MIXING EXAM FORMATS TO ENHANCE EXAMINATION LEARNING AND TEST TAKING SKILLS

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Abstract

The concept of Mixing Exam Formats (MEF) was developed to enhance student learning beyond the exam and to train students to become more familiar with the Fundamental of Engineering (FE) and the Civil Engineering Professional Exam (PE) multiple-choice exam formats. Under this concept, the exam is graded such that each student gets two scores: the first is called “Objective Score” which is based only on grading the multiple choices. The second score “Traditional Score” is based on the traditional grading of the detailed solution. The instructor returns the exams having graded the “Objective” portion. If an “Objective” answer is incorrect the students are required to thoroughly analyze their own work to determine where they made specific errors and why the correct answer was not determined. Students report their findings in a report. The instructor grades the reports and gives a final grade which is a combination of the two scores.

The use of MEF concept helps students understand the material covered in the exam while also improving their test taking skills especially choosing the most correct answer. The concept allows students to identify and eliminate their mistakes. This paper covers the details associated with the concept development, implementation, and student responses of using the MEF concept as a method to extend the learning beyond examination and as a tool that will train students to be more effective when taking the FE and PE exams.

Introduction

Professors use a variety of examination formats to evaluate student learning. Traditional exams usually require detailed solutions in problem-solving exams. The Fundamental of Engineering (FE) and recently the Civil Engineering Principles and Practice Exam (PE) use only multiple-choice format and are considered “Objective Exams”. It is essential for practicing civil engineers to take and pass the PE exam to become professional engineers. No design can be accepted or implemented without being stamped by a professional engineer. The National Council of Examiners for Engineering and Surveying (NCEES) develops PE examinations that are taken by engineers for licensure as professional engineers. (1)

In the academic environment, the choice of exam format and the method of grading the exam greatly affect the effectiveness of the exam in its attempt to evaluate student learning. Also, depending on how the exam is written as “Objective” or Traditional”, it can become a valuable tool for extending leaning beyond the examination. Exams are usually the basis to evaluate how
well students learned course material. The value of exams as a learning tool has always been questioned. Some courses use papers or projects as the basis for evaluation instead. These methods possess the advantage of directing the attention of students to their writing but have the disadvantage of providing the instructor with no opportunity to evaluate how well the students mastered the basic ideas and skills being taught. (2)

In lecture based courses it is even more difficult to replace exams with other means of evaluation especially when the course is problem solving in nature. Therefore exams are likely to continue to be utilized for evaluation but the challenge remains on how to make exams more effective as a learning tool. Using the MEF concept, students are given the opportunity to revisit their graded exams, review, and analyze and learn from their errors. The concept also provides training on reaching the most correct answer through a structured approach where common mistakes are avoided.

Instructors written comments on exams are powerful communications that affect subsequent motivation and maximize students learning from exams. (3) Providing feedback to students is useful but usually marks the end of the learning process from exams. Many Engineering Technology (ET) students at University of Pittsburgh at Johnstown (UPJ) have been introduced to the useful concept “After Action Report (AAR)” which was developed to make the instructor’s general comments on the exam extend the learning process for the students. (4) The AAR concept also gives students an opportunity to provide feedback while analyzing their errors. The MEF concept presented in this paper is considered to be an extension to the AAR concept because the MEF concept not only requires an after action report to be submitted by the students but also uses this exercise to train students to reach the most correct answer by using mix exam formats. ET students were also introduced to the concept of “Syntax Error Analysis” which involves giving the students a problem along with an erroneous solution. Students are asked to analyze the problem to determine where the errors occur in the analysis and make corrections. (5)

Concept Development and Implementation

The MEF concept is introduced to students on the first day of classes. The concept is discussed along with the course syllabus. The intention of using the MEF concept as a learning tool and a way to improve the test taking skills of students are also discussed.

Under the MEF concept, the exam is prepared such that the students are instructed to show all work including the basic formula, step-by-step solution, sketches, units, and a correct final answer. At the same time the students are instructed to select the most correct answer from the four options given for each problem, even if they had to guess one of the options. The exam is graded such that each student gets two scores: one “Objective Score” based only on grading the multiple choices without consideration to the detailed solution provided by the student. The second score “Traditional Score” is based on the traditional grading of the detailed solution without consideration to the multiple-choice options. The instructor returns the exams having graded the “Objective” portion with the answer as either correct or incorrect. If an “Objective” answer is incorrect the students would be required to thoroughly analyze his/her
own work to determine where he/she made specific errors and why the correct answer was not
determined.

