Fall 2016

Engineering Financial Literacy: Modules to teach engineers core business topics

Alexandra Bartlett

ENGINEERING FINANCIAL LITERACY: MODULES TO TEACH ENGINEERS CORE BUSINESS TOPICS

by

Alexandra Bartlett

A thesis submitted in partial fulfillment of the requirements
for graduation with Honors in the Chemical Engineering

_____

Julie Jessop
Thesis Mentor

Fall 2016

All requirements for graduation with Honors in the
Chemical Engineering have been completed.

_____

Audrey Butler
Chemical Engineering Honors Advisor

Engineering Financial Literacy:

Modules to teach engineers core business topics

Author: Alexandra Bartlett, *Chemical Engineering and Finance*

Faculty Mentor: Dr. Julie Jessop, *Department of Chemical and Biochemical Engineering*

Honors Advisor: Dr. Audrey Butler, *Department of Chemical and Biochemical Engineering*

Submitted: 14 December 2016

Abstract

Engineers need to understand how engineering relates to business to graduate from an ABET accredited program. However, a number of second-semester seniors struggled to understand concepts that are covered in the introductory finance course at the business school. There are options available for students to learn about some of the concepts that they might encounter in industry and in class projects, but these materials take time. I created a module that was designed to take less than 40 minutes to reduce the time and stress over learning the core business concepts. The module covers concepts such as interest, present value, and depreciation, which were covered in engineering and business courses. Users can check their understanding of the materials covered with a four question post-module quiz. To supplement the core module, I designed another module that provided information on performing a sensitivity analysis. An Excel worksheet supports the module to provide additional terminology and a worked-out example. Both modules provide a sustainable method of delivery for all disciplines. From a pre-quiz given at a guest lecture to senior chemical engineering students, a gap exists between a student's actual and perceived level of comprehension of economic concepts. Review of the module should narrow or eliminate this gap for many students. However, there is a mental block preventing many students from even attempting to learn more about the financial aspect of a project. Students not planning on pursuing a career in industry have shown an increased level of apathy towards learning about business concepts. Alumni could play a vital role in showing the importance of learning the content covered by the modules. Continued repetition and early exposure to economic concepts will help encourage undergraduate engineers to create a business foundation before launching their careers.

Introduction

Practicing engineers in the United States have a degree from an ABET accredited engineering program. Accreditation requires that the individual with a degree should have:

> *"an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability…[and] the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context."*

Two of the eleven ABET student outcomes require the program to connect engineering to economics. There are 485 ABET accredited four-year engineering programs in the United States alone (ABET, 2016). These programs proved to ABET that students left the program having used economic principles with their design problems. To satisfy requirements set forth by ABET, Georgia Institute of Technology offered an Advanced Engineering Economy course that covered asset price dynamics analysis, market survey analysis, and dynamic cash flow analysis (Hackman, 2009). University of Wisconsin-Madison College of Engineering students can take an upper-level course, Engineering Economics and Management, that focuses on basic accounting concepts, management concepts, and pricing and product decision that engineers in industry will need (Krueger, 2016).

Why does ABET require engineering students to learn about economic concepts when a business degree is the most popular degree nationwide (Stockwell, 2014)? Simple, money. Understanding how to efficiently manage company's money is not the sole responsibility of the finance department. Rather, every group within the firm—including engineering—must consider how decisions impact the company's bottom line. For students looking to go into the workforce, they will need to be able to understand the language and terminology used in product

commercialization. A first-year research development scientist for General Mills "would be developing technical depth and business acumen and develop meaningful insights and translate them into concepts, prototypes, and commercial offerings" (General Mills, 2016). A full-time downstream chemical and process engineering would need to "assume responsibility for development, execution and commissioning of small scale capital programs" (BP p.l.c., 2016). These two companies expect that an engineer will be able contribute their analytical skills to the business side of the engineering problems. General Mills does not expect its new hires to have a high level of business acumen because it emphasizes that it will help new hires develop necessary skills. Exposure to the basics in undergraduate will create a solid foundation for the engineer to build upon. New hires already have enough to learn from an engineering standpoint, so adding business topics to the mix could be overwhelming. For the students that are deciding to delay or forgo practicing in industry, knowledge of business concepts is still beneficial for design courses and for potential career changes in the future.

