AC 2011-1574: TIME TO TRANSITION: FINANCIAL CALCULATORS AND CLICKERS IN THE CLASSROOM

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Time to Transition: Financial Calculators
and Clickers in the Classroom

Abstract

The compound interest tables are a primary teaching tool in the engineering economics classroom. These tables were created nearly a century ago as a time saving device for hand and slide rule calculations. Pocket scientific calculators, which replaced slide rules in the 1970s, are common in the engineering economy classroom. Pocket financial calculators which were also introduced in the 1970s are not. It is still common practice to teach with compound interest tables and scientific calculators in engineering economy classes just as we did over 30 years ago.

Similarly, within the last several decades we've added PowerPoint and on-line study aids, yet many of us have left the lecture relatively unchanged. The display may have shifted from blackboards to overhead transparencies to computer projectors; but the lecture structure is often largely unchanged. The last decade has seen the deployment of low cost student response units, and when used these "clickers" can radically change what happens in a lecture period.

This paper explores the advantages and disadvantages of using financial calculators and clickers in the classroom, along with some of the debate that has appeared in our literature over the past few years. The reasons for current views are explored, and several options that have been tested in the classroom are described. Personal experiences in teaching with these tools are shared. We recommend that it is time for all of us to begin the transition away from reliance on tables, and use the modern tools that new engineers are expected to have already mastered by graduation.

Background

Interest Factors & Calculators

The tables of interest factors used in teaching engineering economy were developed by John Fish for his seminal textbook[1]. For nearly 60 years, the tables plus slide rules or mechanical calculators were used. Then in 1972 the first hand-held scientific calculator, the HP 35, was introduced, which was followed a year later by the HP 80. The HP 12c[2], still sold today, was introduced in 1981. Most companies that sell calculators sell one or more models of financial calculators and programmable calculators that can solve for one of five unknowns: i, n, PV, PMT, and FV. These are referred to as time value of money (TVM) calculators.

The use of financial calculators have been described in detail in many of the leading introductory finance texts by Brigham and Ehrhardt[3]; Ross, Westerfield, and Jordan[4]; Brigham and Houston[5]; Besley and Brigham[6] and have been for over 10 years. Introductory finance texts use a mix of calculators, formulas, and brief tables to teach finance students time value of money. The use of spreadsheets may also be included[5,6], though they seem to be rarely taught as a primary tool. The Ross, Westerfield, and Jaffe text[7] focuses on using spreadsheets. Engineering economics texts until recently have not included references for financial calculators. The recent textbooks by Eschenbach[8] and Newnan et al[9] contain instructions of how to use them. The recent edition of Blank and Tarquin[10] includes an appendix that introduces financial calculators and sums of geometric series as alternate approaches.

The engineering economy literature has largely ignored the use of financial calculators, preferring to focus attention on factor tables and spreadsheets. The principal reasons that instructors avoid using TVM calculators are the mistaken belief that the Fundamentals of Engineering (FE) exam does not allow their use and the typical resistance to changes in pedagogy. There are recent examples in the engineering economics literature where instructors promote the use of TVM calculators[11,12,13].

The use of calculators in the FE exam is strictly controlled by the National Council of Examiners for Engineering and Surveying (NCEES). The 2011 NCEES calculator policy[14] limits the types of calculators to five types:
1. Casio FX-115 (the FX-115 MS, MS Plus, MS SR, and ES are permitted)
2. Hewlett Packard HP 33s
3. Hewlett Packard HP 35s
4. Texas Instruments TI-30 (models TI-30Xa, TI-30Xa Solar, TI-30Xa SE, TI-30XS Multiview, TI-30X IIB, and TI-30X IIS are permitted)
5. TI-36 (models TI-36X II and TI-36X Solar are permitted)

These are the only models that are acceptable for use in the exam. However, the HP 33s and the HP 35s are programmable calculators, and can be programmed to function as a TVM calculator. Thus NCEES does not specifically prohibit TVM calculators, but it does limit them to 40% of the approved models.

Student Response Systems
Research into student response systems, sometimes called student response units, classroom response systems, classroom performance systems, audience response systems, personal response systems, or simply "clickers", began in the late 1960s[15], with articles published in the early 1970s[16, 17]. Early work was focused on improving student learning in large classes in science and mathematics. Initial conclusions were that the technology showed promise in improving student engagement in class.

