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Teaching an Undergraduate Introductory Engineering Economics Course: Successful Implementation for Students Learning

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Teaching an Undergraduate Introductory Engineering Economics Course: Successful Implementation for Students Learning

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Abstract:
In our institution, we offer a one-quarter long "Engineering Economics" class for the Mechanical Engineering (ME) and Mechanical Engineering Technology (MET) curriculum. This 2-credit course explores the economic principles in systematic evaluation of the benefits and costs associated with typical engineering projects. In particular, this course deals with formulating, estimating, and evaluating the economic outcomes when alternatives to achieve a defined purpose are available. Therefore, the purpose of this course is to prepare our engineering students to be qualified to seek solutions of engineering problems/projects in context of economic viability. Plus, this course also helps our students to be better prepared for the Fundamental of Engineering (FE) exam. Students, taking the FE exam, are expected to get about 8 to 10 problems from Engineering Economics.

All the authors of this paper have taught Engineering Economics several times. Therefore, the authors demonstrate in this paper the course elements and the teaching methodologies in detail that each has practiced implementing the course objectives and to achieve the targeted outcomes. This course is designed in such a way so that it fits for both the ME and MET students. However, the MET students are more "hands-on" and have less mathematic knowledge than the ME students. The MET students have mathematical knowledge up to Calculus II, where the ME students have mathematical knowledge up to Calculus IV and Differential Equations. This study also compares the overall performance between the ME and MET students.

Introduction:
Engineering economics is a required course in the mechanical engineering program as well as many other engineering disciplines. It is also a part of the Fundamental of Engineering (FE) Exam. Students are expected to receive about 8 to 10 problems belong to Engineering Economics. As a result, a large number of students takes this particular course at our institution. In this survey, the Needy et. al. [1] showed that the majority of Engineering Economics class consists of above 30 students. In our institution, the number of students varies from forty to fifty, much larger than the number of students in our other engineering courses. The subject or the course contents itself can be seen by many students as foreign to engineering. For example, engineers and/or engineering students are used to practice rigid, explicit equations yielding certain results. These results are usually not a function of social constraints, politics, environments, cultures etc. The results from an economic study depends on many factors and the corresponding mathematical operations behind the results are not guaranteed, especially over longer periods of time. For example, an increase in the price of fuel, wars, tensions, economic state of the country can have drastic results on Engineering Economics problems. This type of uncertainty, the complexity in assessing and analyzing risks, fluctuations in the market, supply

and demand etc. can be a challenge for an engineering student to comprehend. This in contrast to the certainty the engineering students feel when solving a typical engineering problem, such as computing the stress of a part or structure subjected to tensile, compressive and/or bending forces.

While the course itself covers the basic concepts in economics from an engineering point of view, it is still a challenging one to teach. Engineering students need practical problems to solve to comprehend the conceptual of Engineering Economics. While most Textbooks emphasize the practical aspects [2-5], more specifically in the decision-making process, students still struggled to comprehend the several concepts of Engineering Economics. One of the researchers, Alungbe [6], suggests to use personal finances issues, such as financing a car, mortgaging a house etc. as teaching elements of Engineering Economics. This author [6] also suggests discussing relevant contemporary issues on a regular basis throughout the course. Some other researchers, such as Hartman [7] states that the curriculum being taught now is almost identical to that taught many decades ago. While the course covers the same basic concepts, the way it is being taught in some cases has drastically changed. A number of articles, such as Lavelle [8] support the fact that incorporating new technology into the engineering economic curriculum can support the understanding of traditional concepts. While some of these included the use of Microsoft Excel and other computing software packages, some were more involved. Dahm [9] developed an interactive game the students can play that simulates the decision-making process for typical engineers. The game starts with a given amount of money, and the students can make decisions on how to invest it. The game provides opportunities for investment over the semester, as well as additional factors such as price negations for example.

In our institution, we are not using any computational software such as Excel and/or MATLAB the basic elements of Engineering Economics. Rather, we emphasis how to use the Textbook Tables (or Chart) and the necessary equations to solve Engineering Economics problems. We cover the following chapters within the 10-weeks' time.

