment problems is shown in the next slide.
Problem 1 (10 Points): Textbook Problem 1.9

Problem 2: \(4 \times 5 = 20\) Points
Problem 2a: Textbook Problem 1.10
Problem 2b: Textbook Problem 1.12
Problem 2c: Textbook Problem 1.16
Problem 2d: Textbook Problem 1.21

Problem # 3, 4 and 5 are 20 points each

Problem 3: The viscosity of blood is to be determined from measurements of shear stress, \(\tau\), and the rate of shearing strain, \(du/dy\), obtained from a small blood sample tested in a suitable viscometer. Based on the data given below, determine if the blood is a Newtonian or non-Newtonian fluid. Explain how you arrived at your answer. Refer Concept Problems/ Set-1/ Problems 2, 8, 9 and 11

<table>
<thead>
<tr>
<th>(\tau) (N/m²)</th>
<th>0.04</th>
<th>0.06</th>
<th>0.12</th>
<th>0.18</th>
<th>0.30</th>
<th>0.52</th>
<th>1.12</th>
<th>2.10</th>
</tr>
</thead>
<tbody>
<tr>
<td>(du/dy) (s⁻¹)</td>
<td>2.25</td>
<td>4.50</td>
<td>11.25</td>
<td>22.5</td>
<td>45.0</td>
<td>90.0</td>
<td>225</td>
<td>450</td>
</tr>
</tbody>
</table>

Problem 4: A 50-cm x 30-cm x 20-cm rectangular block weighing 150 N is to be moved at a constant velocity of 0.8 m/s on an inclined surface with a dry friction coefficient of 0.27. (a) Determine the required force \(F\) that needs to be applied in the horizontal direction. (b) If a 0.4-mm-thick oil film with a dynamic viscosity of 0.012 Pa-s is applied between the block and inclined surface, determine the percent reduction in the required force to achieve the 0.8 m/s velocity. Make following assumptions:

1) The friction coefficient and the oil film thickness are uniform; 2) The weight of the oil layer is negligible; (3) Linear velocity profile in the oil gap; 4) Assume oil to be Newtonian fluid.

Note: To get full credit:
1) You must draw complete free body diagram; 2) Use the coordinate system that is shown in the figure; 3) Force balance equation(s) should be written as per sign convention. Refer Concept Problems/ Set-1/ Problems 3 and 8

\[V = 0.8\text{ m/s}\]
Problem 5: A circular aluminum shaft of radius, $R$, mounted in a journal is shown in the figure. The symmetric clearance gap, $a$, between the shaft and journal is small and filled with a Newtonian fluid (assume linear velocity profile). The shaft is caused to rotate clockwise by the attached mass, $M$, and massless cord. Develop the first order differential equation for the angular speed, $\omega$, of the shaft as a function of time. Assume, $I$, to be the mass moment of inertia of the shaft about its axis of rotation.

Hint: Try solving practice problem #9 before you solve this problem.
- On each assignment, students were given few “assessment problems”.

- The assessment problems will assess a student’s level of understanding of a) concept problems; b) fundamentals of topics covered in class and c) his/her ability to think logically and solve problems.

- Assessment problems are designed in such a way that minor changes in the problem statement (or figure) make it an entirely different problem. i.e., same set of problems can be used for next few semester.

- Some figures were taken from textbook/reference books and modified using MS-paint.

- Sample assessment problems is shown in the next slide.

- **Assessment: There are total 4 midterm-exams (no finals)**

  - On each exam, one problem similar to assessment problem was given to assess their level of understanding. Refer next slide.
Problem 5: A circular aluminum shaft of radius, \( R \), mounted in a journal is shown in the figure. The symmetric clearance gap, \( a \), between the shaft and journal is small and filled with a Newtonian fluid (assume linear velocity profile). The shaft is caused to rotate clockwise by the attached mass, \( M \), and massless cord. Develop the first order differential equation for the angular speed, \( \omega \), of the shaft as a function of time. Assume, \( I \), to be the mass moment of inertia of the shaft about its axis of rotation.

