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IUPUI Mechanical Engineering Technology Senior Assessment

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Evaluation of IUPUI Mechanical Engineering Technology Senior Assessment Exam

Abstract

This paper discusses the methods and analysis of 6-semesters of senior assessment examination data identifying the courses and subject material students found the most difficult to solve in the MET program Senior Assessment Examination. The analysis results indicate that MET 111 (Applied Statics), MET 213 (Dynamics), and MET 348 (Engineering Materials) are courses in need of potential improvement. Furthermore, subject areas such as the calculation of entropy change, the calculation of pressure drop flow through a pipe, and Hooke's Law are subject material that poses greatest problems for senior students.

For the past 12 years, the Mechanical Engineering Technology (MET) Program faculty at IUPUI require all seniors to take a MET Senior Assessment Examination that is similar in content to the Fundamentals of Engineering (FE) examination. This paper discusses the methods used to provide insightful and actionable inputs for the IUPUI MET program process improvements plan. The raw data consists of test scores from 123 senior students who took the examination from 2014 through 2016.

The Accreditation Board for Engineering & Technology (ABET) is an organization that ensures universities and institutions like IUPUI meet certain accreditation requirements and requires that each program develops a continuous improvement plan. The improvement plan typically consists of a compilation of student materials, employer surveys, and course evaluations used to ensure continuous improvement within a program. In 2004 IUPUI, MET program faculty decided that a standardized senior examination would be part of the program process improvement process, [1].

Introduction

The Department of Mechanical Engineering Technology (MET) at IUPUI, has applied a senior assessment examination as part of the senior capstone course for the past 12 years. It is designed to test the knowledge of MET seniors on core-MET subject areas. The Senior Assessment Exam contains questions and problems from thirteen specific courses in the MET plan of study plus mathematics and physics, Table 1. It is designed to assess as much of the MET plan of study as possible. The examination was styled from the Fundamentals of Engineering (FE) Exam that serves a similar purpose for Mechanical Engineering.

The information from senior assessment examination is part of the current continuous improvement process plan and is used to determine what courses and material in the MET Plan of Study produce the highest and the lowest student performance each semester. This information is then processed and recorded for use by the Accreditation Board for Engineering & Technology (ABET) 6-year review cycle, as well as used internally among MET faculty and staff for course improvement.

Descriptive Statistics, Graphical analysis and statistical analysis of variance methods (ANOVA) techniques are utilized to quantify and compare results based on the number of incorrect responses for each question and question group. Each question group consists of five questions from a single course, and there are typically two groups per course, Table 1.

Table 1. The outline of the MET Senior Assessment Examination by course and period.

Course	Course Number	Total Questions 2001-2013	Total Questions 2014+
QUANTITATIVE METHODS FOR TECHNOLOGY	IET 150	2	2
APPLIED STATICS	MET 111	10	6
APPLIED STRENGTH OF MATERIALS	MET 211	10	10
DYNAMICS	MET 213	12	12
MACHINE ELEMENTS	MET 214	10	10
FLUID POWER	MET 230	10	7
APPLIED THERMODYNAMICS	MET 320	11	10
MANUFACTURING PROCESSES	MET 338	10	8
ENGINEERING MATERIALS	MET 348	10	10
APPLIED FLUID MECHANICS	MET 350	10	10
TECHNICAL GRAPHICS COMMUNICATIONS	TECH 104-MET 204	10	9
INTRODUCTION TO ENGINEERING TECHNOLOGY	TECH 105	5	5

Literature Review

The IUPUI Senior Assessment Examination is based on the Fundamentals of Engineering (FE) Examination. Its purpose is to provide high-quality feedback to the program in the form of inputs into the program process improvement plan and inspired by the many years of published process improvement research on the FE examination. For example, in 2004, Nirmalakhandan [2] conducted analysis, comparing FE examination results and their impact on the Civil and Geographical Engineering (CAGE) Department and courses at New Mexico State University (NMSU). Resulting, in changes to the Fluid Mechanics course that in turn improve students scores in the FE examination.

However, there are some fundamental issues when applying FE examination data as part of a process improvement cycle. Inconclusive results due to the number and confounding of variables in the analysis can occur [3]. Also, there can be problems with the sheer size and scope of data provided by the FE examination that question its quality assurance. Universities cover FE examination subject areas of interest in a variety of ways. There could be an issue with the lack of consistency among test takers. Some programs do not require their students to pass the FE examination or even take it at all, whereas other students are required to pass or were taking the FE examination as a path to the PE examination. Student FE examination performance may not be based only on ability providing questionable process improvement feedback.