1. Time value of money
2. Cash flow diagrams
3. Simple and compound interest
4. Present, future, and annual worth analysis
5. Inflation analysis
6. Rate of return analysis
7. Payback period
8. Depreciation
9. Benefit-cost analysis

Methods and Results:

This 2-credit course in engineering economics explores the systematic evaluation of the benefits and costs associated with engineering projects. The purpose of this evaluation is to help quantify choices of the benefits and costs to determine whether they make or save enough money to warrant their capital investments. The overall results of this process help to provide goods and services that satisfy the consumer at an affordable cost. We (our institution) are in a quarter system, and the course outlines are delivered to students within 10-weeks-time frame. The course is a 2-credit course with 2-hours lecture per week. Students are required to face extensive amount of Homework Assignments and 3 to 4 Exams. All problems associated with HW, and Tests are required to be solved by using equations or using Compound-Interest Tables, without using any software such as Excel and/or MATLAB.

Instructors at our institution have been adapted to use two different methods to teach several concepts of Engineering Economics. One method is using the "Explicit Equations" and the other is using "Compound-Interest Tables". The reason to teach these two methods is that this course is a combined course of Mechanical Engineering (ME) and Mechanical Engineering Technology (MET) students. Traditionally, ME students prefer to use the equations to solve the problems, but MET students prefer to use the table.

We usually start this course by teaching the "Time Value of Money". We teach our students how to compute the "Economic Equivalence" of different Cash Flow Diagrams (CFD) at different times. Few examples of our teaching elements are listed in this Draft Paper.

Example # 1:
We have a cash flow diagram as shown below in Figure # 1. If a bank offers 10% interest compounded annually, then

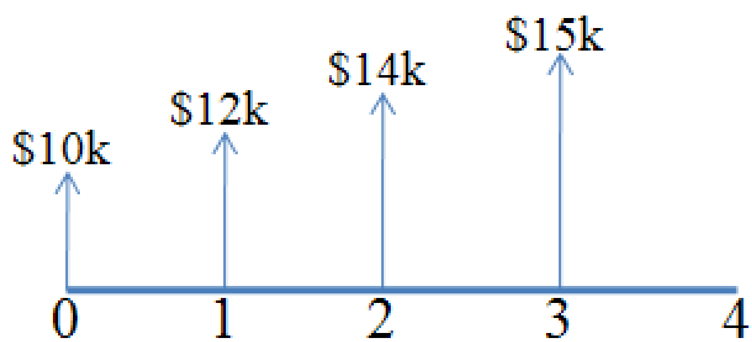


Figure # 1: Example Problem # 1, CFD to Teach the Time Value of Money.

a. Determine the total equivalent worth at the *end* of 4th year.
b. Determine the total equivalent worth at the *beginning* of 1st year.
c. Determine the total equivalent worth at the end of *2nd* year.

Example # 2:

We are depositing some money to a bank according to the Cash Flow Diagram as shown in accompanying figure. The interest rate (i) = 10%, compounded annually. What will be the balance of our bank at the end of 10 years?

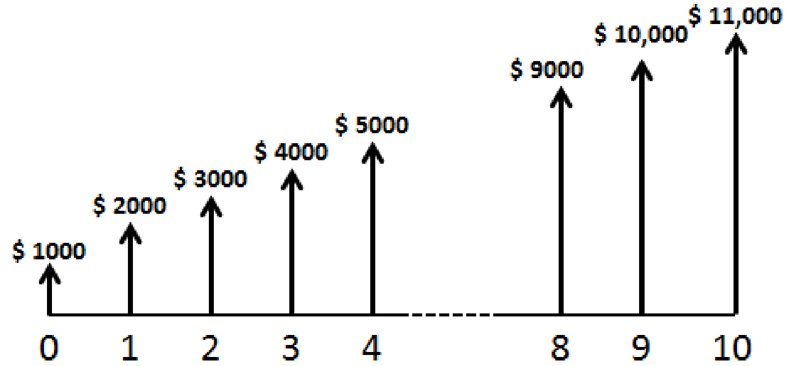


Figure # 2: Example Problem # 2, CFD to Teach the Time Value of Money.

Example # 3:

Your spouse is depositing some money to a bank according to the Cash Flow Diagram as shown in accompanying figure. The interest rate (i) = 10%, compounded annually. Determine the value of X, if the Cash Flow Diagrams of Problem # 2 and Problem # 3 are *economically equivalent*.