Students report their findings in a report submitted to the professor. The instructor grades the
reports and gives a final grade which is a combination of the two scores. A typical grading sheet
is shown in Appendix A. The use of MEF concept helps students understand the material
covered in the exam while also improving their test taking skills especially choosing the most
correct answer. The concept allows students to identify and eliminate their mistakes, which
prevented them from getting the correct final answer.

The Mixing Exam Formats (MEF) concept has been introduced in the Highway Surveying and
Design class. The Highway Design is a junior level course. Only Civil Engineering Technology
(CET) students take the course which is preceded by two-sophomore level courses in
surveying. The Highway course is design and problem solving in nature. It develops students'
ability to use mathematical formulas, specifications and guidelines by design agencies,
assumptions and finally common sense to recommend solutions for a given highway problem.
The Highway Design class contained twenty nine (29) students. Traditionally, exams in highway
design would include problems that require making sound engineering assumptions and may lead
to different solutions or alternative designs.

Analysis of Results

Two exams were given to students with mixing formats as described earlier. The exams results
were analyzed. Twenty nine (29) students took both exams. Table 1 shows a summary of the
results or descriptive statistics of the exams results.

Table 1: Descriptive Statistics for Exams with Mixing Formats

<table>
<thead>
<tr>
<th>Item</th>
<th>Exam 1</th>
<th></th>
<th>Exam 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Objective score</td>
<td>Traditional Score</td>
<td>Final Score</td>
<td>Objective score</td>
</tr>
<tr>
<td>Average</td>
<td>76.2</td>
<td>83.0</td>
<td>86.6</td>
<td>60.7</td>
</tr>
<tr>
<td>Minimum</td>
<td>37.5</td>
<td>53.0</td>
<td>56.0</td>
<td>40.0</td>
</tr>
<tr>
<td>Maximum</td>
<td>100</td>
<td>96.5</td>
<td>99.0</td>
<td>90.0</td>
</tr>
<tr>
<td>Variance</td>
<td>330.6</td>
<td>99.0</td>
<td>104.8</td>
<td>235.2</td>
</tr>
</tbody>
</table>

The following comments can be made on the results of Table 1:

- The “Objective Score” is based only on grading the multiple choices without consideration
to the detailed solution provided by the student. Exam 1 consisted of Eight (8) problems
and so the “Objective Score” for each problem is either 12.5 or 0. Exam two consisted of
ten (10) problems and so the “Objective Score” for each problem is either 10 or 0.
- The “Traditional Score” is based on the traditional grading of the detailed solution without
consideration to what the student circles in the multiple-choice options. Points are
assigned to components of a detailed solution such as basic formula, proper substitution,
logical steps, sketches, units, and a correct final answer.
• The “Final Score” is the “Traditional Score” adjusted for guessing the right answer and for the after action report submitted by the student. If a student could not get the right final answer through the detailed solution but managed to circle the correct answer from guessing or engineering sense he/she gets extra points for that correct guess. Also students get extra credits for revisiting their exams and analyzing their errors as well as providing the detailed correct solutions. The extra credit is to encourage students to take the process seriously.

• The average “Objective Score” was lower than the “Traditional Score” for both exams. This has been also the case for the majority of individual scores as indicated in Table 2. In general, students show in their detailed solution their understanding of the material and their ability to design but many of them can not still get the correct final answer for reasons such as math errors and time constraints as explained in the next section. An ideal situation is when both scores are high and close and that has not been the case for most students.

