# Introducing Engineering – a Seventeen Year Perspective

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Abstract

Wilkes University, in North-East Pennsylvania USA, offers bachelor degrees in Electrical, Mechanical, and Environmental engineering as well as Engineering Management and Applied and Engineering Sciences. For about three decades, our *Introducing Engineering* course has been required of all freshman-engineering majors. This report outlines a period – the last seventeen years – in which one of the authors has had almost continuous experience with this introductory, one-semester course. We also detail certain circumstances leading up to the latest incarnations of this course in the Fall of 2001 and the Fall of 2002.

The course evolved significantly during this time. Yet much of the material, many of the course goals, and perhaps the central theme of the course – problem solving – has remained relatively constant. What has not remained constant is the way the course was delivered. The volume of course material is quite large and varied, so much so that we cannot treat most topics in depth. In spite of this we believe that we have developed a strategy to keep the material both challenging and interesting, and yet not overwhelming to the average student. The course is described from two points of view. One is the course material and student learning, and the other is the influence of involved faculty and their reactions. It is shown how faculty interests as well as outside influences have affected the nature and success of this course.

Introduction and Background

We believe that there are two important metaphors in engineering (and so in engineering education). One is the value of mental discipline to climb over steep parts of the learning curve. The other is the use of the proper tool for the job at hand. These metaphors underlie our pedagogical philosophy that we attempt to justify in this paper. We will call it Theme A. It is, simply stated, a scheme of exposing students to a very large number of ideas, and many challenging topics, in a relatively short time. The topics are mostly of our own choosing and have evolved over time. Each student will inevitably have his or her unique profile in being attracted (or repelled) by the various topics. Students, in effect, will embrace certain ideas and reject others. We recognize and *allow* this – at least to a limited extent. By looking at Theme A and the history of this course, Theme B emerged as the observation that faculty often select course topics in much the same way that the students do in this course; that is, in accord with their own profile. This is why we believe that students can be challenged by being bombarded or peppered with numerous facts, relationships, problem-solving tools, ideas, etc. instead of the (opposite) approach of measured attention to a relatively few, carefully delimited topics.

Table 1. Characteristic Periods in the Evolution of *Introducing Engineering*, IE, Required of Freshman Engineering Majors (and Others) at Wilkes University

| Period (Year) | **A** (1980–85) | **B** (1986–93) | **C** (1994–98) | **D** (1999–2002) |
|---|---|---|---|---|
| Course Name | *Introduction to Engineering* | *Technological Survival* | *Technological Survival* | (*Various*)/ FRF Freshman Foundations |
| Number of Engineering Faculty | 1 | 1 - 4 | 3 - 4 | 1 - 2 |
| Number of Other Faculty | 0 | 0 - 1 | 1 - 3 | 0 |
| Number of Engineering Programs Requiring this Course | 2 - 4 | 5 - 6 | 6 | 4 - 5 |
| Number of Non-Engineering Programs Requiring this Course | 1 | 1 - 2 | 3 | 0 |

History

Wilkes has a small but growing engineering enrollment. During most of the years shown in Table 1, no more than about 50-60 students or two sections of *Introducing Engineering*, IE, were required *for engineering students*. After Period **A** (1980–85) however, the total number of students in the course, renamed *Technological Survival* began to grow. This was in part because more *non-engineering* majors were required to enroll in IE during this period. The number of non-engineering students then peaked in Period **C**, until, now in Period **D** (1999–2002) *no* non-engineering majors are required to take this course. Note also from Table 1 that the number of non-engineering faculty teaching IE followed a similar rise and fall.

Our experience with IE begins around 1985-86, and, taking all of the authors of this paper, extends uninterrupted to the present. The time interval that we label Period **A** in Table 1 is partly pre-history for us however. We have no direct knowledge of the beginning of this period but rely on recalled conversations with those directly involved and on written records. One of us passed this course to another of us at the Period **A** to Period **B** transition. At the same time, the department chair was encouraging innovation and inclusiveness. He even suggested a name change for the IE course to *Technological Survival*, which was adopted.