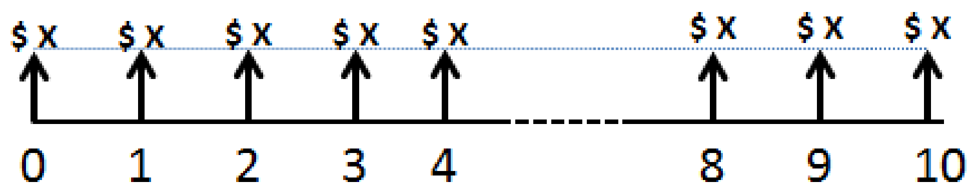


Figure # 3: Example Problem # 3, CFD to Teach the Time Value of Money.

Example # 4:

You opened a bank account three (3) years ago, and made three deposits: $5,000 three years ago, $X two years ago, and $2,000 one year ago. The bank offered variable interest rates as shown in accompanying Cash Flow Diagram. Today your balance shows $10,000. Determine the amount of the deposit made two years ago ($X).

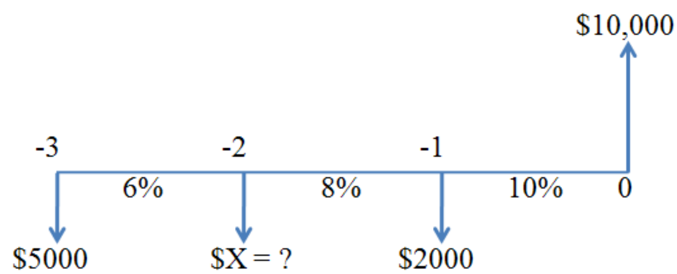


Figure # 4: Example Problem # 4, CFD to Teach the Time Value of Money.

Once students have the good concept on “Time Value of Money”, then they learn to solve several Engineering Economics problems using the concept of Net Present Worth (NPW), Net Annual Equivalence (NAE) and Net Future Worth (NFW) analyses. Few examples are listed below.

Example # 5:
The following cash flow diagram **repeats** for infinite life. At *i* = 10%, what is the **annual equivalence** amount for this infinite series of cash flow?

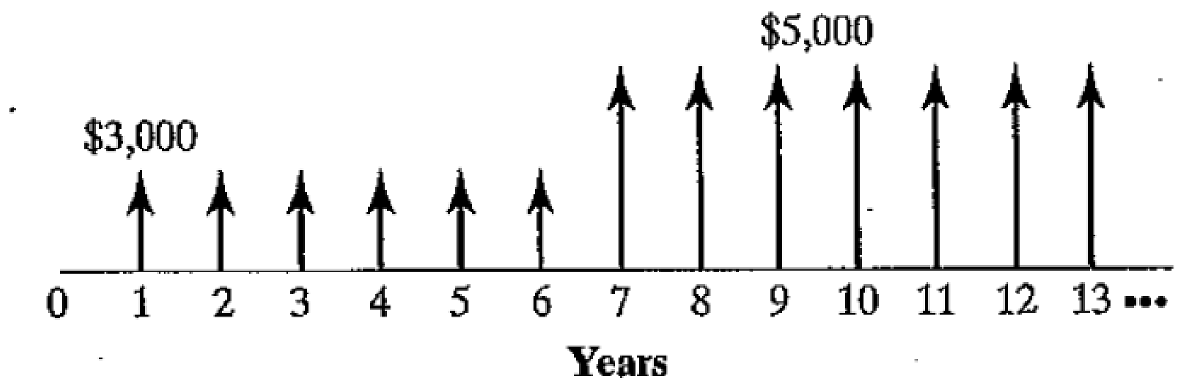


Figure # 5: CFD to Teach the Concept of Annual Equivalence.

Example # 6:
What single payment (X=?) at the end of year 5 is **economically equivalent** to an equal annual series of payment of $1000 from the end of year 3 to the end of year 10? The interest rate is 10% compounded annually. The CFD is shown below.

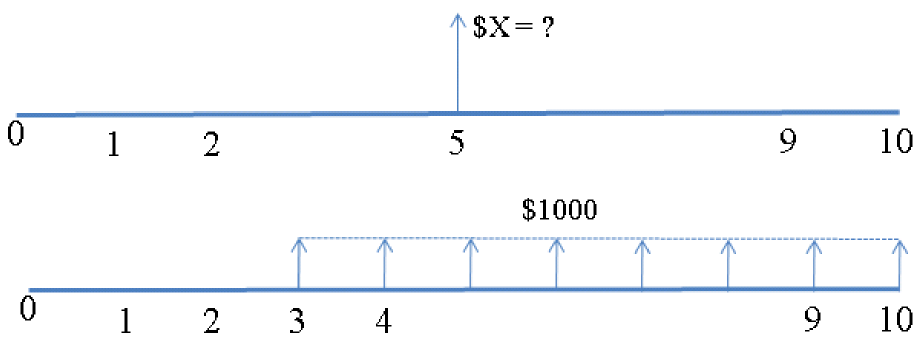


Figure # 6: CFD to Teach the Concept of Annual Equivalence.

