Is It Time For A New Paradigm?

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Abstract

This paper asks the question: should we drastically change the way we teach undergraduate engineering economic? With the widespread availability of spreadsheet software should we rethink the presentation of the material and concentrate on the creation of the cash flow and less on the mechanics of converting the cash flow into a decision variable? The pro's and con's of each option are discussed. This paper is intended to provoke a dialog not recommend a course of action.

Background

Engineering Economics traces its beginnings back to Arthur M. Wellington and his 1887 work, *The Economic Theory of Railroad Location*. In the intervening 108 years the discipline has grown into a well accepted body of knowledge to which incremental improvements are being constantly added.

In 1887, the slide rule was the still the standard computational support tool (as it had been since late in the 17th century. In the intervening years the electronic calculator and the computer have displaced the slide rule (although undergraduate engineering students in the late 1960s were still using the slide rule as the standard computational support tool). In 2005 the student is armed with at least a powerful calculator capable of storing equations and solving a wide variety of involved equations. It is not uncommon for students to quickly program their high-end engineering calculators to provide the table values in lieu of looking up the values and to write simple equations to solve for IRR and other standard application types. Additionally, the student is now (or we argue soon will be universally) equipped with a personal laptop computer with a standard business package to include spreadsheet software (typically Excel® or Quattro-Pro®).

Based on the slide rule (and continued when the first calculators appeared – four functions, add, subtract, multiply, divide), the use of tables for the various common functions used in engineering economic calculations (F/P, P/F, P/A, A/P, P/G, A/G) rapidly became the norm. This use of tables allowed the values to be calculated once (and hopefully insured that the correct value was found through a rather tedious and laborious manual calculation until the computer was available).

Thus, over time, a standard method of expressing the theory and applying it was developed. This standard was also applied to the teaching of the topic as engineering economy became a standard course in engineering curriculums as represented by the inclusion of the topic in the Fundamentals of Engineering Examination.

A review of the current/recent text books we considered typical of those used in undergraduate (and graduate) engineering economy course show the use of the tables mentioned above as the method used to introduce the student to the topic and as the method used to present the application of the theory to practice for the students. These texts do include the use of spreadsheets as another method for solving problems but typically after presenting the table based method. The text books used in this review were:

- *Engineering Economic Analysis, Ninth Edition*, by Donald G. Nenan, Ted Eschenbach, and Jerome Lavelle, 2004[2]
- *Engineering Economy, Sixth Edition*, Leland Blank and Anthony Tarquin, 2005[3]
- *Contemporary Engineering Economics, Third Edition*, Chan S. Park, 2002[4]
- *Engineering Economy, Applying Theory to Practice, Second Edition*, Ted G. Eschenbach, 2003[5]
- *Engineering Economy, Twelfth Edition*, William G. Sullivan, Elin M. Wicks, and James T. Luxhoj, 2003[6]
- *Capital Investment Analysis For Engineering And Management, Third Edition*, John R. Canada, William G. Sullivan, John H. White, and Dennis Kulonda, 2005[7]

There was one exception found to the use of tables - *Modern Engineering Economy* by the late Donovan Young. This text[1] from 1993 uses nomograms in lieu of the tables.

The *Fundamentals of Engineering (FE) Supplied-Reference Handbook, 6th Edition*[8] by the National Council of Examiners for Engineering and Surveying uses the table method also.

The table method can be seen to be the dominate method engineering students are taught and by inference are expected to be able to use.

Is this a new observation? No. Eschenbach[9] reported the same findings in 2002 at the ASEE Annual Conference and forecasted even more use of spreadsheets and computer-based enhancements in the future (2020). Since then many[10, 11, 12, 13, 14] have reported on increased use and new uses of computer-based enhancements (especially spreadsheets) to engineering economics courses. While each of these enhancements are welcome and move the classroom closer to the practice of engineering economics, they are incremental improvements. Is it time for a disruptive change in the underlying paradigm? To this end we need to ask some basic questions of ourselves?

Question 1
What is the goal of the engineering economy course? At the undergraduate level, we would argue that the primary goal is to prepare the student to apply engineering economy effectively in the "field." To effectively apply engineering economy there is a need to understand the theory and have the ability to apply the theory correctly to solve open-ended problems in which the

engineer must both select the correct tool (NPW, Replacement Analysis, etc) to analyze the cash flow and find the appropriate numbers to put in the cash flow (as well as define the appropriate horizon). A secondary objective would be to prepare the student for graduate school.

At the master's level for a student in a typical Engineering Management program, the goal may be the same as for an undergraduate course but with more coverage of advanced topics such as capital budgeting. At the master's level in an Industrial Engineering program, the goal may be more theory driven and concentrated.