From the beginning of Period **B**, if not before, the course text was used sparingly – never was more than about 40% of the text material covered – at least in the form presented by the text's authors. We wished to use the allotted or "liberated" time to inject our own and current supplementary material into the course in order to convey the importance and the excitement of engineering. In recent years, the internet has been "mined" for information in order to accomplish this same goal.

The supplementary material, significant before the advent of the internet, now has become expanded many-fold. The early supplementary material was guided by a large number of sources. For problem solving an early inspiration was Polya's *How to Solve It*. [1] Also consulted was James R. Newman's *The World of Mathematics.* [2] For some of the early years, we actually required students to read several of the poems of Don Marquis's *Archy and Mehitabel*. [3] Now we freely use: <http://slashdot.org/> and <http://whatis.techtarget.com/> with a link to the excellent dictionary at <http://www.m-w.com/>. In recent years, our students have visited numerous engineering and government websites. We also encourage visiting non-USA websites.

Some of us have been influenced by Adams's *Conceptual Blockbusting* [4] as well as A. D. Moore's *Invention, Discovery, and Creativity*. [6] Appendix **A** is a facsimile of a handout that has been used, in one form or another, since September 1990, although it contains some course material that has been used earlier than this date. In recent years (Period **D** in Table 1), it has been used essentially as it appears here.

The key lesson in this Appendix **A** handout, which we cover over a period of several class meetings, is that thinking is not just "talking to yourself in your head." Thinking (and problem solving) is often greatly aided by the use of visualization as well as by the use of other non-verbal modes of reasoning. Thus, visualization is a problem-solving tool. Adams [4] also stresses this point. One important advantage of using the first three problems in this handout is that few, if any, students in a class of thirty will solve them all correctly. This, we hope, makes these examples good attention-getting devices! (At least two of them would seem to *require* visualization to arrive at the correct solution efficiently.) The next few examples on the handout are exercises that connect visualization with mathematical formulas. The final example, Figure 2, is from The Care and Feeding of Ideas. [5] We use it as an introduction to the subject of short-term memory (STM), to underline the importance of practice and drill in learning, and to introduce the topic of study and note-taking methods. Please note that, even by consulting the references cited in Appendix **A**, a full understanding of all the examples in it *as presented to our students* would require the extension of this paper to an excessive length. Alternatively you can find an elaboration of these examples at <http://course.wilkes.edu/ie/solutions>.

In spite of changes in course name, student base, and instructor base, the Wilkes IE course has maintained many common components throughout the past seventeen years. Technical problem solving methodology drawing upon concepts of functional relations including exponential growth and the time-value of money, simultaneous equations and matrices, vectors, complex numbers, dimensions and unit systems, scaling laws, number systems and codes, derivatives, and projected area have been emphasized virtually every year except 1998. In 1997, we tried using a PC version of a high-level mathematics program as an alternative tool to pencil, paper, and calculator but later decided that these computer skills were better suited for inclusion in a separate course such as our new *Computer Utilization in Engineering*. Graphical data present- ation and problem solving techniques have been a permanent component in the IE courses. By now, use of a spreadsheet with a graphing package has replaced graph paper. Examples of exponential growth include college tuition increases and Super Bowl ticket price changes. For scaling we used examples such as the volume of paint required to cover an area such as in painting (different size) cars and the related problem of the volume of glue applied to a given surface with a notched trowel. Other examples include airplane flight, and human and animal metabolism. The classic essay on scaling by Haldane has been used and can be found in The World of Mathematics.[2]

During Period **C** in the mid-nineties when pre-pharmacy students were actually the majority population in this course, it became clear that many, but not all, of these math topics had relevant applications to pharmacy. Engineers are concerned with how the mass of a body or strength of a structural member scales with dimensions while the pharmacist, in some cases, uses an empirical scale law based on a person's height and weight to determine a proper drug dose. Likewise, codes based on binary numbers and the four nucleic acids (A, G, U, & C) were the subject of assigned problems.

The use of peer instruction facilitated by the assigning of teams of 3 to 5 students for classroom problem solving has always been encouraged. This was usually followed up by group out-of-class assignments. Individual problem solving skills are assessed on homework and exams.