Table 2: Statistical Inference of Exam Results

<table>
<thead>
<tr>
<th>Item</th>
<th>Exam 1</th>
<th>Exam 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of observations with</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective Score &gt;Traditional Score (%)</td>
<td>9 (31%)</td>
<td>7 (24%)</td>
</tr>
<tr>
<td>Number of observations with</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective Score &lt;Traditional Score (%)</td>
<td>20 (69%)</td>
<td>22 (76%)</td>
</tr>
<tr>
<td>Average difference (Traditional – Objective)</td>
<td>6.8</td>
<td>6.8</td>
</tr>
<tr>
<td>Statistical Significance of average difference (Traditional – Objective) scores</td>
<td>Significant at $\alpha = 0.05$</td>
<td>Significant at $\alpha = 0.05$</td>
</tr>
</tbody>
</table>

Additional statistics are used to test the significance of the differences in the scores. The statistics along with additional observations are presented in Table 2. As seen in Table 2, more than two-thirds of the students in both exams had “Objective Score” less than their “Traditional Score” indicating that most students have a good feel for the design process and the necessary formulae to use but they struggle to get the final and most correct answer. These students are likely to face the same problem when taking objective exams such as the FE or PE exams where consideration is given only to the final correct answer.

On the other hand, about quarter of students in both exams end up scoring higher in the objective format and that indicates that some students are answer oriented. These students can get the right answer but are unable to show step-by-step solution including how they got the final answer. Many of these students, as discussed in the next section, lose points because they skip steps, do not properly substitute in formula or do not give the source of their design parameters.

The average difference (“Traditional Score” – “Objective Score”) was 6.8 points for both exams (83-76.2) and (67.5-60.7) from Table 1. This difference has been tested for statistical significance using the statistical procedures for testing two population means with unknown but equal variances (6). The difference was found significant at 95% confidence level ($\alpha = 0.05$). This emphasizes the importance of this exercise where students get the opportunity to analyze their exam results and detailed solutions to find out why they could not get the correct final answer.
answer for each problem. The intention is for the students to learn from this experience and try to avoid their common mistakes.

The difference between the average “Objective” and “Traditional” scores did not seem to change from Exam 1 to Exam 2 suggesting that students have not yet shown significant improvement of their test taking skills. It should be noted that it takes time and practice as well as determination on the student part before they can improve their test taking skills and think in a structured way that will eliminate many of their common mistakes. This exercise is a step in this direction.

**Concept Evaluation**

A questionnaire was administered at the end of the semester to obtain feedback from students on the concept and implementation of Mixing Exam Formats (MEF) concept. A copy of the actual form can be found in Appendix B. The questionnaire consists of 14 questions and addresses three main areas: the first includes two general questions about the students’ academic level (freshman, sophomore etc) and whether or not their exams have been graded according to this mix format in other courses before. The second area addresses students’ intentions to take the FE and PE exams and their awareness of the importance of these tests. The third area includes the responses from students on the effectiveness of the MEF concept as a learning tool beyond the examination and its usefulness in training to improve test-taking skills. The fourth area addresses highlights from the students’ analysis of their own work. Figure 1 shows that the Highway class consists primarily of juniors with few seniors.

![Figure 1: Academic Level (Highway Class)](image)

The majority of students do not normally have their exams graded according to this mix format in other courses. Most students expressed that the MEF concept was a new experience for them as shown in Figure 2.
Table 2 summarizes the student responses to questions related to the FE and PE exams. The percent of maximum score and the average response have been used to quantify the response by students to these questions. The maximum score is the number when all students select “Definitely Yes” which has a value of five (5) as their response in favor of the idea (i.e. maximum score = 150 for a class of 30 students). Almost all students realize the importance of taking and passing both the FE and PE exams. All students are also aware that the FE and PE exams use multiple-choice or "Objective" exam format where only the final answer is graded.

Table 2: Student Responses to questions related to the FE and PE exams

<table>
<thead>
<tr>
<th>No</th>
<th>Question</th>
<th>Response</th>
<th>% of Maximum Score (Max=100)</th>
<th>Average Response (Max=5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>I am planning to take the FE or EIT exam.</td>
<td></td>
<td>100.0</td>
<td>5.0</td>
</tr>
<tr>
<td>3</td>
<td>It is important to take the PE exam and become a registered professional engineer in my major.</td>
<td></td>
<td>95.7</td>
<td>4.8</td>
</tr>
<tr>
<td>4</td>
<td>I am aware that the FE and PE exams use multiple-choice or &quot;Objective&quot; exam format where only the final answer is graded.</td>
<td></td>
<td>100.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>
Table 3 summarizes the student responses on the effectiveness of the MEF concept as a learning tool beyond the examination and its usefulness in training to improve test-taking skills.

