



## The Finance and Mathematics Examination ('FAME')

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We believe that there is a need to create an assessment that measures the relationship between a person's financial and mathematical knowledge. We created the Finance and Mathematics Examination (or "FAME") as a response to this problem. There exist assessments that test either financial literacy or mathematical knowledge in isolation but not, previously, one that looks at the two together. We believe that knowledge in these two areas is closely related, and so FAME is an important research instrument.



## 1. Introduction

We believe that there is a need to create an assessment that measures the relationship between a person's financial and mathematical knowledge. We created the Finance and Mathematics Examination (or "FAME") as a response to this problem. There exist assessments that test either financial literacy or mathematical knowledge in isolation but not, previously, one that looks at the two together. We believe that knowledge in these two areas is closely related, and so FAME is an important research instrument.

Our primary intended use for the assessment is to look at the connection between mathematics knowledge and financial knowledge. Research shows that both financial knowledge and mathematics knowledge are connected to beneficial financial outcomes. Further, additional mathematics and finance education lead to improved financial outcomes. Our goal is to increase our understanding by looking at these connections with regard to specific topics.

Current levels of knowledge in both mathematics and finance are worryingly low in the US. We know that increasing them brings a range of benefits affecting an individual's quality of life. Therefore, it is important to find the most effective form of education in these areas.

Research on finance education in particular has shown that such education programs are highly variable in their effectiveness, with some leading to significant improvements in financial knowledge and behavior, and some having no statistically significant effect at all. A question that is not yet fully answered is what aspects of a financial education program make it more or less effective. One key aspect here is if and how *combining* finance and mathematics education, in essence teaching personal finance as an application of math, can lead to positive outcomes.

This instrument can be used to test the effectiveness of courses in regard to math and finance learning by being used as a pre- and post-assessment to check improvement levels in both areas and also look at the correlation between the two kinds of learning. In addition, it can be used to investigate the relationship between math and finance knowledge in target groups, outside of the context of an education intervention. Data gathered from such survey's should provide information both on how effective an individual education intervention has been and also what *kinds* of education intervention are most effective, with regard to improve financial and mathematical knowledge.

In what follows, we will outline the content of the assessment, how it was constructed, and how we checked it for reliability and validity.

## 2. Instrument Design

We set out to create an assessment that addressed the fundamental concepts in finance and the math needed to fully understand these financial concepts. To begin, we drew up criteria for the structure of the assessment. In order to be easily administered, the assessment should be possible to complete in a single lesson (or reasonable homework assignment). To allow for efficient and objective grading, all questions must be multiple choice.

All questions have four options – there is no option to pass or select ‘don’t know’. The reason for this is that different demographic groups have different propensities to guess when an option to pass on the question is available.<sup>1</sup> Assuming guessing is truly random, a participant will increase their score by an expected 0.25 points for each question they guess rather than pass on – thus inflating the scores of those groups that tend to guess more frequently. Removing the option to pass should remove this discrepancy – and ensuring a large sample of students take the survey will eliminate the significance of lucky guesses when analyzing the results.

In line with the stated aim, we stipulated that the survey should include three types of question:

1. Non-mathematical finance questions (f)
2. Pure mathematics questions (m)
3. Financial mathematics questions (fm)

We next drew up a list of key topics of knowledge for a full understanding of personal finance. We based this on our standards for an appropriate course in finance and mathematics.<sup>2</sup> The survey was required to contain questions addressing each of these topics, listed below:

Finance Topic	Description
F1	Wealth
F2	Income, expense, asset, liability
F3	Interest and Future Value
F4	Discounting and Present Value
F5	Payment series
F6	Financial Risk
F7	Insurance
F8	Expected utility
F9	The Stock Market
F10	Diversified and systematic risk

<sup>1</sup> See, for example, Ben-Shakhar, G., & Sinai, Y. (1991). Gender differences in multiple-choice tests: the role of differential guessing tendencies. *Journal of Educational Measurement*, 28(1), 23-35; Bucher-Koenen, T., Alessie, R. J., Lusardi, A., & Van Rooij, M. (2021). Fearless woman: Financial literacy and stock market participation. *ZEW-Centre for European Economic Research Discussion Paper*, (21-015).

