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Paths to Becoming a Millionaire[1]

A Course-Based Undergraduate Education Research (CURE)

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ABSTRACT

The time value of money (TVM) concepts and calculation are the foundation of finance and are integral to nearly all models of valuation.

The ideas of present and future value formulas are the quantitative methods to "equalize" the time differential. Generally, the presentation of these TVM concepts entails a number of separate applications:

1. Present value of a lump-sum amount

2. Future value of a lump-sum amount

3. Present value of an annuity (ordinary and due)

4. Future value of an annuity (ordinary and due)

5. Determination of the amount of equal payment (e.g. loan payment) on an annuity when the present value (e.g. principal of a loan) is known

6. Determination of the amount of equal payment on an annuity when the future value is known.

7. Determination of the number of periods

8. Determination of the interest rate/rate of return/discount rate

and present value of perpetuity and present value and future value of uneven cash flows.

Though students are ideally expected to be able to identify the specific area of application at the completion of the course, they often tend to confuse TVM concepts and choose the wrong formula for a given problem. We use the CURE approach and ask an interesting question “what are the paths to becoming a millionaire?” to not only introduce STEM students to the concept of annuity and an interesting application of math in the field of finance but also to overcome the barrier of business school students’ understanding of the TMV concepts and calculation. We believe this interesting question will draw the attention of students on the thought process instead of the mechanical selection and manipulation of a formula and integrate all the aforementioned TVM problems in one project.

This paper will include Annuity Model, Dr. Wang’s class report and Dr. Lin’s class report.

Introduction

Course-Based Undergraduate Research Experiences (CURES) have emerged in recent years in response to studies showing the benefits of undergraduate research internships and national calls to engage more STEM undergraduates in doing research. CURES are high impact learning-teaching activities in which students conduct authentic science investigations in the context of a laboratory course, especially in the life sciences, biology, chemistry, and marine sciences, etc. In other words, CURES encourage engagement, interactions and hand on research to improve understanding and learning in undergraduate science and engineering. Dr. Wang is a business professor who teaches Finance Mathematics for years and I work on computer modeling that connect classroom mathematics and real-life issues. We want to apply CURES pedagogy to work on Financial Mathematics. We were selected to CURES workshop in June 2022 by Morehouse College. During the workshop, we developed a workable project for our students. As I mentioned before no one project can fit to all level students. Hence, I revise our project to fit my freshman students.

Dr. Wang’s Class

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Project Title: Paths to Becoming a Millionaire

Learning Objectives

Students can calculate the present value and future value of a lump-sum amount.

Students can calculate of present value and future value of an annuity (ordinary and due)

Students are able to determine the amount of equal payment (e.g. loan payment) on an annuity when the present value (e.g. principal of a loan) is known.

Students can determine the amount of equal payment on an annuity when the future value is known.

Students can determine the number of periods.

Students can determine the interest rate/ rate of return/ discount rate.

Students can calculate the present value of perpetuity and present value and future value of uneven cash flows.

Student Activities:

The project title draws the attention of students on the thought process instead of the mechanical selection and manipulation of a formula and integrate all the TVM applications in one project.

Students are asked to review context from textbook and work on the following questions:

Your parents will retire in 18 years. They currently have $250,000, and they think they will need $1,000,000 for retirement. The highest possible annual interest rate they can earn is 7%, will they be able to reach their $1,000,000 goal in 18 years with today's only $250,000?

Your parents will retire in 18 years. They need to decide how much the amount of money they need to set aside today so it can grow to $1,000,000 in 18 years. Help your parents to determine the amount they need to set aside assuming they can earn a return of 10% per year on their savings.

Your parents will retire in 18 years. They currently have $250,000, and they think they will need $1,000,000 at retirement. What annual interest rate must they earn to reach their goal, assuming they don't have any additional funds?

Your parents will retire in 18 years. They can save $25,000 per year from this year forward, and they think they will need $1,000,000 at retirement. The highest possible annual interest rate they can earn is 7%, will they be able to reach their $1,000,000 goal in 18 years if started saving $25,000 per year for the next 18 years?

Now suppose you can only save $5,000 annually, but you still want to have the $1,000,000 in thirty years. What rate of return would enable you to achieve your goal?

Suppose you need to accumulate $1,000,000 and have it available thirty years from now. Suppose further you can earn a return of 8% on our savings. How much do you need to save per year at the end of each year?

Suppose your grandparents just purchased a twenty-year annuity with their $1,000,000 nest egg. They learned the interest rate on their investment is 8%. What will be their annuity payment?

Finally, Students are asked to conduct research on paths to becoming a millionaire and submit a professional report.