Currently, there are five engineering students pursuing dual degrees in finance and engineering. Three of the students are in the industrial engineering discipline, and the other two are studying chemical engineering. Since May 2013, only two people graduated with a B.B.A. in finance and a B.S.E. The number of students graduating with minors in business administration has grown from 10.3% of graduating engineering students in May 2013 to 14.6% in May 2015. As much as 16.1% of the graduating class had completed the requirements for a business minor. An increasing number of students have seen the value of supporting their engineering education with business concepts. Engineering undergraduate students at the University of Iowa have options if they want to learn about the business side of projects without having to double major. They could take the Engineering Economy course (IE:2500), watch videos Khan Academy on

core finance topics (Khan, n.d.), look through the Project Evaluation courses on MIT OpenCourseWare (Sussman & Martland, 2011), read *Economics for Dummies* (Flynn, 2011), or skim a finance textbook. While all except the last option will provide a good overview of key business concepts, these options require some time commitment to complete, as well as to find the relevant topics. Time is what undergraduate engineers typically lack. Ideally, there should be a resource that takes no more than 50 minutes to cover the core topics of business that engineers might face in school and post-graduation positions.

Last year, I instructed my chemical engineering classmates on how to do a discounted cash flow analysis for several homework assignments. Component by component, I explained to them what each part of the process meant, provided some examples of what other names the term would go by, and clarified how to calculate each piece. We walked through a problem to allow them the opportunity to apply the concepts. This process helped my classmates complete the homework. I wanted to expand the audience that could learn these concepts. When one of those individuals returned from a summer internship, she told me that her manager was surprised she had known what he meant when talking about revenues and expenses for their project. He was impressed with the understanding of these core and basic concepts, which highlights that engineers do not need to be accountants or investment bankers to impress employers. This feedback provided the necessary encouragement to create sustainable supplementary learning materials.

Method

With guidance from the University of Iowa Center for Teaching, I developed course objectives around which to frame the module. I designed the module so that the student would meet three objectives:

1. Be able to demonstrate an understanding of fundamental economic concepts
2. Be able to perform a basic discounted cash flow analysis
3. Be able to identify common business terminology

With the framework outlined by the objectives and notes taken during the economic review session given by Dr. Julie Jessop for Chemical Engineering Process Design II (Design II, CBE:4110), I created a preliminary module to provide the user a basic understanding of economic concepts to those who have not had previous business classes and would serve as a review for those who have had business classes or Engineering Economy. This preliminary module was posted on the course website for Design II. A Survey Monkey survey (Appendix F) at the end of the module asked for feedback on content, mode of delivery, and module length from those individuals using it.

To obtain immediate feedback, I wanted to work with students. Chemical Engineering Process Design I (Design I, CBE:4109) meets for 50 minutes three times a week during the fall semester of a chemical engineering student's senior year. The professor granted me one lecture to cover economic topics. One lecture was not going to be of any help to the students if I hopped around from topic to topic. To decide what topic to focus on in the timeframe, I spoke with the professor to determine what topics he would cover in his economic-focused lectures. He was going to cover all the topics that I had in my module, which is found in Appendix B. There was one topic left that I knew came up in project analysis, but I had only ever been taught how to approach it in my advanced finance courses. This topic was sensitivity analysis. I had wanted to cover it in the module, but refrained from doing so to keep the module focused and short. The lecture offered me the opportunity and platform to build off the instruction that the students had received earlier in the class. Between my lecture and the previous lectures in Design I, every

individual in the class should have adequate exposure to topics that would arise as part of their design reports. The module used for the lecture is found in Appendix A, and the associated Excel file can be found in Appendix C.