The following comments can be made on the results of Table 3:

- Overall, the majority of students (score 93.5%) feel Mixing Exam Formats (MEF) helped them get some training to become more familiar with the FE and PE exams formats. For this training to be effective, students need to continue this activity in other courses.
- Almost all students indicated that revisiting their exams helped them learn the material better because they had to analyze "where" and "why" they made the error(s). Most students arrived at the right answers after analyzing their own work.
- A high percentage of students (score about 82%) agreed that the Mixing Exam Formats (MEF) even helped them identify "problem solving" weaknesses they had.
- With a score of about 84%, students indicated that Mixing Exam Formats also helped them improve their test taking skills especially choosing the most correct answer. It is expected that test taking skills of students are likely to improve with more practice, keeping in mind the common mistakes identified in their after action reports.
- Most students indicated that revisiting their exams once helped identify and eliminate their

<table>
<thead>
<tr>
<th>No.</th>
<th>Question</th>
<th>% of Maximum Score (Max=100)</th>
<th>Average Response (Max=5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Mixing Exam Formats (MEF) helped me get some training to become more familiar with the FE and PE exams formats.</td>
<td>93.6</td>
<td>4.7</td>
</tr>
<tr>
<td>6</td>
<td>Revisiting my exam helped me learn the material better because I analyzed &quot;where&quot; and &quot;why&quot; I made the error(s).</td>
<td>93.6</td>
<td>4.7</td>
</tr>
<tr>
<td>7</td>
<td>Mixing Exam Formats (MEF) helped me identify &quot;problem solving&quot; weaknesses I have/had.</td>
<td>82.9</td>
<td>4.1</td>
</tr>
<tr>
<td>8</td>
<td>Mixing Exam Formats (MEF) helped in improving my test taking skills especially choosing the most correct answer.</td>
<td>83.6</td>
<td>4.2</td>
</tr>
<tr>
<td>9</td>
<td>Revisiting my exam helped identify and eliminate my mistakes and allowed me to determine the correct final answer.</td>
<td>88.6</td>
<td>4.4</td>
</tr>
<tr>
<td>10</td>
<td>Grading such that the final score is based on the &quot;Traditional Score&quot; with adjustment for guessing the right answer and the after action report is fair and encouraging.</td>
<td>93.6</td>
<td>4.7</td>
</tr>
</tbody>
</table>
mistakes and allowed them to determine the correct final answer to each problem in the exam.

- Finally, the vast majority of students feel grading such that the final score is based on the "Traditional Score" with adjustment for guessing the right answer and the after action report was fair and even encouraging.

The results of the survey for the last portion of the questionnaire involved the students identifying the main reason(s) for not reaching the final correct answer and the main reason(s) for losing points even though the right answer was reached. Students could check as much as they see apply. The responses are displayed in Figure 3.

As shown in Figure 3, more than two-thirds of the students indicated math errors and time constraints are the predominant sources of their exam mistakes and inability to determine the correct answer to exam problems. Six other factors were also identified by students as reasons for not reaching the right answer. When students do reach the correct final answer, they may still lose points if their work is not complete. Figure 4 gives the factors students thought were reasons for loosing points in a given problem even though the final answer was reached.

**Figure 3: The main reason(s) for not reaching the final correct answer**

<table>
<thead>
<tr>
<th>Reason</th>
<th>Percent of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math Errors</td>
<td>68</td>
</tr>
<tr>
<td>Did not read problem correctly</td>
<td>54</td>
</tr>
<tr>
<td>Formula not in the equation sheet</td>
<td>36</td>
</tr>
<tr>
<td>Substituted wrongly in the formula(e)</td>
<td>36</td>
</tr>
<tr>
<td>Made a mistake in the assumption(s)</td>
<td>32</td>
</tr>
<tr>
<td>Did not study as I should have</td>
<td>21</td>
</tr>
<tr>
<td>Not enough time to complete problem</td>
<td>18</td>
</tr>
<tr>
<td>Other reason(s), specify</td>
<td>4</td>
</tr>
</tbody>
</table>
Finally, all students in this class unanimously indicated that the concept of Mixing Exam Formats (MEF) is helpful as an additional learning opportunity and offers useful training on reaching the most correct answer.

Conclusions

- Students’ detailed solution show good understanding of the material and their ability to design but many cannot still get the correct final answer for reasons such as math errors, time constraints and poor test taking skills. In other words, most students have a good feel for the design process and the necessary formulae to use but they struggle to get the final and most correct answer. These students are likely to face the same problem when taking objective exams such as the FE or PE exams where consideration is given only to the final correct answer.