Assessment Method:

We will compare the scores on the tests given to the students in previous semester to the scores on the similar tests given to students in current semester after the completion of the CURE project.

Data Analysis

First of all, we look at the descriptive statistics for both classes, then we did two sample t-test with 10% significant level and get the following results.

Descriptive Statistics	
Mid-term Exam Scores in Spring 2022 without CUREs	
Mean	66.37834821
Standard Error	2.156291551
Median	67.85714286
Mode	76.78571429
Standard Deviation	17.25033241
Sample Variance	297.5739682
Kurtosis	-0.02871542
Skewness	-0.548592571
Range	78.57142857
Minimum	21.42857143
Maximum	100
Sum	4248.214286
Count	64

Descriptive Statistics	
Mid-term Exam Scores in Fall 2022 with CUREs	
Mean	71.03365385
Standard Error	2.74457805
Median	77.67857143
Mode	80.35714286
Standard Deviation	19.79143378
Sample Variance	391.700851
Kurtosis	-0.388068667
Skewness	-0.788663674
Range	73.21428571
Minimum	26.78571429
Maximum	100
Sum	3693.75
Count	52

t-Test: Two-Sample Assuming Unequal Variances (10% significant level)		
	Scores without CUREs	Scores with CUREs
Mean	66.37834821	71.03365385
Variance	297.5739682	391.700851
Observations	64	52
Hypothesized Mean Difference	0	
df	102	
t Stat	-1.333777906	
P(T<=t) one-tail	0.092623647	
t Critical one-tail	1.289906533	

The descriptive statistics show the average test score of students with CUREs project is higher than the average test score of students without CUREs project. However, when we look at the comparison T-test result, the p-values is 0.092 which is high the most commonly used 5% of significant level,

we cannot say there is a significantly statistical difference that Test score of students with CURE projects is better than the average score of students without CUREs project. But we can see the students have more interaction with instructor and classmates, and more engagement in the class meeting time.

Dr. Lin's class

Project Title: Ways to Be Financial Sufficient Retirement

Dr. Wang and I joined the "A Course-Based Undergraduate Education Research (CURE)" workshop at Morehouse University that were held from June 11 to June 13, 2021. During the workshop we developed a student research project for our student who is learning Mathematics Finance.

My students are freshmen who took course Math 1001 Quantitative Skills. We only have two chapters of saving and Loans. I modified the project so that fits in my student's level. Our textbook only covers three formulas: Compounding, Annuity, and payout annuity.

Compounding Interest: $A = P_0(1 + \frac{r}{n})^{nt}$

Annuity: $A = \frac{PMT((1+\frac{r}{n})^{nt}-1)}{r/n}$

Payout Annuity: $P_0 = \frac{PMT(1-(1+\frac{r}{n})^{-nt})}{r/n}$

I let students work on computer modeling for annuityThrough small group discussion, students have more interaction and engagement with classmates and instructor.

Learning Objectives:

This is not working on financial planning as other financial companies that design retirement plan for their clients.

Students can calculate the future values given initial deposit and time of maturity using compounding interest formula.

Students can calculate future values given regular payment.

Students can calculate regular payment given expected future values.

Students can calculate regular payment given loan amount.

Students can calculate the expected loan amount if they know the payment they can afford.

Student Activities:

Students go through Annuity Model and understand the mathematics background of annuity.

Small Group discussion about when and how to use formulas that students learned in the classes and how to develop a retirement plan.

List all formulas from Chapter 6 of textbook and explain the purposes of each formula.

Find one example for each formula that student can use that formula from (2) to find solutions.

Develop your retirement plan that includes:

When do you expect to get retired?

How many more years do you expect to enjoy your life after retirement?

How much income do you expect to have each month after retirement?

In order to achieve your goal, what amount of funds in your retirement account before your retirement?

What is your investment plan to achieve the financial goal of item (d)?

Mathematical calculations are required to support your claims.

Format of the paper

1. Title page: Title, author name; author affiliation.

2. Abstract

3. Introduction: apply student activities 1, 2 and 3 above to this part in narrative way.

4. Body of your research: Detail research about item 4

5. Conclusion: Is your plan executable?

6. References

Computer Modeling for Ordinary Annuities

Learning Objectives:

Be able to develop and revise computer modeling processes.