The MET Senior Assessment Examination provide a valuable alternative. Since the department writes the examination, it can be fine-tuned to focus on the main issues directly relate to MET students. One challenge of this approach is creating and maintaining a balance for the examination, keeping it fair for the students taking it. In 2011, Parent made a note of the same issue for the Electrical Engineering (EE) Department's senior exit examination at San José State University [4]. The department had their own program specific senior exit examination; however, scores were always very low as it was not a requirement to pass the exam. The Electrical Engineering Department eventually changed the examination to be a graduation requirement with a passing grade of 70%. Additional student help including online pre-tests were added to the program requirements, and students began to take the examination far more seriously resulting in improved senior exit examination scores.

Methodology

The sample population for this study was students in the MET program at IUPUI, specifically seniors, consisting of 123 students. The Senior Assessment Examination serves as the final examination for the MET capstone course, resulting in a data pool size of between 15 to 39 students per semester.

The examination consists of thirteen subject areas, each based on a course from the MET plan of study. Each question block on the examination is based on concept material from the course. Students sit for the Senior Assessment examination towards the end of the semester in mid to late April or November. The duration of the examination is 4 hours and once graded a statistical analysis is employed to provide inputs into the next process improvement cycle. This paper discusses the analysis methods and results for the 6-semester period from Spring 2014 through Fall 2016.

Results

Simple descriptive statistics, graphical analysis, and analysis of variance (ANOVA) were used to identify the individual inputs that feed the following semester process improvement cycle. Chairs, Directors, and faculty available time are limited, and so the process improvement and work-flow for this type of analysis must be simple to apply, easy to understand, economical to complete, but provided high-quality data. Two simple statistical techniques were employed to analyze the raw data in this study. Firstly, a One Way ANOVA technique was utilized to determine statistically significant differences between courses. Then the courses selected via ANOVA were updated based on a sorted mean percent incomplete response table.

ANOVA Method

Problem Statement:

Are there significant differences between courses based question block mean percentage of incorrect question responses?

Data Format: mean percentage of incorrect question responses.

$$X = \frac{\sum(Incorrect\ responses\ for\ each\ question)}{Number\ of\ students\ taking\ the\ examination\ in\ semester} \times 100$$

1. Null Hypothesis Statement: The means of each incorrect response course are equal, $H_o = \mu_{T104} = \mu_{T105} = \mu_{I150} = \mu_{I350} = \mu_{M111} = \mu_{M211} = \mu_{M213} = \mu_{M214} = \mu_{M230} = \mu_{M320} = \mu_{M338} = \mu_{M348} = \mu_{M350}$
   Alternate Hypothesis Statement: H_a = One or more of the above mean scores are not equal.
2. Select method: ANOVA 1 way. All model assumptions such as normality have been met.
3. The confidence level of 95% was selected. Therefore, Alpha = 0.05
4. Determine the ANOVA F-statistic : $F_{obt} = 30.057$

ALL COURSES ANOVA

Score

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7474.838	12	622.903	30.057	.000
Within Groups	1347.075	65	20.724		
Total	8821.913	77			

5. Determine F-critical by using a software package like SPSS or Minitab: F_{cv}= 1.91
6. If $F_{obt} > F_{cv}$ then we must Reject the Null Hypothesis
7. Perform residual analysis.

8. Using Minitab determine p-value and translate the statistical test results into practical conclusions.

ANOVA analysis indicates Applied Statics (MET 111), Dynamics (MET 213), Applied Thermodynamics (MET 320), and Engineering Materials (MET 348) were found to have high incorrect response counts that significantly differed from the other courses listed in Table 1. Also, the course mean percentage of incorrect responses were stable over the 6-semester period analyzed, Table 2 and Figure 1. Based on a review of results presented in Table 2 Applied Strength of Materials (MET 211) and Fluid Power (MET 230) were also included as courses for consideration for subject material.

Table 2. Percentage of incorrect responses for individual courses.