Part of the difficulty of teaching is that prior experience varies student to student. Not every engineering student must take Engineering Economy or Introductory Financial Management (FIN:3000). To gauge the student's comfort with the concepts previously covered, I asked the students four questions at the beginning of lecture. The questions posed were straightforward:

- How many of you are confident that you know how to value a project?
- How many of you are sure you that you can value a project using guidance from a classmate or professor?
- How many of you are unsure about what is going on with the business side of the project?
- How many of you do not care about these topics?"

Asking the students whether they cared was critical in understanding the interest level that the class had in connecting design concepts learned in class to realistic expectations that a company would have. After asking each question, I recorded the number of hands raised. Following the informal questions, I presented a four-question quiz (Appendix D) composed of questions from the Introductory Financial Management course materials. Students had five minutes to complete the quiz. It took me about two minutes to complete the quiz with a financial calculator, which is why I gave more than double the time for the students. For those who took the lecture quiz, I anticipated that 20% would find the quiz easy, 60% would find the quiz doable, and 20% would find the quiz a challenge.

Results and Discussion

Comprehension

Twenty-four students attended lecture. From the poll at the start of lecture, no one raised their hands when asked if they were completely confused. Six students raised their hands saying that they were confident in the economic material. Eight students believed that they would be comfortable with the economic concepts in projects if they had some extra guidance. Every student answered the first question—about the key relationship between internal rate of return and net present value—incorrectly. Figure 1 shows the distribution of the scores.

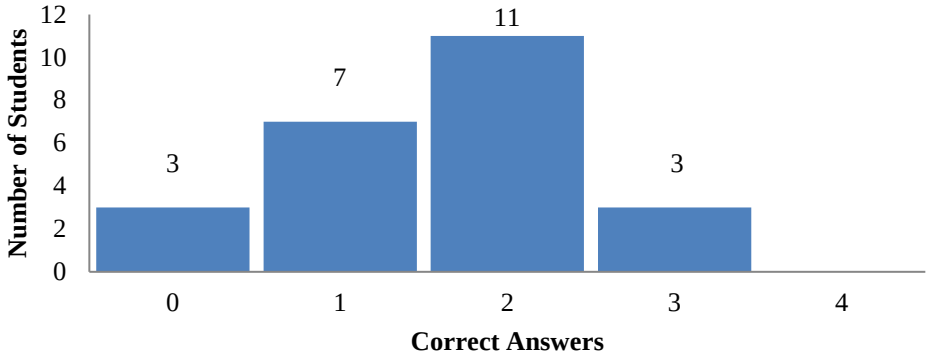

Figure 1 Score distribution from lecture quiz

There were 3 students that answered all 4 questions incorrectly, which was unexpected considering that no one thought that they were completely lost. As seen in Figure 1, 14 students would likely be able to answer the material without significant guidance, because they answered 50% and 75% of the questions correctly. Seven individuals need more help than they thought. Not everyone gave a response to the question about how they felt about the economic concepts, so it is difficult to determine if the people who thought they understood actually fell in the 50-75% range or in the 0-25% range. My lecture did not cover the concepts covered in the pre-quiz, so it did not provide any insight into the helpfulness of the lecture. The pre-quiz did show that students needed further coverage on the basics. I made the module available to those who wanted

to review the topics covered in the knowledge assessment and to look at how the four questions were solved. In the lecture, I should have opened it up for questioning to allow students to gain further insight on the core finance concepts tested. In a lecture, one student's question might apply to several students. If I were to redo my lecture, I would go through the solutions and have the students grade their quizzes. By grading their own quizzes, the students would have realized that their level of comprehension was not where they thought it was. Quizzes would still have to be collected, so that I could review the mistakes made by the students. In the module (Appendix B), I gave possible errors that students might have made in solving the problem by looking at the mistakes made during the in-lecture quiz. In the lecture, I should have opened it up for questioning to allow students to gain further insight on the core finance concepts tested. In a lecture, one student's question might apply to several students.