Some type of team-based design project has been a continuous requirement for all IE courses. Both the topic and the team composition (typically 4 to 5 members) are assigned. Topics are usually open ended, so the team must define its specific problem and consider possible solutions. Sometimes a project prototype is actually built, but usually the assignment only requires a proposal with a detailed plan to solve a particular problem. An oral progress report and a written final report with a specified format are required. The format typically requires an executive summary, problem description, plan of work, identification of key personnel, and a cost analysis.

Once, during Period **C** (1997), the assigned teams were deliberately formed with both pre-pharmacy and engineering students on the same team; and, because these majors were in different breakdown sessions, several of the plenary meetings had to be dedicated to team project meetings. These majors had different career goals but they were essentially all freshmen with similar academic preparation in math and science. This particular year, a proposal poster session was added and the presentations were evaluated both by faculty and students with awards made for the top-rated presentations.

Attention to technology and learning skills has always been part of IE at Wilkes. These include study skills, note taking, and time management. Programming in BASIC and use of a scientific calculator were part of IE in the early eighties. Today, calculators remain as an important tool. The use of a word processors and spreadsheets became a course requirement in the early nineties as computers became more available. Electronic communication, the internet, and web-page development had to be formally presented in the mid-nineties, but most of today's engineering freshmen are fluent in these technologies when they arrive at college. The Wilkes Library staff has always provided workshops for the IE courses. They are able to provide guidance in locating specific project-related information. Traditional bibliographic search methods using a card catalog for locating texts and hard copy of abstracts for searching published research have naturally been supplanted by computer searches for in-house texts and both search engine and fee-based database searches for other materials.

A final constant in this course has been the focus on careers in engineering and professional development. Curricular requirements and options in the different engineering programs have typically been explained in the discussion section in preparation for second semester registration. Early on, in Period **A** (1980–85), recent graduates and other invited speakers described their industrial experiences and opportunities for engineers in graduate school. Officers of the campus student engineering clubs and organizations had an open invitation to describe their mission and solicit freshman participation. During Period **B** (1986–93), presentations on Proposal Development and Project Management were added. As the course population grew, a plenary session was instituted to present common issues. For the first three years of Period **C** (1994–98), presentations were by invited speakers. In 1994 the presentations primarily focused on career opportunities in each of the disciplines represented by the course enrollment. However, presentations of more general interest such as Professional Responsibilities and Law, Proposal Development, and Project Management were also included. The more general interest presentations were found to be more appropriate for the mix of majors in this course and were given more emphasis in the following two years. Titles included: *Information & Data Management, Funding Personal and Business Projects, Effective Professional Writing, Entrepreneurship, World Wide Web, Pollution Prevention in Pennsylvania, Simulation, Communication Technology,* and *HazMat: An Engineer's Perspective in the Pharmaceutical Industry*.

Trends

To accommodate the perceived needs of the non-engineering majors, the subject matter and topics for this course expanded to a degree that extensive changes in course content were made during Period **C**, and in particular in 1998. During this period the number of faculty involved in the planning of this course grew to include representatives from Engineering, Math and Computer Science, Biology, Chemistry, Physics, Environmental Science, and Pharmacy. This was done as the course was repeatedly modified to accommodate additional non-engineering majors. In spite of faculty hard work there were competing priorities for the course emphasis and direction by this diverse group of faculty. During this period, each course instructor was constrained to follow the compromised course syllabus and to use substantially a common exam. This compromise seemingly kept the involved faculty from buying into the course completely, and eventually at the first opportunity the course was eliminated from the curriculum as part of a university-wide reorganization. This differs from the experience of period B when only engineering faculty were involved in organizing this course and they readily came to consensus on the course content.

Following elimination of the *Technological Survival* course, The Engineering Division then applied to the curriculum committee for a new course, *Introduction to Engineering*. This application was approved, and we found ourselves, essentially, back at the beginning (see Period **D** in Table 1.) The experienced reader may, perhaps, smile at this development. This circumstance thus has motivated us to describe it below as a want of sufficient self-selection.