	Course	SP14	FA14	SP15	FA15	SP16	FA16	MEAN
Applied Statics	MET 111	63.64%	70.00%	60.00%	65.71%	60.00%	63.53%	63.81%
Dynamics	MET 213	71.59%	62.50%	63.24%	57.14%	61.11%	64.22%	63.30%
Applied Thermodynamics	MET 320	69.55%	59.29%	57.65%	62.86%	59.23%	52.35%	60.15%
Engineering Materials	MET 348	61.82%	62.86%	60.00%	52.86%	57.69%	54.71%	58.32%
Strength of Materials	MET 211	50.00%	55.00%	61.76%	52.86%	54.62%	48.82%	53.84%
Fluid Power	MET 230	53.90%	51.02%	44.54%	53.06%	51.65%	56.30%	51.74%

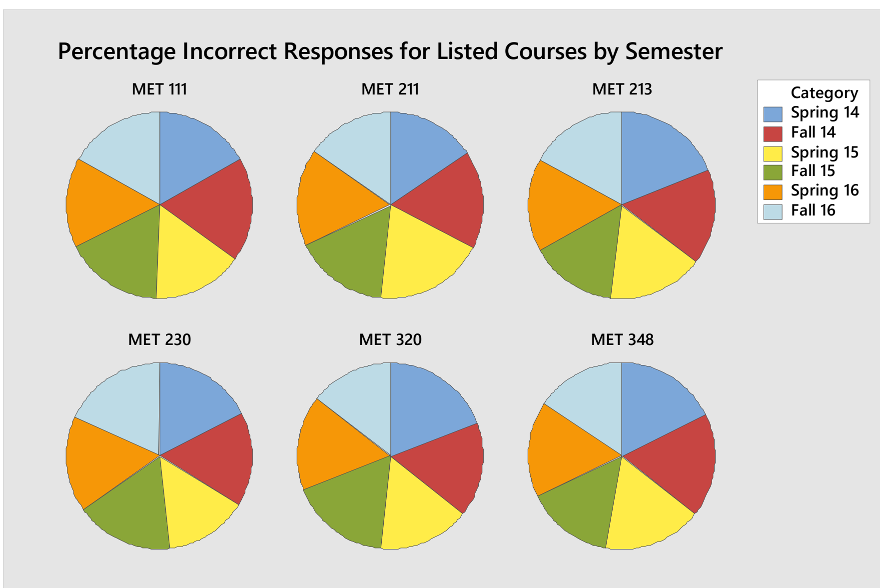

Figure 2. Pie Chart of mean percentage incorrect responses by course from Spring 2014 through Fall 2016.

The ANOVA results, discussed above, were based on the mean percentage of incorrect responses per question divided by the number of students taking the examination in a given semester. An alternative approach is to simply sum the number of incorrect response per question per semester and sort by highest occurrence, Table 3. The high-count questions were then further investigated for possible errors or ambiguity in wording, but were judged reasonable and were added to the pool of inputs for process improvement purposes.

Table 3. Specific course material for the top 12 highest total incorrect responses (n =123).

COURSE	Course Material	Total Number of Incorrect Responses
MET 320	Entropy change in solids	117
MET 348	Crystal Structure	112
MET 230	Rough Pipe Turbulence	110
PHYS 218	Hooke's Law	105
MET 230	Air Compressor Selection	104
MET 211	Shearing Stress in Beams	103
MET 320	Carnot Cycle	102
MET 204	Dimensioning	102
MET 348	Miller Indices	101
MET 211	Stress-Strain relationship	100
MET 211	Maximum Tensile Stress	98

Individual Course Analysis

MET 111 Applied Statics

As shown in Table 2, Applied Statics (MET 111) has the highest mean percent incorrect response count by course. A breakdown by subject material indicates that students find centroids, reaction forces, and cable tension problems to be the most difficult to solve, Table 4 and Figure 3. The percentage spread of individual questions over the 6-semester gives a rough estimate of short-term variation due to changes in instructor and student cohort aptitude. As more examination data sets are processed, it may be possible to apply Statistical Process Control (SPC) to provide further insight into faculty and adjunct performance, student cohort variation, and gain immediate insight into the general health of the MET program.

Table 4. The distribution of percentage incorrect response for MET 111 Statics.