After the lecture quiz was administered, I changed the second question so that it gave a clearer picture on the student's understanding of the material. Originally, the question read: "*Your brother has offered to give you either $5000 today or $10,000 in 10 years. If the interest rate is 7% per year, which option is preferable?"* As it was given, the question allowed students to arrive at the correct answer without doing the math correctly. This error arose from not checking whether the correct answer could be selected if the student made the common mistakes associated with present value calculations. To update the question, I added "*by how much?*" as a secondary question. Lack of foresight underlined the difficulty of developing questions for students who have less exposure to concepts than I do. Technically, the students came to the correct conclusion, which means they understood the time value of money. They simply performed the present value calculations incorrectly. Students will not necessarily fail a course or blow up a plant if they cannot hand calculate a present value. Excel will calculate present value

for students. However, students need to understand that basic present value calculations so they can be prepared for other projects or job assignments that have changes in the interest or the annual cash flows over the course of an investment horizon.

Balancing the depth of coverage of the updated fundamentals module was critical. Too much material would not only take time from busy engineers, but it would likely have frustrated those without any previous exposure. Too little would have also have made it less helpful than the resources already easily accessible on the internet. Supplementary content on valuing a product or accounting basics would be helpful for students. For those students who want to learn more, business courses would be advantageous. So far, however, the module has been delivered to students in their senior year. In-depth coverage and application in Chemical Engineering curriculum is not required until senior year. Earlier emphasis on the importance of moderate business acumen is necessary to inspire students to seek out courses or tools that provide such understanding.

Understanding Importance

At lecture, 11 people (or 46% of the those who attended class) said that did not care. Approximately half of the senior class does not care about economic concepts despite all of them graduating in less than a year. This apathy is worrisome for three reasons. First, these seniors are entering a world where there is a significant chance that they will need to draft a budget or work on developing a new product. Second, those not going into industry have applied to graduate programs or are unsure of their plans. Both have uncertain plans, so they should be prepared in case they must go into industry. Lastly, a lack of interest in business amongst the seniors could trickle down to the underclassman as seniors serve as teaching assistants in underclassman

courses. If juniors or sophomores hear that seniors not putting forth much effort in the economic portion of design reports, the underclassmen could cease to care about it as they go through their own reports.

Finance is math. Simple math. Despite being able to handle differential equations, engineering students still do not care to learn more about the business side of engineering. It is not that they could not do it, but it is that these students do not see why they need exposure to business concepts. Mentioning the word business activates a mental block and prevents the students from attempting to comprehend it. Ever met someone who said that they were bad at math? This mental barrier is the same thing. While those bad at math hide behind this statement and pull out a calculator to determine the tab after tip at a restaurant, people afraid of business just trust numbers spit out of Excel without giving them a reality check. Breaking down the mental block will be difficult. Repetition might be the best way to address the issue. The first introduction to economic concepts is in Engineering Problem Solving I (ENGR:1100). If the core classes—Thermodynamics (ENGR:2130), Circuits (ENGR:2120), and Statics (ENGR:2110)—have problems that require applying business principles to economic concepts, students would be reminded that business is important. Engineering professors have reminded students about how important money is when scaling-up or selecting a reactor. If more professors mention how a decision impacts a company, students might be more inclined to consider what the professors are saying and actually want to understand the business topics. Seminars likely have speakers who have worked on a capital project or a budget. If the speakers are encouraged to discuss this part of their job, it might prompt those students attending and listening to pursue coursework or experiences with business. Younger alumni speaking about how much finance and other business concepts comprise of their daily tasks would be extremely beneficial.