Recognize that an annuity involves equal, regular payments or deposits

Be able to correctly apply the savings annuity formula and solve for any unknown using modeling

Be able to correctly apply the payout annuity formula and solve for any unknown using the modeling

Be able to correctly apply the loan formula for amortized loans and solve for any unknown using the modeling

Solve real world problems that involve both planning for retirement and withdrawing from retirement accounts

Recognize how the proportions of a payment going toward principal and interest change over the life of a loan

Steps of The Modeling Process

The modeling process is cyclic and closely parallels the scientific method. The process is cyclic because all the step we might return to an earlier stage to make revisions and continue the process from that point. The steps of the modeling process are as following:

Analyze the problem

At this stage, we determine the problems' objective and decide on the problem's classification.

Formulate a model

In this stage, we design the model, forming an abstraction of the system we are modeling that include

Gather data

We collect relevant data to gain information about the system's behavior.

Make simplifying assumptions and document them

Determine variables and units

Establish relationship among variables and submodules

Determine equations and functions

Solve the model

This stage implements the model.

Verify and interpret the model's solution

Once we have a solution. We should carefully examine the results to make sure that they make sense and that solution solves the original problem.

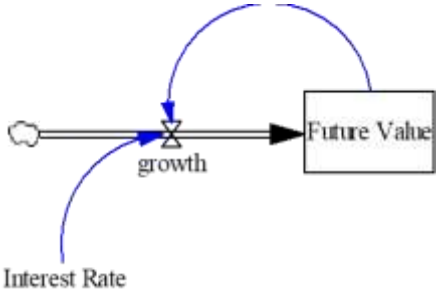
Simple Compounding Interest Model:

Model Description:

Variables: Future Value, is our variable and interest rate, time, and transaction types are parameters. We assume that the initial deposit is P, the interest will be compounded monthly for t years, and the account interest rate is r.

Diagram:

Continuous Model:



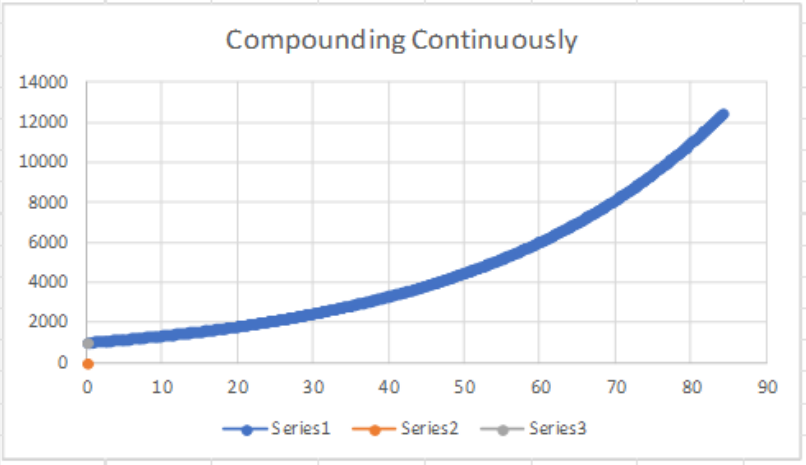
Equation: The change of future value is proportional to the current quantity or $\frac{F(t+h)-F(t)}{h} = r * F(t)$, F(t+h) = F(t) + h*r*F(t) ……The formula we use in Excel.

If the account is compounding monthly for t years then the interest rate becomes r/12, and the transaction count becomes 12t.

Assumption: F (0) = P = 1000, compounded monthly, t = 10, and r = 3% annually.

Continuous model we get solution from Excel below:

Trasaction	F	h =	0.2	r =	3%	t =	10	Deposit=	1000
0	1000								
0.2	1006								
0.4	1012.036								
0.6	1018.108								
0.8	1024.217								
1	1030.362								
1.2	1036.544								
1.4	1042.764								
1.6	1049.02								
1.8	1055.314								
2	1061.646								
2.2	1068.016								
2.4	1074.424								
2.6	1080.871								
2.8	1087.356								



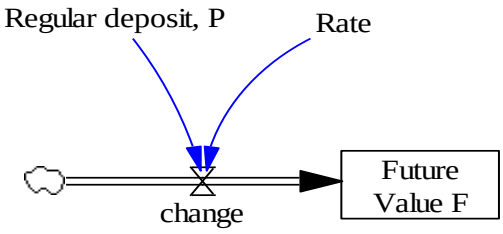
Ordinary Annuities

Most of us aren't able to put a large sum of money in the bank today. Instead, we save by depositing a smaller amount of money from each paycheck into the bank. This idea is called a savings annuity. This is how most retirement accounts work. In this course, we will assume that you put equal amounts of money into the account on a regular schedule (every month, year, quarter, etc.) and let it sit there earning interest. Suppose you start out by making monthly deposits of $1000 into an account that earns 6% annual interest. We assume that the account is compounded with the same frequency as we make deposits unless stated otherwise. If payments are made monthly, we assume interest is compounded monthly. If payments are made annually, we assume interest is compounded annually. We will also assume in this course that all compounding and payments occur at the END of the month.