- The grading results of two exams using the MEF concept revealed a number of interesting observations including statistically significant differences between the “Objective” and “Traditional” scores for the majority of students. An ideal situation is when both scores are high and close and that has not been the case for most students in this class. Some students end up scoring higher in the objective format. These students can get the right answer but are unable to show step-by-step solution and how they got the final answer. Many of these students will lose points because they skip steps, do not properly substitute into the formulae or do not give the source of their design parameters.
It takes time and practice as well as determination on the student part before they can improve their test taking skills and think in a structured way that will eliminate many of their common mistakes. The MEF exercise is a step in this direction.

Most students expressed an understanding and appreciation for the MEF concept, endorsing the additional learning opportunity provided and the training on reaching the most correct answer.

It is important to continue this activity in other courses and administer similar surveys in order to continue getting feedback from students and validate the statistical results.

References


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Appendix A: Exam Grading Sheet

**University of Pittsburgh at Johnstown**

*CET1121 – Highway Surveying and Design*

**Grading Sheet**

*Exam 2*

*Fall 2002*

Name: ______________________________

<table>
<thead>
<tr>
<th>Problem Number</th>
<th>Objective Score*</th>
<th>Traditional Score**</th>
<th>Final Score***</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>5</td>
<td></td>
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<td></td>
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<tr>
<td>6</td>
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<td>7</td>
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<td>8</td>
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<td>9</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Objective Score is based only on circling the right answer. Your score for each problem is either 10 points or zero.*

**Traditional score is based on your detailed solution including selecting the right formulae, substitution, final answer, units etc. Guessing the right answer from the given options has no effect on this score.*

***Final score is your traditional score adjusted for:
1. Guessing the right answer.
Appendix B: Mixing Exam Formats: Questionnaire

University of Pittsburgh at Johnstown – Engineering Technology

Please answer each of the questions below based on your individual experience with the new exam format that includes “Objective” and “Traditional” scores.

Course Name: _______________  Academic Level: _____ Fr _____ So. _____ Jr. _____ Sr.

Major: _______Civil __________ Mechanical ___________ Electrical _________ Other

1. Have your exams been graded according to this mix format in other courses before?
   YES                                    NO

Please circle the appropriate response to each of the questions below. The range of responses is from "1" meaning "Definitely No" to "5" meaning "Definitely Yes".

2. I am planning to take the FE or EIT exam before graduation.

3. It is important to take the PE exam and become a registered professional engineer in my major.

4. I am aware that the FE and PE exams use multiple-choice or “Objective” exam format where only the final answer is graded.

5. Mixing Exam Formats (MEF) helped me get some training to become more familiar with the FE and PE exams formats.

6. Revisiting my exam helped me learn the material better because I analyzed "where" and "why" I made the error(s).

7. Mixing Exam Formats (MEF) helped me identify "problem solving" weaknesses I have/had.

8. Mixing Exam Formats (MEF) helped in improving my test taking skills especially choosing the most correct answer.

9. Revisiting my exam helped identify and eliminate my Mistakes and allowed me to find the correct final answer.
10. Grading such that the final score is based on the “traditional” Score with adjustment for guessing the right answer and the after action report is fair and encouraging.

11. The main reason(s) for not reaching the final correct answer:
   - Math Errors
   - Did not read problem correctly
   - Did not have the right formula in the equation sheet
   - Used the wrong formula(e)
   - Substituted in the formula(e) with the wrong information
   - Made a mistake in the assumption(s)
   - Did not study material as I should have
   - Not enough time to complete problem
   - Other reason(s), specify

12. The main reason(s) for losing points even though the right “Objective” answer was reached:
   - The right answer came from guessing
   - Did not show the substitution in the formula
   - Did not give the source(s) of information
   - Skipped a step or more
   - Errors in Units or significant figure
   - Other reason(s), specify

13. My “Objective” score compared to my “Traditional” score was generally:
    - Slightly Lower
    - Significantly Lower
    - Slightly Higher
    - Significantly Higher

14. Overall, I found the concept of Mixing Exam Formats (MEF) helpful as an additional learning opportunity and offer useful training on reaching the most correct answer.

    YES          NO