<sup>2</sup> See Marley-Payne, Dituri & Davidson (2021) FiCycle Standards for Finance and Mathematics. *FiCycle Working Paper Series*.

F11	Length of investment

Using the previously cited standards, we then considered the mathematics required to understand these financial topics, to create a list of mathematical topics that also must be addressed:

Math Topic	Description
M1	Arithmetic/Percent/Fraction
M2	Basic algebraic manipulation and substitution
M3	Exponents
M4	Sequences and series
M5	Probability
M6	Expected value
M7	Binomial distributions
M8	Normal distribution

In addition, to specifying the topics, we considered what *types* of questions we should ask. We classified questions as falling within three cognitive categories, following the work of Bloom:<sup>3</sup>

1. Knowledge (K)

- Recognition and recall— the ability to remember facts in a form close to the way they were first presented

2. Comprehension (C)

- Grasp the meaning and intent of information— the ability to tell or translate in own words

3. Application (A)

- Use of information— the ability to apply learning to new situations and circumstances

The survey is intended to include questions that address each of the described categories. To summarize the sets of categories are as follows:

<sup>3</sup> See Bloom, B.S. (Ed.). (1956). *Taxonomy of educational objectives: The classification of educational goals, handbook 1: Cognitive domain*. New York: McKay.



- Question type: f (finance)/m (mathematics)/fm (financial mathematics)
- Cognitive type: K (knowledge)/C (comprehension)/A (assessment)
- Financial Topic: F1-F11
- Math Topic: M1-M8

With these specifications finalized, we turned to creating the questions that would meet our criteria. To start, each member of our three-person team drew up a list of questions, which we edited together, before drawing up a long-list of 60 potential questions to include in the survey. We sent this list out to a team of expert evaluators, looking for recommendations on potential changes, as well as which questions to eliminate. The team of evaluators is as follows:

- John Campbell, Professor of Economics, Harvard University
- Paul Gray, Assistant Principal of Mathematics, New Design High School
- Tim Kaiser, Junior-Professor of Economics and Economic Education, University of Koblenz-Landau & DIW Berlin
- Anand Marri, Dean of the Warner School of Graduate Education and Human Development, Rochester University
- Mark Saul, Executive Director, Julia Robinson Mathematics<sup>4</sup>

Based on this feedback, we revised our questions and selected 34 to include in the survey. These questions, and their categorizations are included as an appendix.

### 3. Test Results

To test our measurement instrument for reliability and validity, we sampled responses from a range of high school students. The students in our sample were attendees of high schools we have a prior relationship with. All were using the FiCycle course in financial mathematics in the following school year. Respondents completed the survey before beginning the course.

Table 1 provides information on averages scores in the key question categories. In all cases, averages are between 30 and 40%, and standard deviation between 18 and 24 percentage points. These figures are within an acceptable range for students who have not yet received any training in the relevant subject areas.<sup>5</sup>

Category	Average Score	Standard Deviation
Finance	39%	24%
Mathematics	39%	18%
Financial Mathematics	32%	23%
Total	36%	18%

*Table 1*

<sup>4</sup> Disclaimer: This feedback process should not be interpreted as endorsement by evaluators

<sup>5</sup> If the scores were much lower, they would be less useful in distinguishing respondent aptitude. If they were significantly higher, there would not be much room to grow, limiting the ability to measure student learning.

Average scores for individual questions are provided in the appendix – the percentage of correct answers for individual questions ranges from 15% to 61%, with a median of 36%.

To check for reliability, we randomly assigned questions in each category into equally sized sub-groups. Then we checked the correlation between score in each of the two categories using OLS linear regression. In each question category there was a statistically significant correlation coefficient, confirming reliability. Regression results can be found in the appendix.

We took several steps to ensure validity. In the study design, as discussed, we solicited feedback from experts in the fields of finance, mathematics, and education, and modified the questions in light of their advice. An additional check on validity for the mathematics questions, was that we aligned the content with the Common Core State Standards for high school mathematics. As an additional check on validity for the finance questions, we included in our sample survey the “Big 6” questions for financial literacy, as used for example in the 2018 National Financial Capability survey.<sup>6</sup> These are a well established and widely used measure of financial literacy. We checked the correlation between score on the big 6 on our finance questions (including those on financial mathematics). We found a statistically significant positive correlation, confirming validity. Regression results can be found in the appendix.