Proving that these concepts will be helpful in the future to engineering students has been difficult. Trying to convince those that are set on going into graduate, dentistry, or medical school after graduation that they might need to worry about industry as a backup is not an easy sell. Perhaps the difficultly stems from the module's content being less applicable to coursework than I believed. Since no students provided feedback via the survey given at the end of the module created for the 65 students enrolled in Design II, I have limited insight into how useful the content coverage was. Verbally, classmates told me that the module was helpful for completing their senior design project when they used it. This feedback did not tell me which material was most useful to them. Therefore, I made few changes to the scope of the material when updating the module. Coverage for the final module was limited to the core concepts that have been reviewed many times in several finance and core business courses and that I deemed crucial for multiple classes and life after graduation. Feedback from students with internship experience or young alumni would further sharpen the focus of the material. Refocused module topics would emphasize to underclassman that business does matter, and thus encourage the students to look for ways to incorporate business material in their education plan.

Distribution

As digital files, the modules and supplementary Excel workbook are sustainable. Distribution has been exclusive to chemical engineers. Even though the coverage has been sufficient to support chemical engineering seniors through their design projects in Design I and II, the remaining five engineering disciplines have not had access to the content covered. One way to disseminate the information would be to work with the professors who teach design in other departments. To broaden the distribution and highlight the industry importance, the module should be digitally available with the other career preparation resources made available by the

College of Engineering's professional development team. Once the modules are distributed, it would provide additional resources to a wider group of engineers. Without a business elective focus area, Biomedical Engineering and Civil & Environmental Engineering departments would benefit the most from an overview module. If the modules were available on the professional development website, alumni struggling with the business concepts early in their career could have reference. If these alumni ever spoke to a class, the module may get additional publicity.

An alternative would be to create a shorter document for the Hanson Center for Technical Communication (HCTC). This document would have a list of major business terms and synonyms. While it would be brief, this document would serve as a translation guide for engineers that use a variety of resources that cover business concepts. Connecting terms among different authors and courses should reduce not only the confusion, but also the frustration often associated with learning business concepts. A sample of the term cheat sheet can be found in Appendix E. The most convenient and appropriate location for this document would be the HCTC because understanding the terms in the guide would allow an engineer to better communicate their engineering solutions in the context of business and with appropriate business terminology.

Conclusion

The modules were created for engineers to establish a solid foundation in the basic business principles they would likely encounter in engineering roles. Both modules were designed to be sustainable. While these materials did not successfully convince students to learn about cash flows or present value, they are sustainable and will provide resources for when students experience a situation in which they have to work with unfamiliar business concepts.

Key to establishing business literacy in engineers is alumni with industry experience. With the support of alumni and professors, the modules would become a helpful refresher rather than the only business instruction an engineer will have. Engineering students could reach this level of understanding if they took introductory business courses or Engineering Economy. Growing exposure to traditional business classes seemingly decreases the need for the module. To allow time for adding business courses or preparing for internships, alumni from industry should speak to the importance of business early in the education career. Until the mental barrier is knocked down, the module will still prove useful for the remaining 83-90% of the engineering students apprehensive about learning more on business topics. Continued encouragement from alumni and professors to take business courses will be crucial for undergraduate students to create more realistic solutions for class projects and to stand out in a new position.

References

ABET. (2016). *Accrediation* . Retrieved from ABET: http://main.abet.org/aps/Accreditedprogramsearch.aspx

BP p.l.c. (2016). *bp Careers*. Retrieved from BP: https://jobs.bp.com/job/blaine/process-control-engineer/198/2981576

General Mills. (2016). *University Recruiting-Research & Development Scientist/Engineer*. Retrieved from General Mills: http://careers.generalmills.com/job/6751386/university-recruiting-research-development-scientist-engineer-minneapolis-mn/

Hackman, S. (2009, August). *Advanced Engineering Economy*. Retrieved from Georgia Tech: http://www2.isye.gatech.edu/~shackman/isye6225_F09/index.htm

Krueger, C. (2016, August). *EPD 611: Engineering Economics and Management*. Retrieved from University of Wisoncons-Madison: https://courses.engr.wisc.edu/ie/ie313.html

Stockwell, C. (2014, October 26). Same as it ever was: Top 10 most popular college majors. *USA Tday*.