Material	Spring 14	Fall 14	Spring 15	Fall 15	Spring 16	Fall 16	AVERAGE
Centroid	77%	93%	82%	71%	74%	59%	76%
Reaction Forces	50%	86%	71%	71%	59%	76%	69%
Cable Tension	91%	57%	41%	79%	62%	71%	67%
Moment of Inertia	68%	64%	47%	64%	64%	76%	64%
Support Loads	32%	50%	59%	43%	41%	35%	43%

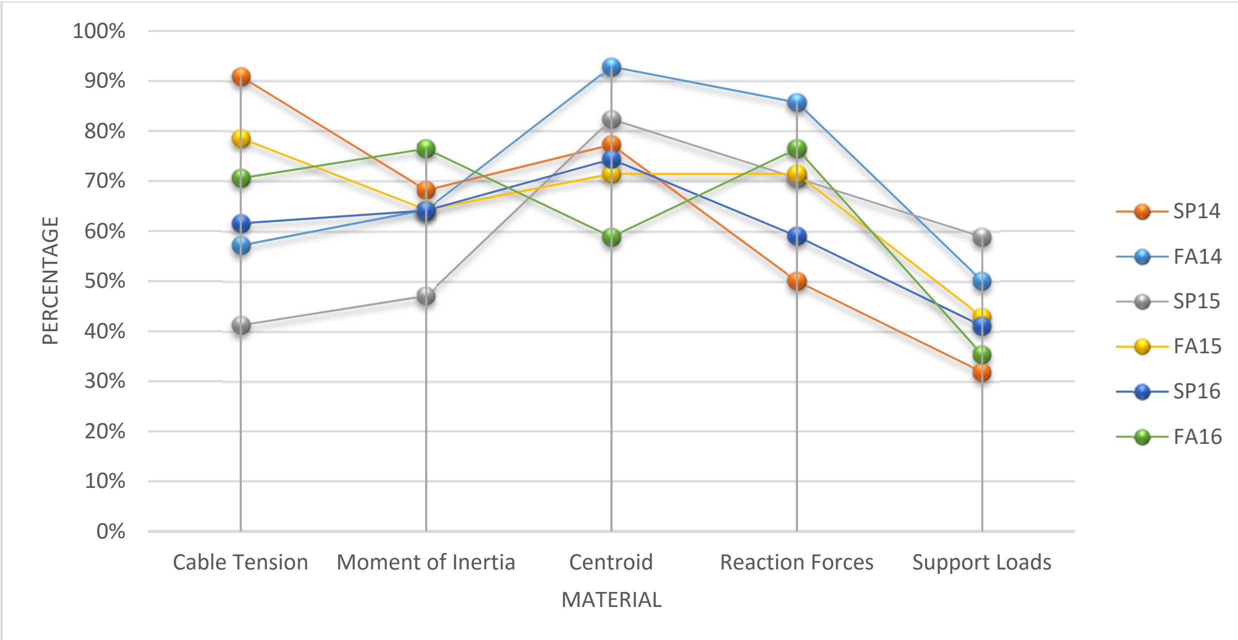

Figure 3. Distribution of incorrect response percentage for MET 111 Statics, by material over the 6-semester evaluation period.

MET 213 Dynamics

Dynamics (MET 213) has the second highest mean percent incorrect responses, Table 2. The percentage of incorrect responses by semester indicate that questions based on polar coordinate systems, the radius of curvature, and acceleration and stopping distances posed the greatest challenge to senior students, Table 5. Also, questions based on acceleration around a curved path (Curvature Radius 1) generated the largest spread in percentage results, Figure 4.

Table 5. The distribution of percentage incorrect response for MET 213 Dynamics.

Material	Spring 14	Fall 14	Spring 15	Fall 15	Spring 16	Fall 16	AVERAGE
Polar Coordinate System	82%	79%	88%	71%	72%	71%	77%
Curvature Radius 2	86%	79%	76%	71%	85%	65%	77%
Acceleration and Stopping Distance	91%	86%	65%	64%	69%	71%	74%
Springs & Velocity	36%	64%	76%	64%	77%	76%	66%
Particle Acceleration	77%	57%	53%	57%	62%	71%	63%
Gravity Straight Up	50%	64%	71%	64%	49%	71%	61%
Acceleration & Friction	73%	57%	47%	64%	59%	65%	61%
Radius of Curvature	86%	50%	47%	50%	46%	65%	57%
Ballistics	68%	50%	41%	50%	51%	65%	54%
Gear Train	50%	64%	35%	36%	54%	29%	45%
Curvature Radius 1	64%	21%	65%	7%	33%	35%	38%