Example # 7:
The FedEx Company is considering purchasing a forklift truck out of two options as shown below.

Item	Truck A	Truck B
Initial cost, I	$25,000	$30,000
Annual Operating Cost, A	$5,000	$2,000
Life, N	3 years	6 years
Salvage value, S	$6000	$8,000

The company's MARR is 10%. Assuming the truck is need only for 12 years.

a. Draw CFD for Truck A
b. Draw CFD for Truck B
c. Apply the appropriate concept (NPW or NAE) and select the most *economical* truck.

Example # 8:

The Toyota car dealer is advertising a standard 24-month lease of $1,200 per month for its new 2023 Camry. The *standard lease* requires a down payment of $5,000 plus a $2,000 refundable initial deposit now. The first lease is due at the end of month 1. *Alternatively*, the dealer offers a 24-month lease plan that has a single up-front payment of $35,000 plus a refundable initial deposit of $2000. Under both options, the initial deposit will be refunded at the end of month 24. Assuming an annual interest rate of 6% but compounded monthly.

a. Draw CFD of Standard Lease (SL) option.
b. Draw CFD of Alternative Lease (AL) option.
c. With the basis of **NPW**, which option (standard lease or alternative lease) is preferred?

Students are allowed to use either the "Explicit Equation" method and the "Compound-Interest Table" method to solve the Engineering Economics problem. For example, the equation method for single cash flow is as follows:

$$F = P(1 + i)^N$$

where F is Future worth of the cash flow, P is Present worth of the cash flow, i is a compound interest, and N is number of years. The Compound-Interest Table method for single cash flow is as follows:

$$F = P(F/P, i, N)$$

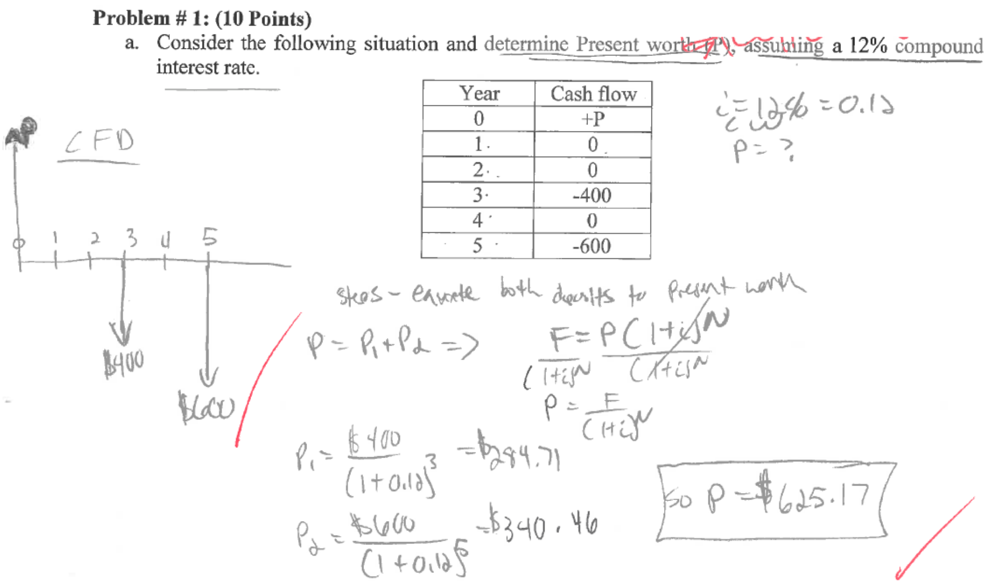
	Single Payment		Equal Payment Series				Gradient Series			10.0%
N	Compound Amount Factor (F/P,i,N)	Present Worth Factor (P/F,i,N)	Compound Amount Factor (F/A,i,N)	Sinking Fund Factor (A/F,i,N)	Present Worth Factor (P/A,i,N)	Capital Recovery Factor (A/P,i,N)	Gradient Uniform Series (A/G,i,N)	Gradient Present Worth (P/G,i,N)	N	
1	1.1000	0.9091	1.0000	1.0000	0.9091	1.1000	0.0000	0.0000	1	
2	1.2100	0.8264	2.1000	0.4762	1.7355	0.5762	0.4762	0.8264	2	
3	1.3310	0.7513	3.3100	0.3021	2.4869	0.4021	0.9366	2.3291	3	
4	1.4641	0.6830	4.6410	0.2155	3.1699	0.3155	1.3812	4.3781	4	
5	1.6105	0.6209	6.1051	0.1638	3.7908	0.2638	1.8101	6.8618	5	
6	1.7716	0.5645	7.7156	0.1296	4.3553	0.2296	2.2236	9.6842	6	
7	1.9487	0.5132	9.4872	0.1054	4.8684	0.2054	2.6216	12.7631	7	
8	2.1436	0.4665	11.4359	0.0874	5.3349	0.1874	3.0045	16.0287	8	
9	2.3579	0.4241	13.5795	0.0736	5.7590	0.1736	3.3724	19.4215	9	
10	2.5937	0.3855	15.9374	0.0627	6.1446	0.1627	3.7255	22.8913	10	
11	2.8531	0.3505	18.5312	0.0540	6.4951	0.1540	4.0641	26.3963	11	
12	3.1384	0.3186	21.3843	0.0468	6.8137	0.1468	4.3884	29.9012	12	
13	3.4523	0.2897	24.5227	0.0408	7.1034	0.1408	4.6988	33.3772	13	
14	3.7975	0.2633	27.9750	0.0357	7.3667	0.1357	4.9955	36.8005	14	
15	4.1772	0.2394	31.7725	0.0315	7.6061	0.1315	5.2789	40.1520	15	
16	4.5950	0.2176	35.9497	0.0278	7.8237	0.1278	5.5493	43.4164	16	
17	5.0545	0.1978	40.5447	0.0247	8.0216	0.1247	5.8071	46.5819	17	
18	5.5599	0.1799	45.5992	0.0219	8.2014	0.1219	6.0526	49.6395	18	
19	6.1159	0.1635	51.1591	0.0195	8.3649	0.1195	6.2861	52.5827	19	
20	6.7275	0.1486	57.2750	0.0175	8.5136	0.1175	6.5081	55.4069	20	
21	7.4002	0.1351	64.0025	0.0156	8.6487	0.1156	6.7189	58.1095	21	
22	8.1403	0.1228	71.4027	0.0140	8.7715	0.1140	6.9189	60.6893	22	
23	8.9543	0.1117	79.5430	0.0126	8.8832	0.1126	7.1085	63.1462	23	
24	9.8497	0.1015	88.4973	0.0113	8.9847	0.1113	7.2881	65.4813	24	
25	10.8347	0.0923	98.3471	0.0102	9.0770	0.1102	7.4580	67.6964	25	

Figure # 7: Example of the Compound-Interest Table.

Here, some students solve the problems using the Explicit Equation method, where others solved the same problem using the Compound Interest Table. Few examples are listed below

Example # 9:
Consider the following situation and determine Net Present Worth (NPW), assuming a 12% compound interest rate.

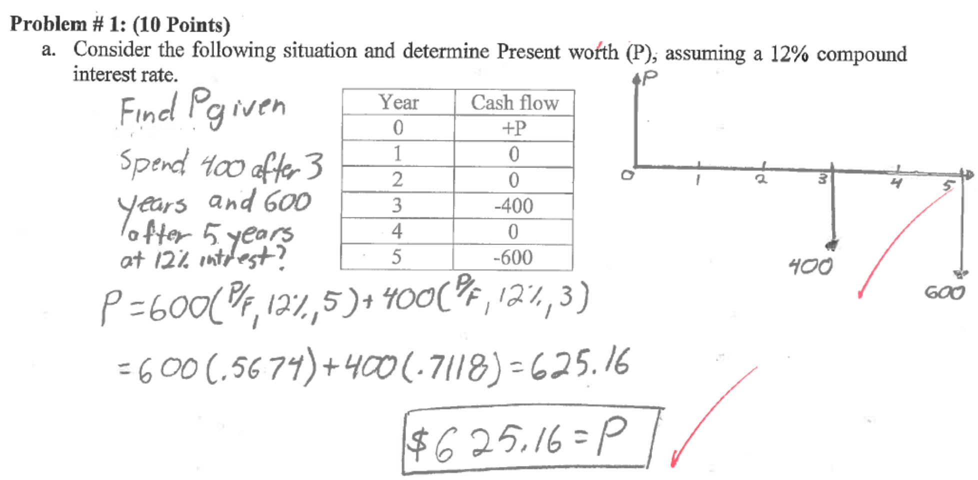
Year	Cash flow
0	+P
1	0
2	0
3	-400
4	0
5	-600


Problem # 1: (10 Points)

a. Consider the following situation and determine Present worth (P), assuming a 12% compound interest rate.