We also ran a regression to examine the relationship between score on mathematics questions and score on finance questions. We found a statistically significant positive correlation, confirming our hypothesis that knowledge levels in the two areas are connected.

#### **4. Instrument Uses**

This instrument is intended to measure the relationship between mathematical and financial knowledge. Given the relatively short length of the assessment and the randomness inherent in multiple choice questions, this should only be used to investigate sufficiently large populations of students. It is *not* intended to be a reliable indicator of an individual student’s knowledge level.

Researchers may use the assessment to measure the level of math knowledge, finance knowledge, and/or the correlation between them in a given population. In addition, if the assessment is given to the same participants at multiple points in time, it can be used to measure the change in their knowledge level. If possible, in this case, there should be a way to match assessments taken by the same individual, anonymized as appropriate. It will then be possible to track patterns in improvement.

In this context, both researchers and education administrators may use the instrument as pre-assessment and post-assessment to measure the effectiveness of an education intervention. It should not be used, however, to determine student grades. If used in a range of education interventions data may be able to provide insight into the pressing question as to what features of education

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<sup>6</sup> See FINRA (2019). The State of U.S. Financial Capability: The 2018 National Financial Capability Study. *FINRA Investor Foundation*.

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interventions make them more or less effective in improving students' financial and mathematical knowledge. We look forward to seeing the results of such future research.



## Appendix

## A. FAME Questions

Question	Answer	Rationale	Category	Finance	Math	Cognitive
1. Suppose you have \$100 in a savings account earning 2 percent interest a year. After five years, how much money will you have in your savings account? a. More than \$110 b. Less than \$110 c. Exactly \$110 d. Cannot be determined	a.	Due to compound interest, you earn \$2 the first year and strictly more than \$2 for the next 4 years	fm	f3	m 3	c
2. Mr. Davidson has a blue shirt, a white shirt, and a striped shirt. He also has a purple tie, a grey tie, a yellow tie, and a black tie. He has black pants and navy pants. An outfit consists of a shirt, tie and pants. How many outfits can Mr. Davidson have? a. 9 b. 12 c. 14 d. 24	d.	He has 3 shirts, 4 ties, and 2 pants, which gives $3*4*2=24$ total combinations	m		m 5	a
3. What is the value of $6x + y$ , if $x=3$ and $y=6$ ? a. 9 b. 18 c. 63 d. 24	d.	$6*3+6=24$	m		m 2	c





4. What number is 7% more than 50?
- 57
  - 3.5
  - 107
  - 53.5
5. Suppose you owe \$1,000 on a loan and the interest rate you are charged is 18% per year compounded annually. If you didn't pay anything of, at this interest rate, when would the amount you owe reach \$2,000? (Assume there are no additional fees or charges)
- Around 2 years
  - Around 4 years
  - Around 7 years
  - Around 10 years
6. When investing in the stock market, which of the following is true?
- Investing in a single company usually provides the least variable return
  - Investing in a range of companies from diverse industries usually provides the least variable return
  - Investing in a range of companies from the same industry usually provides the least variable return
  - There's no way of knowing which strategy can reduce investment risk
7. Imagine that the interest rate on your savings account is 1 percent a year and inflation is 2 percent a year. After 5 years, how much would the amount of money in your account likely buy at the grocery store?
- More
  - Same
- d. 7% of 50 is 3.5
- m m c  
1
- b. Using the rule of 72,  $72/18=4$  so it takes 4 years for your money to double
- fm f3 m k  
3
- b. The returns of companies in different industries are less likely to be correlated, grouping a lot of these together reduces overall variability
- f f1 c  
0
- c. Inflation reduces spending power, so if it is greater than interest, then overall spending power is lower
- fm f3 m c  
1