For simplicity let us concentrate on undergraduate and terminal master's degrees. The conclusion can then be drawn that the practice of engineering economy is the emphasis of the course.

Question 2

How is engineering economy practiced? Let us here limit the discussion to the level equivalent to a plant in a manufacturing environment. The theory presented in the undergraduate engineering economy course is very appropriate to this level based on feedback from students and recent graduates. For the vast majority of the students in terminal master's degree programs, this theory (especially if it includes capital budgeting and valuation topics) is also very appropriate. Having verified that the theory is appropriate, the question becomes one of is it presented in a way compatible to it use in practice? Based on 20 years of practice, this is problematic. The practice of engineering seems to out pace the teaching in the application side. In the early 1980's practicitioners were writing programs in Basic on PDP-11s and AIM 65s to find the IRR of projects – not using the trial and error approaches taught. The advent of PCs with spreadsheet software made this even easier. The development of built-in financial functions in the spreadsheet software makes the use of tables in the practice of engineering obsolete.

From an after the classroom standpoint, the only time tables are relevant to today's engineer is during the FE Exam. Since engineering economy is such a small part of this exam and since this exam should also be evolving to meet the practice of engineering, this seems little reason to cling to the use of tables in the classroom.

Question 3

Is the use of the table method the best way to teach engineering economy to future practitioners? It is an effective way – who can argue against success. Another argument is "If it ain't broke don't fix it" - this is only useful as an argument in a limited sense at best and even then when there are competing priorities and limited resources, which hardly applies in this case. Another argument is that the spreadsheets are easy to learn and use so let the student learn their use as an additional skill – this seems to beg the issue of the best method to teach the material.

A Discussion

The students, in general, see the use of spreadsheets as compatible with their personal goals – develop tools which will help them in their current and future positions. Many good texts are available to the teacher of undergraduate and terminal degree master's course in engineering economics. Having used several of the texts listed (or earlier editions) in the last ten years, they are excellent. During the last two offering of a graduate engineering management course in "engineering economics", the course was taught using a text with extensive spreadsheet supplements and even end of chapter problems suggested for spreadsheet solutions. Since both courses were taught using distance teaching – in one case two way audio / one way video and in the second case two way video and audio – the decision was made to emphasize the "spreadsheet" approach in the presentation of theory and application.

This approach yielded some interesting results:

- The spreadsheet approach seems very compatible to the teaching of the subject.
- The spreadsheet approach seems very compatible with the students' learning style.
- The vast majority of the students uses spreadsheets on a regular basis – see it as the standard computational support and *a common communication* tool – and are excited to find more uses for the tool.
- The students, in general, see the use of spreadsheets as compatible with their personal goals – develop tools which will help them in their current and future positions.
- The students who are not familiar with spreadsheets, those who do depend on the text as their "learning" tool, those not doing the homework, and those who had trouble with the concepts in general used table methods to attempt to solve the problems come test time.
- A text based on the use of spreadsheets as the primary theory presentation and application tool was needed.
- An additional set of functions are needed to efficiently do engineering economy applications using spreadsheets.

Pro's

There are several positive aspects to the spreadsheet approach, many of which are in the prior paragraph.

Another possibility with the spreadsheet approach includes starting with a clean slate. The traditional teaching paradigm is being replaced with a student-centric, technology-driven approach taking full advantage of the capabilities of the computer – not using the computer solely as a replacement for the slide rule. Students today a fully computer literate and see it differently than those who embraced the computer to make our lives easier by mapping our existing processes onto its capabilities. We would argue that it is time to look at the discipline in an attempt to make revolutionary changes in lieu of evolutionary and incremental changes. This has implications for both teaching and the way we present our research.

When changing to the spreadsheet paradigm, the emphasis seems to naturally shift from the calculation to the generation of the cash flow – arguably where the practicing engineer adds value to the process – elements (the costs, the benefits, and the horizon). Additionally, the annual cash flow no longer needs to take on (unrealistically) rigid patterns to accommodate our ability to process them. Cash flows can be flat, irregular, and geometric gradients (in lieu of generally unrealistic arithmetic gradients) and can be made of the many elements found in a typical "real" project. The problem becomes more of choosing the appropriate model and less of number manipulation.

An added benefit to this approach could include either a shorter course, in programs desperately seeking ways to include new knowledge areas, or inclusion of more material which students need but which is being squeezed out of programs. Examples of related material are cost accounting fundamentals, cost estimation, financial understanding, and multi-goal satisfaction.