Year	Cash flow
0	+P
1	0
2	0
3	-400
4	0
5	-600

Figure # 8: A Student Work Using the Equation Method for Example # 9.


Problem # 1: (10 Points)

a. Consider the following situation and determine Present worth (P), assuming a 12% compound interest rate.

Year	Cash flow
0	+P
1	0
2	0
3	-400
4	0
5	-600

Figure # 9: A Student Work using the Compound-Interest Table for Example # 9.

Example # 10:

How many years will it take to double your investment of $2,000 if it has an interest rate of 6% compounded annually?

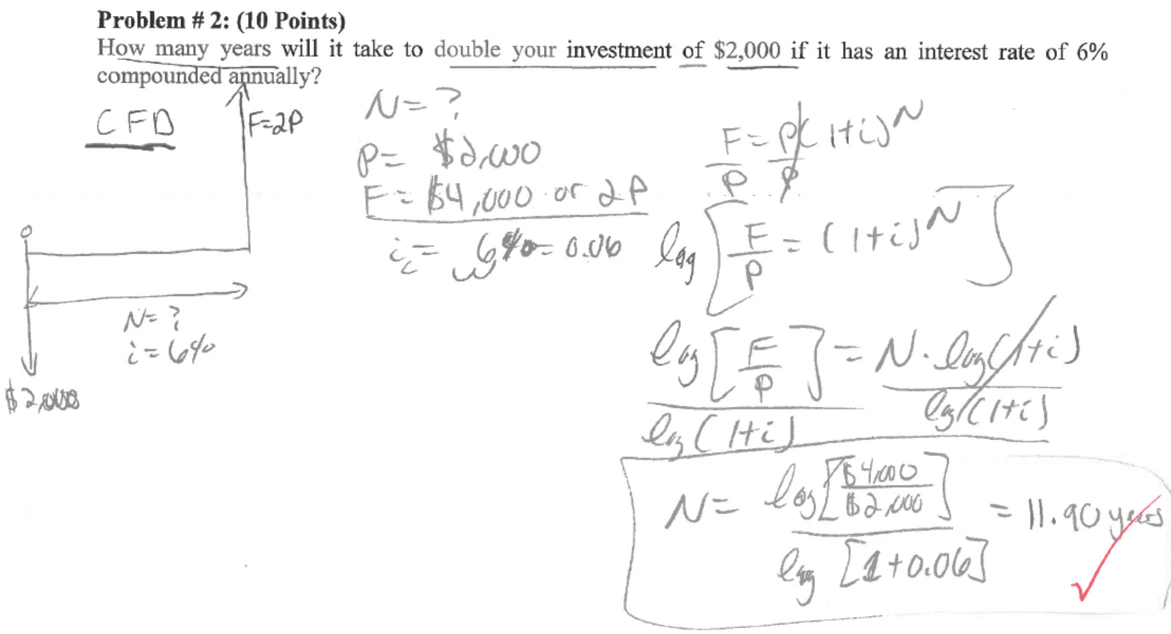


Figure # 10: A student Work using the Equation Method for Example # 10.