Over the years, use of student response systems slowly increased, and the systems were tried in a variety of courses[18, 19, 20, 21, 22]. During this time, the technology itself improved. The earliest units were hard-wired, and then infrared (IR) transmitters were used to communicate with one or more base units. These required students to 'point and shoot', similar to operating a TV remote control. If the lecture hall was large, multiple receivers were needed to compensate for the distance to the students. The signal was not always received on the first try, and the units were a bit slow. In general, the IR units were viewed as somewhat difficult to use. More recent units use radio frequency (RF) transmitters that do not require 'point and shoot'. The RF clickers are more reliable, faster, and generally easier to use. The prices of the RF units are similar to the IR units.

There are a variety of brands available, including Turning Technologies, i>Clicker, interwritelearning (PRS), and eInstruction. Most brands require that the instructor use the firm's unique presentation software, which operates in slideshow mode as a Microsoft PowerPoint add-on. The i>Clicker units work as an independent window on the desktop, and so there aren't any

software compatibility issues. Some clickers have a set of letters for students to select from among multiple choice question responses. Some higher cost units also allow for numeric or text input. It appears that all brands have the capacity to be registered to students as unique individuals and also to connect with course management software such as Blackboard.

In recent years, there has been significant reporting of the use of clickers in engineering courses[23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33]. Various studies have examined the benefits of clickers in courses along the academic spectrum[34]. The use of clickers has only recently been included in the engineering economics literature[35, 36]. The findings in engineering economics largely parallel those in other disciplines, namely, that clickers can be a useful aid. However, they do require effort by the lecturer to use them effectively.

Advantages and Disadvantages of TVM Calculators

There are reasons for continuing to employ the interest factor tables in the classroom. Students may find it easier to grasp the concepts behind the economic analysis if they see how cash flow diagrams are broken down into patterns of individual and serial cash flows. Explaining how the individual interest factors are used to determine the values of the cash flows at a common time point can aid students in learning engineering economy.

Once students have a basis for understanding the calculations of net present worth, financial calculators can be of great assistance. Alternatively, an expanded factor notation that is similar to standard spreadsheet annuity functions can be used to introduce TVM calculators from the very beginning of an engineering economy course.

TVM calculators have time-saving advantages. They permit students to rapidly and more easily analyze problems. Fractional interest rates that are not in the tables can be used in analysis which permits more realistic problems to be examined. There is a high potential for errors in looking through a table and keying the numbers into intermediate calculations. An analysis[36] by one of the authors found that 30% of exam errors are related to looking up an interest factor and writing down the wrong entry or transposing digits. Time saved through easier calculations and direct rather than iterative solutions for n and i can be reinvested in solving more complicated problems. This is particularly helpful in testing students where time is limited. Engineering economy is more than a class in financial arithmetic – students need to practice a range of techniques and demonstrate their grasp of the underlying concepts. Time spent looking up the proper set of factors and checking to make sure that numbers were accurately transcribed is not value added. Reducing the potential for transcription and calculation errors allows students a greater opportunity to be judged on how well they demonstrate mastery of the subject matter rather than their brute force mathematics calculation. The results obtained with financial calculators are also more accurate since they don't have the rounding effects of the interest factor tables.

There are some disadvantages to relying on financial calculators starting with the extra expense for engineering students who have most likely already invested in a scientific calculator. Engineering students may be reluctant to buy another calculator that will have limited applicability in other courses. Students may resent being required to purchase a TVM calculator

or spend the time programming in financial functions. Instructors may have to require the use of financial calculators to ensure that all the students are capable of fully keeping up the pace of solving problems particularly for in-class clicker examples. In universities and departments where the FE exam is taken by most or all students, the HP 33s and 35s extend the time savings and reduced error rate to make the class requirement direct preparation for improved exam performance.

Fortunately, financial calculators tend to be less expensive than scientific calculators. Basic models can be purchased for less than $30. Used calculators that could be resold later would further reduce the cost burden. Students with programmable scientific calculators can also program in the cash flow equation to solve for any of the 5 variables. Some of the more advanced scientific calculators include financial functions. For example, the TI-83 Plus has menus for financial functions including TVM, cash flows, and amortization analysis.