Con's

The primary concern with changing paradigms is that the current one works. It gives the student an in-depth understanding of the under-pining of the equations and calculations performed. The working of the models is well understood by the student as this is the emphasis of the problems. The collection of the data to be used in the cash flow can/should be covered in more detail somewhere else. In engineering programs, we do not want students to only know how to fill in the blanks and have the calculations be result of a "black box conversion". It is extremely important that engineers have a "feel" for the result that the model outputs and are able to apply a "sanity check" to this output which does not happen with "black box calculations". Any change in teaching must insure that this "feel" for the models output be retained.

The current body of literature is compatible with our text books. Students who are going on to do research in the discipline will need to be fluent in both representations. Doctoral students in the discipline will not be ready to do research based on prior course work alone.

It will take time for the research to reflect the teaching. Those currently researching and writing in the field will need time to change. Those writing in the new paradigm will need to know where their work will be considered for publication.

If the proposed paradigm was to gain wide spread acceptance, teaching methods will need to be re-tooled. This can take time. Those of us who have been teaching under the current paradigm are comfortable with it and change will move us outside this comfort zone. This is a major consideration. In many technologies, this requires a generation.

Education is changing and only so much change can be accommodated at one time. This change must be prioritized. Examples of the changes currently being experienced include distance learning (web-base, asynchronous, traditional), more computer-supported learning technologies (labs, homework problems, self-paced learning), and increased active learning (versus the traditional lecture). Active learning is a must. Distance learning seems inevitable. Computer-supported learning technologies offer large gains in productivity. Is it too much to try and change the material presented at the same time everything else is changing?

Possible Solutions

A possible approach to this opportunity is submittal of a proposal to NSF to fund development of course material which could be used as a course text supplemented with a more traditional text. We are planning to submit such a proposal to NSF and will be actively seeking others to be involved.

A second approach is for one of the text book authors to fill the void with a text targeted to those courses where the discussed method is appropriate. While we do not plan to take this approach, we would be very interested in providing input and reviewing/testing such a book.

Conclusion

Opportunities abound for change. Some of the opportunities are basic to the teaching of engineering. Others are discipline specific. Which ones do we embrace as a discipline? We would like to propose an in-depth look at the presentation of the discipline to the future practitioner in which we take a practitioner-centric view, take advantage of technology and the students' comfort with it, and add-in those active learning elements which are most effect. We see this as an ambitious proposal but see it as critical to the health of teaching the discipline so that its benefits are realized and applied.

Bibliographic Information

1. Young, Donovan, *Modern Engineering Economy*, John Wiley and Sons, 1993
2. Nenan, Donald G., Ted Eschenbach, and Jerome Lavelle, *Engineering Economic Analysis, Ninth Edition*, Oxford University Press, 2004
3. Blank, Leland, and Anthony Tarquin, *Engineering Economy, Sixth Edition*, McGraw Hill Higher Education, 2005
4. Park, Chan S., *Contemporary Engineering Economics*, Third Edition, Prentice-Hall Inc., 2002
5. Eschenbach, Ted G., *Engineering Economy, Applying Theory to Practice, Second Edition*, Oxford University Press, 2003
6. Sullivan, William G., Elin M. Wicks, and James T. Luxhoj, *Engineering Economy, Twelfth Edition*, Prentice Hall (Pearson Education Inc.), 2003
7. Canada, John R., William G. Sullivan, John H. White, and Dennis Kulonda, *Capital Investment Analysis For Engineering And Management, Third Edition*, Pearson / Prentice Hall, 2005
8. National Council of Examiners for Engineering and Surveying, *Fundamentals of Engineering (FE) Supplied-Reference Handbook, 6th Edition,* National Council of Examiners for Engineering and Surveying, 2003)
9. Eschenbach, Ted G., "The Engineering Economy Course of 2020", ASEE Annual Conference and Proceedings, 2002, Session 1639
10. Ristroph, John H., "Distance Tutoring in Engineering Economics: Equivalence Modeling", ASEE 2003 Annual Conference Proceedings, 2003, Session 1639
11. Merino, Donald N, and Kate D. Abel "Teaching Basic Accounting to Engineering Economy Students: Are Computer Tutorials More Effective than Traditional Classroom Lectures, ASEE 2002 Annual Conference Proceedings, 2002, Session 1639
12. Grasman, Scott E., "Teaching Engineering Economic Via Distance Education", ASEE 2002 Annual Conference Proceedings, 2002, Session 1639
13. Dahm, Kevin, "Interactive Simulation for Teaching Engineering Economics" ASEE 2002 Annual Conference Proceedings, 2002, Session 1339
14. Dahm, Kevin, Ravi P. Ramanchandran, Sean Broderick and Chris Panchesine, "Teaching Engineering Economics Using a Web-Based Interactive Simulation" ASEE 2002 Annual Conference Proceedings, 2003, Session 1526

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