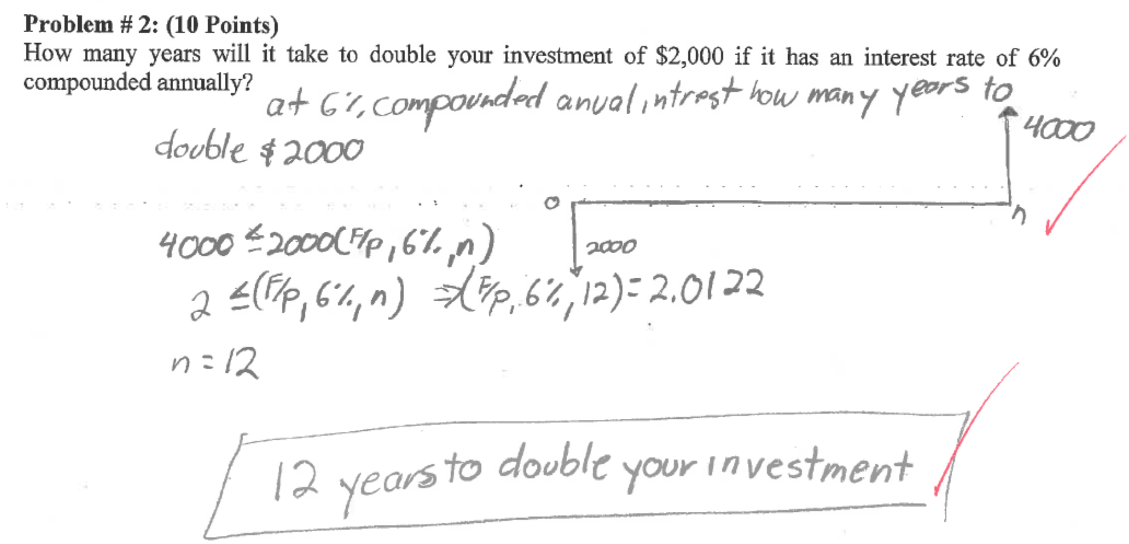


Figure # 11: A student Work using the Compound Interest Table for Example # 10.

Similarly, we teach the other important elements of Engineering Economics, such as Inflation Analysis, Rate of Return (ROR) Analysis, Payback Period, Depreciation and Benefit-Cost Analysis.

In this paper, we would like to show the overall performance of the ME and MET students, regardless of which methods they used to solve the Engineering Economics problems. For example, the Figures # 12 and # 13 shows the Grade Percentage of the ME and MET students over the last several years. It seems that few MET students are equally capable, similar to the ME students, to solve Engineering Economics problems.

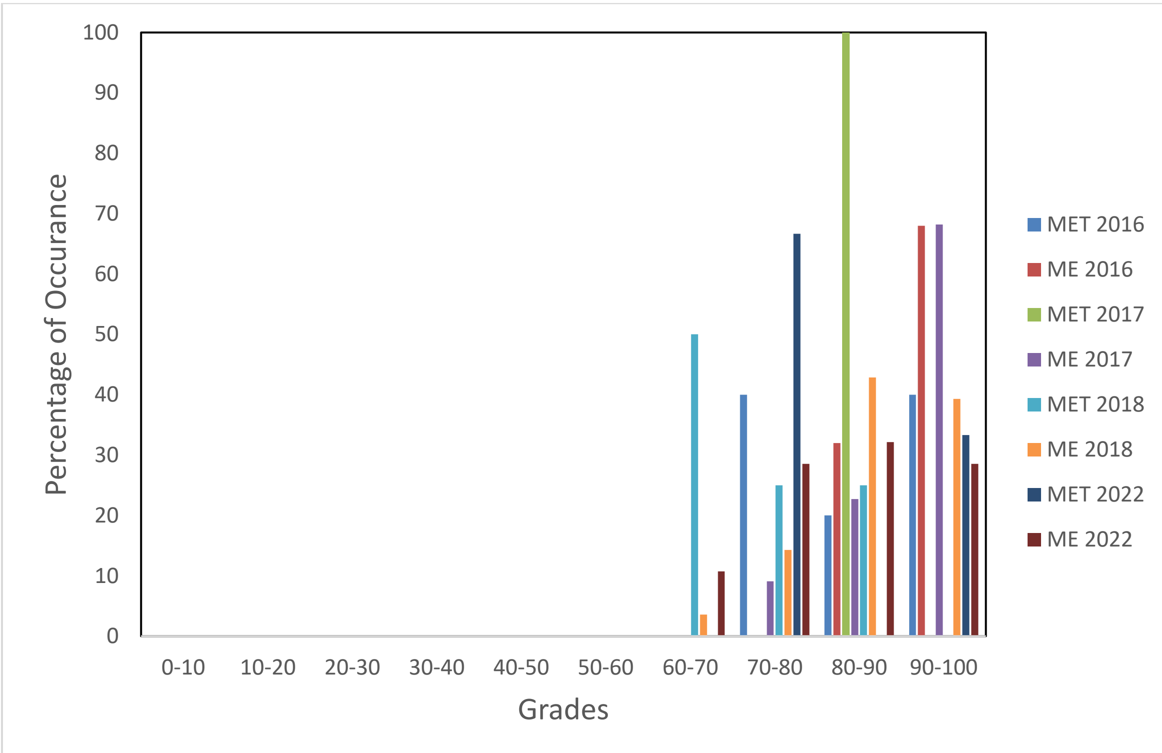


Figure # 12: Average Student's Grades for the ME and MET Majors.