Advantages and Disadvantages of Clickers

Clickers have advantages for both lecturers and students. A lecturer can gain immediate feedback at key points in the lecture to assess how well students understand the concepts being presented. Rather than just a few confident students responding, the anonymity encourages increased participation by quieter, less confident students. The entire class can be polled quickly so the lecturer knows whether to review the material again or continue on. Students can participate easily without risk of being embarrassed in front of their peers by a wrong answer. This is particularly true for students that may be less willing to speak publicly because English is a second language. The anonymity of responses also encourages more candid answers to questions involving ethical quandaries. Regularly polling the class about problems encourages students to remain engaged. If students see that a significant portion of the class reached the same wrong conclusion about a particular question it may reassure them that they are not alone in having some difficulty. The explanation of why each answer is correct or incorrect may be sufficient, or if many students answered incorrectly, the instructor can pose another example to be answered.

Software for the clickers can allow them to be used in a way that identifies the student responses to the instructor and connects with course management software to log the results. This capability means clickers can be used to take attendance, administer quizzes, award class participation points, and monitor how individual students are performing even in classes with large enrollments. This in turn promotes better student participation and reduces the effort required by the instructor. This can lead to more improved student performance than with traditional instruction methods. Some studies have shown that clicker utilization is associated with better instructor reviews and that large freshman orientation classes' student retention improves.

Surveying two classes with undergraduate and graduate students found that over 80% of both sets of students found the clickers beneficial[36]. Undergraduate students reported the biggest advantage of using the clickers was in learning from mistakes (40.4%), helping them to stay focused on the class (29.8%), and previewing calculations for homework (29.8%). The graduate students' responses regarding the biggest advantage of clickers was primarily split between

aiding them in learning from mistakes (64.7%) and helping them to stay focused on the class (11.8%).

As with financial calculators, the additional cost of clickers is a disadvantage. The cost for new clickers ranges from $35 to $60 per unit depending on the level of functionality. The price is often halved for used clickers. The less expensive clickers are limited to entering a choice of five letter options (A – E) rather than numerical results or textual responses. Students may be reluctant to purchase the devices for use in only one class. Students can also be intimidated by the clickers when confronting a question they don't have a quick response for. A disadvantage for lecturers is the need to develop a higher level of technical sophistication to properly integrate and utilize clickers in the classroom. Lecturers need to judge how many times to utilize the clickers in a single lecture. Polling the class 3 – 15 times is usually feasible, but clickers can be over utilized which slows material coverage. As with all technological aids, errors in use and random failures can occur causing disruption to the lecture.

Lessons Learned from the Front Lines

Two of the authors have experience teaching with these tools ranging from a first time user to 23 classes over more than 20 years. This provides a basis to share some personal experiences with these tools. The findings largely support those reported in the literature.

TVM Calculators
Utilizing TVM calculators requires the same theoretical understanding as using tables, but students can solve problems much faster. In general, students learn to use the TVM calculators quickly, and enjoy using them. The students tend to make far fewer errors when using financial calculators. In one case, a student that repeatedly made errors when looking up interest factors from the tables abruptly stopped making errors when he began using a TVM calculator. This tool allows instructors to spend more time focused on teaching engineering economics, and less time dealing with financial arithmetic.

Clickers
Clickers dramatically change the classroom dynamics. Students and their instructors receive immediate feedback on whether the students understand the current material. Students spend more time responding to questions and less time passively listening or focusing on matters other than the class. In large classes it is impractical to rely on an instructor's skill at studying students' nonverbal signals to judge whether a concept has been effectively conveyed. Asking the students if they understand a particular concept and are ready to proceed is often of little use since few students will publicly admit to being confused and quite often students don't realize they don't accurately understand material until they have trouble solving a problem. The cost is that the speed of the class slows down to the pace of the slowest student that an instructor is willing to wait for.

Clickers increase student attention in class. Students have admitted that they cannot mentally drift off because they never know when a clicker question might come up. With greater attention and commitment to providing an answer (right or wrong) students are more involved in the class, which creates a form of dialogue.

This occurs in small classes as well and can even be seen when "loaner clickers" are used for a one-week trial. With only enough loaner clickers for a fraction of the students, the format is normally to discuss the problem with a small group and then click to provide the group's answer. International students are often reluctant to speak up in class due to lack of confidence about their command of English or speaking with an accent. This is often accentuated by not wanting to lose face with an incorrect answer. However, once the reticent international students had received reinforcement that others shared their reasoning, they were much more willing to participate in discussions following the clicker questions.