**Hint:** Try solving concept problem # 9 before you solve this problem.
Problem 9: The thin outer cylinder (mass $m_2$ and radius $R$) of a small portable concentric cylinder viscometer is driven by a falling mass, $m_1$, attached to a cord. The inner cylinder is stationary. A Newtonian fluid of viscosity, $\mu$, lies between the clearance gap ($a$) of the two cylinders. Neglect bearing friction, air resistance, and the mass of liquid in the viscometer. Obtain in algebraic expression, the torque due to viscous shear that acts on the outer cylinder at angular speed, $\omega$. Derive the differential equation for angular speed of the outer cylinder as a function of time. $J_{\text{thin-cylinder}} = MR^2$; Assume linear velocity profile in the gap. Answer: Please refer solution.
Problem 4: A 73-mm-diameter aluminum (S.G. = 2.64) piston of 100-mm length resides in a fixed 75-mm inner diameter steel tube lined with an oil ($\mu = 0.13 \text{ N.s/m}^2$). A mass $m = 2 \text{ kg}$ is suspended from the free end of the piston. The piston is set into motion by cutting a support cord. What is the terminal velocity $V$ of mass $m$? Assume a) linear velocity profile within the oil; b) oil as Newtonian fluid.
For Assessment

Semester – Fall 2013
Course: ME-231/ ThermoFluid Mechanics-1 (1 Sections)
Total # of students enrolled: 52
Total # of students who took the survey: 14

- Individual student’s grade on assessment problem were noted down.
- Individual student’s grade on exam problem were noted down.
- Overall performance of class on assessment and exam problem is shown and compared in the next few slides.
- A short survey was conducted to gauge student’s perception about “concept” and “assessment” problems.
Distribution of Student Grades on Assessment Problem and Exam-1/ Problem # 4

Numbers in red indicate the percent of students scoring in the range shown along the x-axis.
Distribution of Student Grades on Assessment Problem and Exam-2/ Problem # 3

Numbers in red indicate the percent of students scoring in the range shown along the x-axis.
Distribution of Student Grades on Assessment Problem and Exam-3/Problem #2

Numbers in red indicate the percent of students scoring in the range shown along the x-axis.
Distribution of Student Grades on Assessment Problem (HW) and Exam-4/ Problem # 1

Numbers in red indicate the percent of students scoring in the range shown along the x-axis
Comparison of Homework Scores with Overall score at the end of semester

- Assignments with "Assessment Problems" - Fall 13
- Assignments with Textbook/Reference Book Problems - Spring-13

Overall Scores vs. Homework Scores graph.
1. How did you utilize the practice/concept problems posted on BlackBoard?

<table>
<thead>
<tr>
<th>#</th>
<th>Answer</th>
<th>Response</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I didn’t use them as I didn’t think they were helpful</td>
<td>2</td>
<td>14%</td>
</tr>
<tr>
<td>2</td>
<td>Only before exams</td>
<td>7</td>
<td>50%</td>
</tr>
<tr>
<td>3</td>
<td>I did them before doing homework as it helped me with the assignment</td>
<td>1</td>
<td>7%</td>
</tr>
<tr>
<td>4</td>
<td>I did them as soon as they were posted, without first looking at the solution</td>
<td>3</td>
<td>21%</td>
</tr>
<tr>
<td>5</td>
<td>Other *</td>
<td>1</td>
<td>7%</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>14</strong></td>
<td></td>
</tr>
</tbody>
</table>

* I used them before the test and thought they were very helpful. I like have the solutions separate as well.
2. Rate your agreement or disagreement with the following statements:

<table>
<thead>
<tr>
<th>#</th>
<th>Question</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The practice problems were helpful in building a strong fundamental concept of fluid mechanics for me</td>
<td>8</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Working through the practice problems helped me perform better on the midterm exam</td>
<td>4</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>Without the practice problems, I would have struggled much more with the homework assignments</td>
<td>1</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>I found the virtual office hours helpful before exams</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Does not apply</th>
<th>Total Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>7</td>
<td>14</td>
</tr>
</tbody>
</table>
3. Provide any comments that you would like to share about the practice problems

Text Response

I did not utilize the practice problems or the virtual office hours.
I thought that the practice problems especially were a great idea, but I didn't find that I needed the extra practice.

I never used the virtual office hours but having the extra practice problems definitely helped when studying for the exams.
I encourage you to keep using them. It definitely helped me on the last exam.

The practice problems were very helpful when studying for exams.
They provided a larger base of solved practice problems to study for those students without the solution manual for the textbook.

Your commitment to the success of your students is phenomenal.

The practice problems were a big help, and helped me perform well on the exams.
They were a great way practice the homework problems.
Final Thoughts

– Few of the project objectives were achieved. For e.g., performance on assessment problems on HW, exam problem similar to assessment problem, increase in traffic during office hours, minimizing the effect of solution manual (atleast, as far as the homework grade is concerned).

– Most students will rise to the level that we challenge them.

– This is a work in progress. Need more data to do statistical analysis.

– A small percentage of unhappy students.
Acknowledgement

- Diane Hagni, CERTI Coordinator, Missouri S&T.
- Dan Cernusca, Instructional Design Specialist, Missouri S&T.
- EdTech Support Team.
- My Students.
- CERTI
Questions