- c. Less  
d. Cannot be determined
8. At the start of the month your net worth is \$500. Over the course of the month, your assets increase in value by \$300, and your liabilities increase in value by \$150. What is your net worth at the end of the month?
- a. \$500  
b. \$650  
c. \$800  
d. \$950
9. Which of the following is a correct definition of net worth?
- a. How much cash you have  
b. Your assets minus your liabilities  
c. Your income minus your expenses  
d. Your assets plus your income
10. Eduardo has a monthly income of \$3,000 and \$2,000 of this covers essential expenses. Each month he likes to spend \$300 on clothes and \$500 on entertainment. He wants to save \$800 a month so he can start his own business. Which of the following is true?
- a. Eduardo can meet all his goals  
b. Eduardo's only option is to reduce his entertainment spending  
c. In order to create a budget, Eduardo must make a trade-off between his goals for saving and spending  
d. Eduardo should give up on saving money
11. What is  $5^a \times 5^b$  equal to?
- a.  $5^{(a+b)}$   
b.  $5^{(ab)}$   
c.  $(5a)^b$   
d.  $25^{(ab)}$
- b. Your assets increase by \$150 more than your liabilities, so your net worth increases by \$150 fm f2 m a 1
- b. Definitional f f1 k
- c. It's impossible mathematically for Eduardo to meet all his goals. This means he must make a tradeoff, but he isn't forced to make any single specific decision fm f2 m c 1
- a. Rules of exponents m m k 3



- |   |  |                        |
|---|--|------------------------|
| <p>12. Given an interest rate of 4.3%, which investment would grow faster?</p> <p>a. An investment which earns annual compound interest</p> <p>b. An investment which earns simple interest</p> <p>c. An investment which earns quarterly compound interest</p> <p>d. Cannot be determined</p>  | <p>c. The shorter the compounding periods, the higher the return</p>   | <p>fm f2 m c<br/>3</p> |
| <p>13. You have \$2,000 in credit card debt and \$100,000 debt on your mortgage. You have \$1,000 available to reduce your debt. What is your best option?</p> <p>a. Pay it toward the mortgage since that is the bigger debt.</p> <p>b. Pay it towards your credit card as that has the higher interest rate.</p> <p>c. Pay equal amounts off both loans to reduce them evenly.</p> <p>d. Just keep the cash</p> | <p>b. Credit cards have a much higher interest rate than mortgages, so you will decrease future value of your liabilities most by reducing your credit card debt the maximum amount.</p> | <p>fm f4 m a<br/>3</p> |
| <p>14. Which of the following is most likely to raise your credit score?</p> <p>a. Don't take on any debt</p> <p>b. Get a large number of credit cards</p> <p>c. Take out manageable loans, and repay them on time</p> <p>d. Make the minimum payments on a credit card</p>   | <p>c. This is how credit scores are calculated. The other answers either do not allow you to build a credit history or can hurt your credit score</p>                                    | <p>f f6 c</p>          |
| <p>15. A geometric sequence has the recursive definition <math>a_{n+1} = a_n \cdot 1.1</math>. The first term in the sequence is <math>a_1 = 3.7</math>. What is the 4<sup>th</sup> term in the sequence?</p> <p>a. <math>3.7 \times (3 \times 1.1)</math></p> <p>b. <math>3.7 \times 1.1</math></p>  | <p>c. <math>a_n = a_1^{(n-1)}</math>, by rules of geometric sequences</p>  | <p>m m c<br/>4</p>     |



- c.  $3.7 \times (1.1)^3$   
d.  $3.7 \times (1.1)^4$
16. There are 24 odd numbers from 7 to 53 (including 7 and 53). What is the sum of those 24 numbers?
- a. 600  
b. 655  
c. 720  
d. 1440
17. What is a financial benefit to using a mortgage to buy a house, rather than paying rent?
- a. It means you get a house for free  
b. You get an asset, and increase your wealth as you pay off your mortgage  
c. Mortgage payments are always less than rent payments  
d. If you have to make mortgage payments, you don't have to pay off your student loans
18. You roll a regular six sided die. What is the probability it lands on a 5 or a 6?
- a.  $\frac{1}{2}$   
b.  $\frac{1}{3}$   
c.  $\frac{1}{5}$   
d.  $\frac{1}{6}$
19. There are two bags each with six marbles; one of the marbles in each bag is red, the other marbles are green. If you pick one marble from each bag, what is the probability that both marbles are red?
- c. To find the sum of an arithmetic sequence, add the first and last terms, divide by two, and multiply by the number of terms m m a 4
- b. Rent payments do not do anything to increase your net worth, while mortgage payments reduce liabilities. f f1 c
- b.  $\frac{2}{6} = \frac{1}{3}$  m m c 5
- d. The two picks are independent events so the probability of both occurring is equal to the product of the individual probabilities:  $\frac{1}{6} * \frac{1}{6} = \frac{1}{36}$  m m a 5