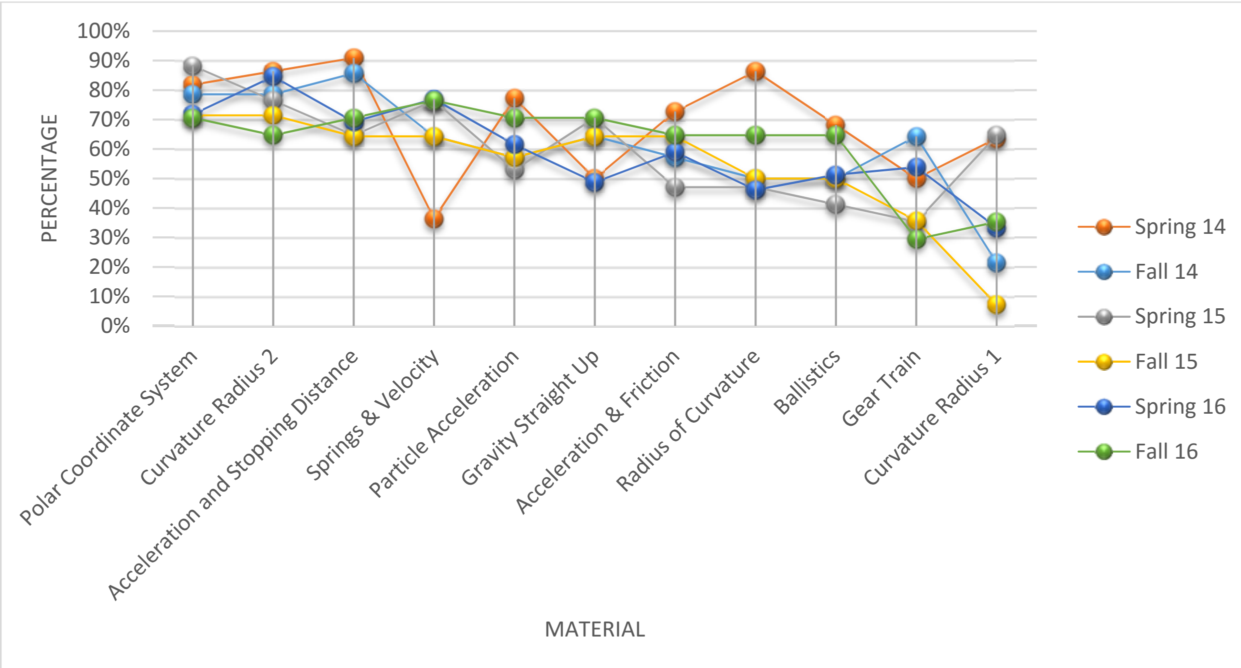

Figure 4. Distribution of incorrect response percentage for MET 213 Dynamics, by material over the 6-semester evaluation period.

Discussion

The MET Senior Assessment Exam is the culmination of all the core MET program courses in one single examination. Not only does it double as a tool to test outgoing seniors to ensure they have mastered the necessary skills and knowledge that they will need as graduates, but it provides inputs into the MET program continuous process improvement plan. The time consumed in the actual analysis was relatively small when compared to processing the raw score data into a usable form. The raw data is received in the form of a pdf file that is then manually converted into an Excel spreadsheet. This process is quite time-consuming, and is a problem that needs to be addressed in future analysis cycles.

The One Way ANOVA tests, descriptive statistics, and graphical analysis resulted in Applied Statics (MET 111), Dynamics (MET 213), Applied Thermodynamics (MET 320), and Engineering Materials (MET 348) were flagged as having high mean incorrect responses over the 6-semester test period. Also, ANOVA testing indicated this group of courses were statistically significantly different from the other courses (alpha = 0.05). Further investigation of subject groups within each MET course based on the number of incorrect responses produced a list of subject material for further process improvement for each of the flagged courses.

Conclusion

The results presented in this paper demonstrate that simple graphical analysis and statistical techniques can be utilized to provide high-quality inputs into the program-specific process improvement plan. The analysis presented also indicate that a simple count of incorrect responses or an unbiased mean percent of incomplete responses provides high-quality, actionable improvement inputs to a process improvement plan. Further findings include:

1) The collection and formatting of raw data posed the greatest difficulty in the data analysis process. The IUPUI Testing Center and asked to change their results reporting format.

2) Adding Statistical Process Control (SPC) tools to provide further insight into faculty and adjunct performance, student cohort variation, and provide a gauge of the general health of the MET program.

3) Tables 3, 4, and 5 represent the key process inputs into the individual course and program process improvement plans. Instructors are now asked to select one or two key input subject areas per course to improve each semester and report their findings in the ABET process improvement documentation.

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