Another approach is to have students answer individually, but if a majority of the class is incorrect call for the students to discuss the problem with a neighbor and then respond to the question again. Students are naturally more engaged in the material when they are discussing it and have incentive to thoughtfully consider a question. This practice aids understanding regardless of whether students correctly answer the question or not. Students are much more willing to vote with clickers since it spares them from publicly offering an answer and because the display of answers is a group summary.

Problem solving in class with clickers can work well, but it can take a lot of time. If students are using factor tables, problems can require extensive time to solve. Combining clickers with TVM calculators speeds up problem solving, and makes the time requirement far more manageable. Without financial calculators, available time limits the types of problems that students can solve in class to those that are very simple. The types of problems do not need to be as limited if students have TVM calculators. The two technologies complement each other well and combine to enhance the learning environment.

Clickers appear to increase learning. For example, in one discussion regarding the Payback Period, all the students in the class indicated that they understood it. A clicker problem was then presented, and half of the students got it wrong. This gave feedback to the students about whether they understood the concept or not, and demonstrated that half of them did not completely understand it. After additional discussion, the difficulties were resolved. Without clickers, neither the students nor the instructor would have realized the lack of understanding until the next test.

Clickers do slow the pace of the class. Dialogue takes longer than monologue. Less material can be covered in the same amount of time, but the level of learning is much greater. The top students may not be exposed to quite as many items, but average (and probably top) students master more material. Overall, student learning is greatly enhanced, and the grades earned tend to be higher. When surveyed, students recommended the use of clickers in spite of the added cost.

The instructor must find a 'happy medium' on how often clicker questions are used. There can be too many or too few questions. A typical lecture style can be supplemented by one question about every fifteen minutes which one author finds to be about right. Another author has shifted to clicker based lectures which may consist of 15 clicker questions and 5 to 15 figures, tables, and bullet point summaries.

Students have indicated that they do not want clickers to be used as continuous quizzes for the right answer, nor do the authors think that would be useful. Software can be used to track whether students get the questions right, and it is possible to make participation points depend on achieving some percentage of correct answers. However, the most experienced of us has only done a handful of clicker quizzes in over 20 courses and has never tried to track the percentage correct. Another option would be to record the percentage of clicker questions on which a student voted as the class participation metric. This would allow even very shy students to have a way to participate, and the grading of class participation would be based on a more straight-forward quantitative measurement.

Using clickers in an informal way can generate interest and genuine excitement when students get the answer right. Clickers facilitate learning, as well as generating more genuine interest in class. This can make the educational experience more enjoyable for both students and instructors.

Conclusions

Separately or in conjunction, financial calculators and clickers can be particularly beneficial in teaching engineering economy. Financial calculators provide an analytical tool that is more similar to spreadsheet models than the use of scientific calculators, and yet is more controllable in a testing environment than using computers. They allow students to more rapidly and easily analyze complicated problems while reducing the potential for errors. Using financial calculators allows students to focus on analyzing the problem rather than completing tedious calculations.

Clickers encourage students to be more engaged in class and allow instructors to efficiently obtain feedback from the class at regular intervals. Rather than relying on experience and intuition to judge how well students are grasping the concepts, instructors can quickly determine if a sufficient majority of the class is ready to proceed or whether another example problem is needed. This is a powerful tool for engineering economy where complex concepts can stymie students that normally excel in quantitative analysis.

Using the two technologies together is particularly powerful in the introductory engineering economy classroom. The use of TVM calculators allows students to quickly solve more realistic practical problems. This allows more effective use of clickers to gauge the students' conceptual understanding of how to find the value of cash flows.

These technologies cannot be implemented without additional costs to the student and/or the university (some departments have carts with clickers and/or TVM calculators). The majority of students are unlikely to voluntarily purchase these tools unless they are required for a class. If they are required for class, then it is the responsibility of the lecturer to make proper use of them to ensure the students have the best opportunity to benefit from their purchase (and to avoid justifiably scathing student critiques when technology is required to be purchased and then not used).

In summary, to ensure instructors are providing students with the skills and knowledge they need for practical application in their careers it's time to stop focusing on interest tables. The tools that are actually used in the real business world are financial calculators and spreadsheets. If we are not teaching our students how to use these tools, then we are not adequately preparing them for jobs in today's employment market.

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