- a. 1/18
- b. 1/6
- c. 5/36
- d. 1/36

20. You are starting a business selling surfboards. Each surfboard sells for \$150. On the each day of the summer you think there is a 30% chance you will sell one board, a 50% chance you will sell two and a 20% chance you will sell three. What is your expected average daily sales?

- a. \$135
- b. \$150
- c. \$285
- d. \$300

21. There is a 10% chance of your phone breaking and the cost of replacement is \$500. The cost of insurance is \$100. There is a 0.1% chance of your home/apartment being damaged in a fire, the cost of repair is \$50,000. The cost of insurance is \$100. Which is more useful from a financial perspective?

- a. Phone insurance, since it is more likely to pay off
- b. Home/apartment insurance, since the risk from a loss is so great
- c. They are equal since they have the same expected value
- d. Neither is good insurance since they have negative expected value

22. Company XYZ is worth \$1,200,000. They offer 2000 shares. Susan buys \$27,000 worth of XYZ. How many shares does Susan own?

- a. 27
- b. 45
- c. 600
- d. 1,173,000

c. From the definition of expected value:  
 $150*(0.3*1+0.5*2+0.2*3)=285$

fm f8 m c  
6

b. Catastrophic events come with additional downstream cost as people's regular savings and income are not able to mitigate the damage. In these cases, insurance is valuable.

fm f7 m c  
1

b. Share price =  $1200000/2000=900$ ,  
 $27000/900 = 45$  shares

fm f9 m c  
2



23. You make an investment of \$1,000, which after one year has an expected value of \$1,150, and a standard deviation of \$250. What is the lowest value for your investment at the end of the year approximately 98% of the time, if the results are normally distributed?
- a. \$1,000  
b. \$900  
c. \$650  
d. \$150
24. When is it most appropriate to invest in stocks?
- a. You need to double your money in a year.  
b. You want to use your investment for a down payment on a house in 3 years' time.  
c. You are saving for retirement which is 20 years away.  
d. You will use this money to pay your bills at the end of the month.
25. You buy a car at a fair price that you need in order to drive to work. Which statement is true?
- a. You acquired an asset and increased your wealth.  
b. You acquired an asset and increased your cash.  
c. You acquired an asses and did not increase your cash.  
d. You decreased your cash and did not acquire an asset.
26.  $\log(4) + \log(5) =$
- a.  $\log(9)$   
b.  $4^5$   
c.  $\log(20)$
- c. 98% of the time, results will be no more than two standard deviations below the mean. fm f9 m k 8
- c. The risk of a low of negative return from a stock market investment is much lower with a longer period of investment. f f1 a 1
- c. A car is an asset, and if you bought it a fair price, i.e. that asset's value, your wealth would be unchanged. f f2 a
- c. Laws of logs m m c 3



- d. 20
27. Which of the following factors will make it easier for you to meet your retirement goals?
- a. Retiring earlier
  - b. Earning a higher rate of return on investments
  - c. Higher inflation rate
  - d. Lower social security payments
28. APR stands for
- a. Additional Profit Return
  - b. Annual Percentage Rate
  - c. Annual Percent Return
  - d. Annual Profit Rate
29. Which of the following pairs of events is independent?
- a. The event that the forecast calls for rain on Tuesday in Chicago; and the event that a person in Chicago has an umbrella with them on Tuesday.
  - b. The event that the forecast calls for rain on Tuesday in Chicago; and the event that a person in Paris has an umbrella with them on Tuesday.
  - c. The event that George owns a dog; and the event that George buys dog food.
  - d. The event that George has the flu; and the event that George misses work.
30. According to the efficient market hypothesis, what is the best investment strategy?
- a. Use an index fund that diversifies risk and keeps fees to a minimum.
  - b. Use a well-qualified financial advisor who charges higher fees in order to beat the market.
- b. Higher return increases the future value of your investments, all others decrease your retirement spending power. f f5 c
- b. Definitional f f2 k
- b. Weather in Chicago and Paris are independent, all other pairs of events are related m m a 5
- a. According to EMH the best you can do is get the market rate of return and diversify to reduce risk as far as possible f f1 c 0