Appendices

Appendix A: Sensitivity Analysis Module

Sensitivity Analysis_vCurrent.pc

Appendix B: Fundamental Module

HonorsProject-Economic fundamentals_

Appendix C: Excel Workbook

Practice_Sensitivity Analysis_vCurrent.xl

Appendix D: Quiz Questions and Answers

1. *An engineer is forecasting a four-year project's future cash flows to the firm to be $450 million, $475 million, $515 million and $550 million. If management requires an IRR of 35%, what is the project's NPV?*

   NPV=0 by definition as IRR is the internal rate of return needed to have a NPV of 0.

2. *Your brother has offered to give you either $5000 today or $10,000 in 10 years. If the interest rate is 7% per year, which option is preferable? By how much?*

   So the **10,000 in 10 years is preferred** because it is worth more **($83.49)**.

   $$\text{PV} = \frac{10,000}{1.07^{10}} = 5,083.49$$

   Alternatively:

   $$FV = 5000 * (1.07)^{10} \approx \$9836$$

So the 10,000 in 10 years is still preferable because $5,000 is less valuable in that time period. **$164**

3. *A company purchases a new piece of equipment for $500,000. It expects it will have a useful life of 5 years. At the end of its useful life, the company will sell it for $25,000. How much will the company be able to expense each year if uses straight-line depreciation?*

$$\frac{500-25}{5} = \$95{,}000 \text{ per year (Assuming straight-line depreciation)}$$

4. *Assuming the depreciation expense is $95,000 per year, using a tax rate is 40% and knowing that the gross margin in year four is $600,000, what is the company's free cash in year four?*

GM (Rev-COM) is 600,000. Since no other operating expenses are given, the FCF in year 4 is: 600,000-95,000 = 505,000 * (1-0.4) = 303,000 (EBIAT) + 95,000 = $**398,000**

Remember that depreciation is a non-cash expenditure, so it must be added back after it reduces the company's tax burden.

Appendix E: Sample Term Cheat Sheet

1. **Common abbreviations in economic analysis**
   - Interest (discount rate when discussing alternative projects): i, r
   - Number of periods: n
   - Present value: PV
   - Future value: FV
   - Net Present Value: NPV
   - Discount factor/weight: d
   - Earnings before interest and tax: EBIT
   - Earnings before interest, tax and depreciation/amortization: EBITDA
   - Cost of goods sold: COGS
   - Selling, general and administrative expenses: SGA

2. Common terms and alternative names

- Total income: total revenue, net sales, sales revenue = selling price * quantity sold
- Total product cost: cost of manufacturing, total manufacturing expense
- Net profit: Gross income * (1-t); net income, net earnings, bottom line
- Operating income: Gross margin - SGA
    - EBIT
- Gross profit: net sales – COGS
    - Gross margin
    - Gross income
- Net income: revenues-COGS-depreciation/amortization-SGA-interest-taxes-other expenses
- Top line growth: growth in sales
- Bottom line growth: growth in net income

Appendix F: End-of-Module Survey

1. Was the information presented in the module clear?

    a. Very clear
    b. Somewhat clear
    c. Clear
    d. Somewhat confusing
    e. Very confusing
    f. Other (please specify)
2. Which parts are still confusing after going through the module?

3. Was PowerPoint a useful medium to present the information?

    a. Yes
    b. No
    c. For some topics
4. Is there another presentation method that would be more helpful?

    a. Audio
    b. Lecture Capture
    c. Quizzes
    d. Other (please specify)
5. Were there any topics that you wished were covered?