In this example with monthly payments, we assume the 6% is compounded monthly (or0.5% each month). So, you make your first $1000 deposit at the end of the first month. At the end of the second month, you make another $1000 deposit PLUS you earn 0.5% interest on the prior balance (in this case 0.5% of $1000 = $5) making the balance in your account $2005 at the end of month 2. In general,

Ending Balance = Prior Balance + o.5% Interest on Prior Balance + Monthly Payment.

Diagram:



The change of A is equal to proportional to A and the regular deposit P.

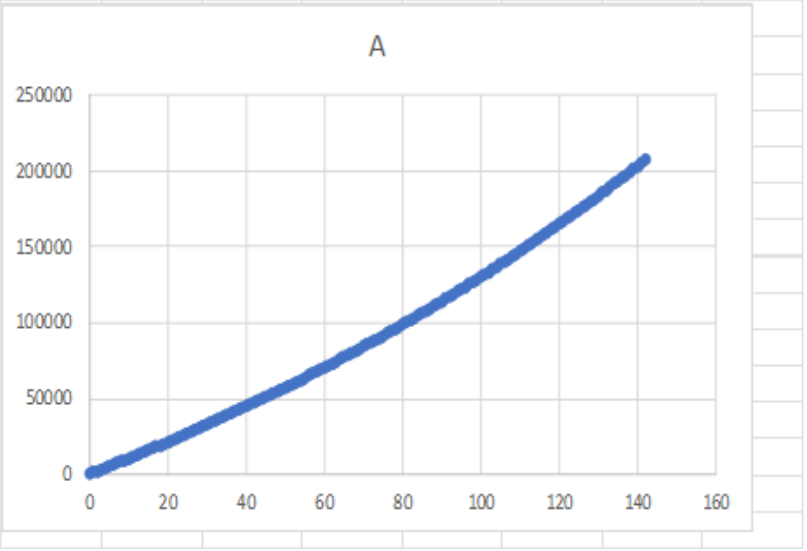
$$\frac{dA}{dt} = P + \frac{r}{n}A$$

The discrete formula is $\frac{A(t+h)-A(t)}{h} = P + \frac{r}{n}A$, where h = 1.

Therefore A(t+1) = A(t) + (P+$\frac{r}{n}A$)

Let A be the annuity amount at time t, r be the annual rate, t be the time, P be the amount of regular deposit, and n be the number depends on the transition type such as n = 12 if the annuity is compounded monthly.

	A	by Formula	r =	6%	n =	12	t =	12	h =	1
0	1000	1000								
1	2005	2005								
2	3015.025	3015.025								
3	4030.1	4030.10013								
4	5050.251	5050.25063								
5	6075.502	6075.50188								
6	7105.879	7105.87939								
7	8141.409	8141.40879								
8	9182.116	9182.11583								
9	10228.03	10228.0264								
10	11279.17	11279.1665								
11	12335.56	12335.5624								
12	13397.24	13397.2402								
13	14464.23	14464.2264								
14	15536.55	15536.5475								



During the group discussion session, I overheard some student's talk in some groups such as:

1. I am more interested in Annuity Model, and expect to apply modeling approach to other topics.
2. I will deposit 90% of my income when I have a professional job. In such a way I will have enough retirement fund.
3. I would like to be a cyber security specialist, so I can make a good income.
4. I expect to have 100 thousand dollars monthly after retirement to enjoy retirement life.
5. I will change my major to computer science and specify cyber security. I will have a better chance to have a high-income job to support my retirement plan.
6. My parents will set up a trust fund for my retirement. I don't worry about it.
7. ……

Assessment Approaches:

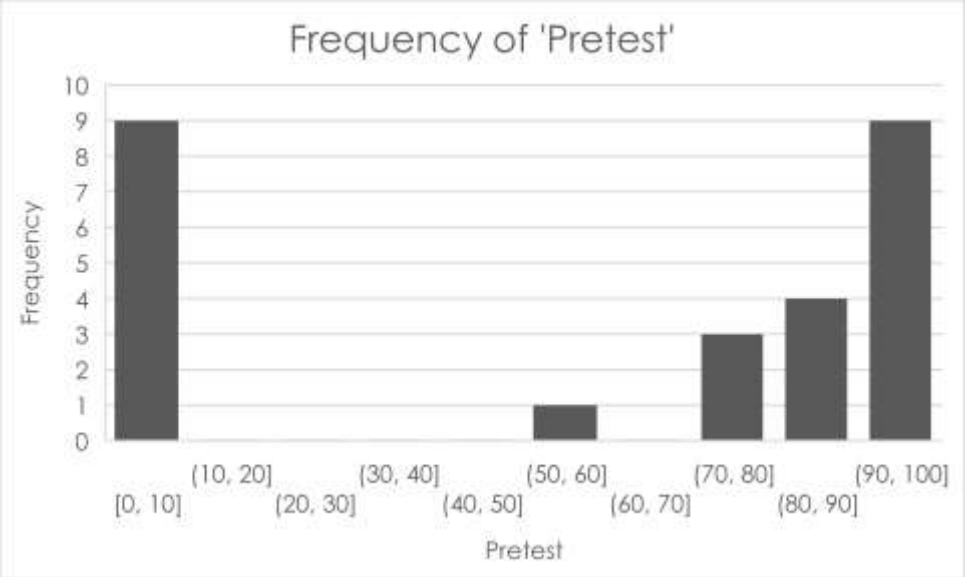
I did regular instruction on Chapter 5 Compounding Interests and Chapter 6 Saving and Loans. After they completed assignments, I gave them a test on these two chapters as our pre-test.

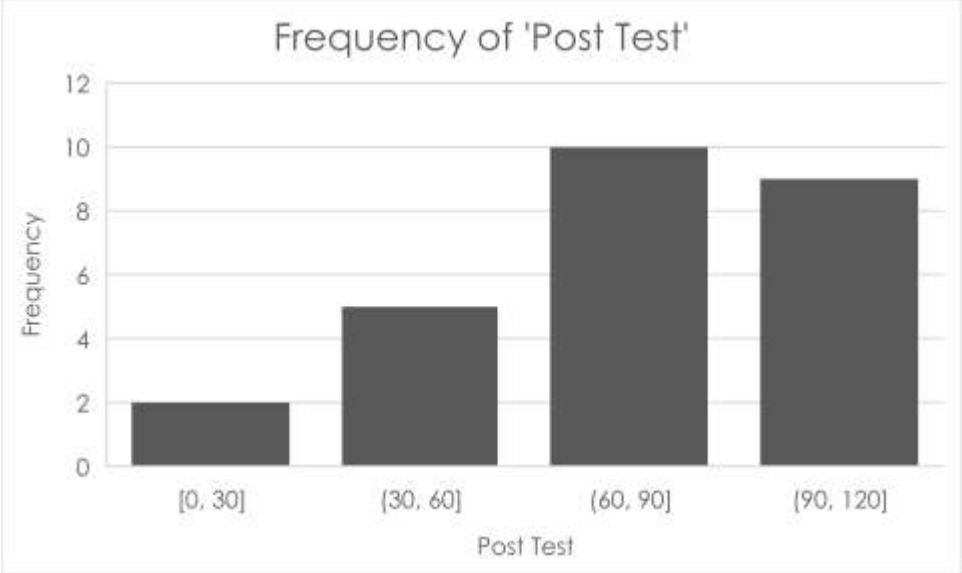
After the test, students work on computer modeling for Annuities and retirement project. I gave them a similar test as our post-test after the students submitted their research project.

Data Analysis:

I decided to make a comparison between these two tests using paired T-test.

First of all, I looked at the histogram of test scores for both tests.





From these two charts, we can see student's post-test scores are better than student's pre-test scores. Next, I did paired comparison t-test.

Data of student's tests.

Pretest	Post Test	Project
0	35.3	0
100	100	92
100	54	95
100	100	0
80	82	0
82	87	90
0	0	75
100	80	85
82	80	0
0	0	0
100	97	80
4	71	80
82	97	95
0	55	0
100	100	95

0	80	95
0	100	85
0	45	0
95	85	80
100	72	85
53	93	0
0	53.3	0
78	100	95
82	73	0
78	90	75
100	100	85

Statistical Results:

Paired T-test: T = 0.013067

Correlation Coefficient between Pretest and posttest = 0.631586

Correlation Coefficient between Pretest and project = 0.358049

Correlation Coefficient between Posttest and project= 0.382998

P-value is 0.0013 which is smaller than any commonly used significant level 5% or 10%. I can conclude that there is a statically evidence that working on project can improve student's learning. However, since the data set is so small, and several students missed the project and tests, I will continuously use this approach for my classes in the following semesters to get convincible conclusions.

Reference:

1. 2022 CURES workshop materials.
2. Tracey Haynie, Jenifer Bohart, Carla Stroud, College Mathematics, 1st Edition, page 119 – 146, Scottsdale Community College.
3. 2019 Lin, Class Notes
4. 2020 Wang, Class Notes