- c. Keep your money out of the stock market because it's completely random.  
d. Invest in the largest and oldest companies.
31. Which of the following is NOT TRUE about probability?
- a. Probability is a measure of how likely an event is to occur  
b. Probability is measured with a number between 0 and 1  
c. A probability of 0 means an event only happens one time in a million  
d. Probability can be expressed as a ratio
32. You have a discounting rate of 7%. What is the present value of \$1000 received in three years' time?
- a. \$934.58  
b. \$816.28  
c. \$930.00  
d. \$790.00
33. Each day, your investment has a 70% chance of going up in value, and a 30% chance of going down in value. Over 100 days, which of the following outcomes is least likely?
- a. Your investment goes up 75 times and down 25 times  
b. Your investment goes up 85 times and down 15 times  
c. Your investment goes up 40 times, and down 60 times  
d. All outcomes are equally likely
34. Which of the following will most likely help you achieve the goal of covering your retirement expenses, while having enough cash available for present consumption across your working life?
- a. You save exactly the same amount each month for your whole working life  
b. You wait to start saving till you are older
- c. Probability 0 means an event NEVER happens m m k  
5
- b.  $PV=1000*1.07^{-3}$  fm f4 m c  
3
- c. Expected value is 70 up and 30 down - option c is the furthest from the mean, and so is least likely due to properties of binomial distributions fm f1 m a  
0 7
- d. This allows you to use a reasonable amount of your income for consumption across your entire working life. f f5 c



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- c. You invest a large lump sum when you're young to maximize the interest you earn
- d. You save an increasing amount over the course of your career as your income increases



<b>Question</b>	<b>Correct Responses</b>
Q6	64%
Q25	60%
Q1	55%
Q24	53%
Q23	50%
Q10	47%
Q26	47%
Q33	46%
Q7	45%
Q30	45%
Q14	44%
Q21	43%
Q9	40%
Q11	40%
Q27	39%
Finance	39%
Mathematics	39%
Q8	38%
Q29	38%
Q34	36%
Total	36%
Q5	35%
Q2	33%
Q19	33%
Q3	32%
Financial Mathematics	32%
Q12	31%
Q13	31%
Q22	31%
Q16	30%
Q20	30%
Q31	30%
Q28	29%
Q17	28%
Q18	28%
Q15	27%



Q4 26%  
Q32 18%

**B. Scores**

<b>Question</b>	<b>Correct Responses</b>
Q1	55%
Q2	33%
Q3	32%
Q4	26%
Q5	35%
Q6	64%
Q7	45%
Q8	38%
Q9	40%
Q10	47%
Q11	40%
Q12	31%
Q13	31%
Q14	44%
Q15	27%
Q16	30%
Q17	28%
Q18	28%
Q19	33%
Q20	30%
Q21	43%
Q22	31%
Q23	50%
Q24	53%
Q25	60%
Q26	47%
Q27	39%
Q28	29%
Q29	38%
Q30	45%
Q31	30%
Q32	18%
Q33	46%
Q34	36%
Finance	39%

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Financial	
Mathematics	32%
Mathematics	39%
Total	36%

### C. Reliability Regressions

	Coefficient Value	Standard Deviation	R <sup>2</sup>
Financial Mathematics	0.22 **	(0.07)	0.05
Finance Mathematics	0.29 ***	(0.07)	0.09
Overall	0.32 ***	(0.06)	0.12
	0.50 ***	(0.06)	0.30

\*\*\*  $p < 0.001$ ; \*\*  $p < 0.01$ ; \*  $p < 0.05$ .

### D. Other Regressions

Independent Variable	Outcome Variable	Coefficient Value	Standard Deviation	R <sup>2</sup>
Math Score	Finance Score	0.38 **	(0.05)	0.25
Big 6 Score	Finance Score	0.26 ***	(0.05)	0.15

\*\*\*  $p < 0.001$ ; \*\*  $p < 0.01$ ; \*  $p < 0.05$ .