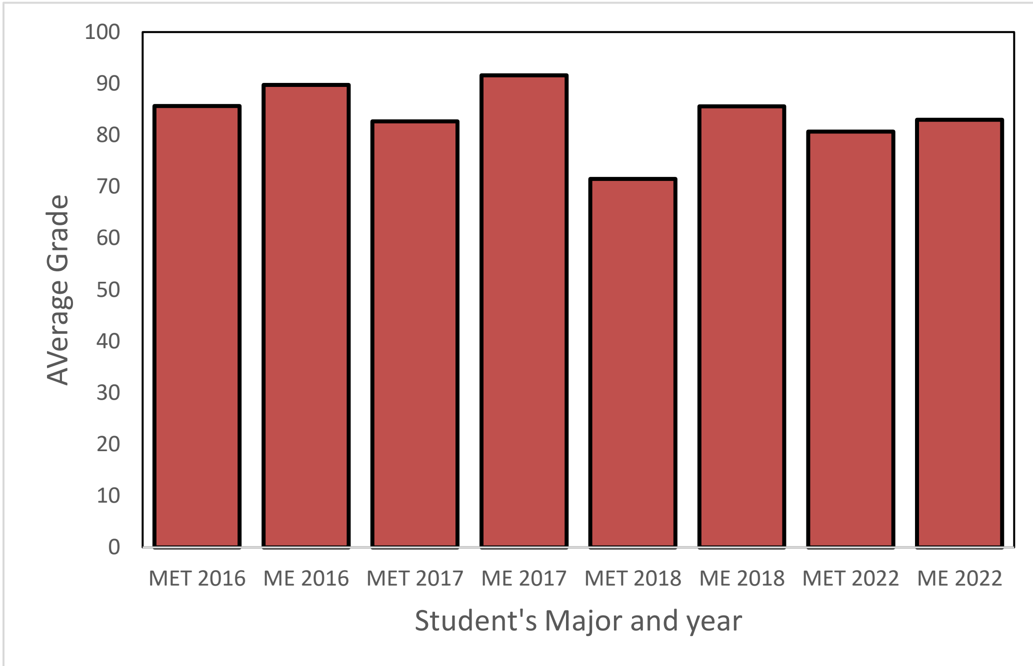


Figure # 13: Average Student's Grades for the ME and MET Majors.

Table 1: Mean and Standard Deviation of the Student Performance versus Grades

	MET Students				ME Students			
	2016	2017	2018	2022	2016	2017	2018	2022
Count	6	3	4	3	26	22	28	28
Average Score in Final	85.7	82.7	71.5	80.7	89.8	91.6	85.6	83.0
SD	11.1	3.8	11.3	8.7	5.4	6.9	8.1	10.7

	Total MET Students	Total ME Students
Count	16	104
Average Score in Final	80.15	87.5
SD	3.02	1.94

Examination of Figures # 12 and #13 and Table # 1 shows that in general the MET students did not perform as well as the ME student's grades. This is expected since most of the ME students are more comfortable with mathematics and analysis. However, this trend or result may not always accurate. It is noteworthy to mention here that the test results are quite variable from term-to-term, which is a result of the type of problems that were assigned and the expectations of the instructor. Analysis of these results indicate that we need to better define the type of problems used for the tests and how to better explain them. Having each instructor use similar problems in their class lectures and in the tests would allow us to better evaluate the students' performance in this course.

Conclusions and Recommendations

We have found that by having the students solve many different Engineering Economic problems is the best way to teach the economic analysis of engineering projects. In addition, even though both the ME and MET students haven't had any economics prior to taking this course, our experience has been if the problems are well-organized and explained to the students, they can better grasp the material. Having students solve various problems not only teaches the students how to learn economics but also prepares them to take the economic portion of the FE exam.

We have also found that our MET students have a little bit more difficult time then our ME students to solve general economic problems. This was indicated by the results of our problems we used for student's grades. This is probably because MET students are generally less comfortable with problem solving than our ME students. While the results of our study methods did support this conclusion, the assessment of our students learning could be better improved by using similar problems in every class taught. However, there is still some variability even when this is the case due to the different expectations and interpretations of the instructor when performing the assessments.

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