But first, we continue with our trends. For the next two years one of us was in sole charge of *Introduction to Engineering*. He decided to reinstate many of the mathematical and engineering topics that had been pared away at the end of Period **C**. Now the course was required only of our engineering majors. Then, in 2001, another remarkable thing happened. The University required all freshman students to take an introductory course, called a Freshman Foundation Course (FRF). This meant that the Engineering Division once again had to apply for approval of a new course to replace *Introduction to Engineering*. Luckily, the guidelines for the new FRF courses were almost all being met by *Introduction to Engineering*, so, with a few minor changes, a "new" IE course, FRF 101 *Ideas into Reality* was born. Finally last year, with two of us teaching, we further modified and renamed the course FRF 101, *The Engineering Perspective*. Here the major change was an increased emphasis on the career component and the introduction of a hands-on component. At this time, most of the engineering programs at Wilkes began an optional, but strongly recommended Engineering Co-op opportunity slotted in the second semester of the Junior year. One of the Co-op academic requirements is a student presentation describing the Co-op experiences. Several of these Co-op presentations along with additional presentations by alumni were scheduled into last year's FRF version of an Introductory Engineering (FRF-IE) course, *The Engineering Perspective*.

At the same time, in order to tie in with classroom discussions of such topics as number systems and codes, we tried a new twist. This was a hands-on project to verify logic gate truth tables. Teams were supplied with requisite components in kit form. Because of the press of time and events this hands-on component had to be severely truncated however. The hands-on component will be rethought and will likely be incorporated into next fall's FRF-IE courses.

Operating under the FRF umbrella turns out to be quite easy. A special committee approves all

FRF course proposals and the guidelines include a relatively modest list of learning objectives and course outcomes. The actual subject matter is up to the individual instructors. The courses come from all disciplines. Recent course titles include: "Exploring the Arts," "Movies and History," and "Communicating Science." An FRF requirement is that students get to elect the particular FRF course that they wish to enroll in. In practice, because of self-selection by the students and pre-registration advisement, all but a handful of those freshmen with a declared engineering major become enrolled in an FRF IE course.

What of the trend to include more and more topics? Under the FRF umbrella we can have *some* non-engineering students in the IE courses. However these students are presumably all self-selected. We therefore feel that it is fair to include many "tough" engineering topics. Grading has to compensate for the difficult material. Credit is given for attendance as well as for doing many simple assignments.

Furthermore, the final grade is arrived at by means of a weighted average. The scheme is illustrated by the grading example below and has been used successfully for certain course components especially for in-class, closed-notes tests.

Suppose a student has the following grades (based on 100) for four components of the course:

E1= 22 E2= 95 E3= 100 E4= 85

$$am = \frac{22 + 95 + 100 + 81}{4} = \frac{298}{4} = 74.5$$

$$wm = \frac{4 \text{ x } 100 + 3 \text{ x } 95 + 2 \text{ x } 81 + 1 \text{ x } 22}{4 + 3 + 2 + 1} = \frac{869}{10} = 86.9$$

In the above example the student's arithmetic mean (am) is a 74.5%. Based on this alone, this student might receive a 2.0 or a 2.5 for the course (based on a 0 – 4.0 grading system). Using the weighted mean (wm) calculation to represent this student's performance and, in this case using the weights 4, 3, 2, 1, the student's "average" is 86.9, perhaps a 3.5! Note that in this "grade inflation" scheme the *greatest* weight is given to the *highest* grade. Which of these two averages better represents the student's performance?

Conclusions

*Introducing Engineering* finds itself in a cozy position because it fits in with University FRF guidelines that permit us to draft our own objectives and to cover virtually any material that we choose so long as it has academic merit. On the plus side, we can incorporate any and all topics that we like into the course. On the other hand, plenary sessions are not allowed according to the present FRF guidelines. This limits the interactions between faculty, outside speakers, and students in the course context. But more importantly, within our own FRF IE courses we are confident that Theme A can work: We happily bombard our students with our special "engineering" knowledge and expect them to acquire exposure to all of it but to achieve competence in only some subset of it. The great strength of this FRF system is that all faculty members from all disciplines offering the FRF course select the theme, the topics, as well as the method of delivery for their courses. Then, based on a short course description, the student selects one of the FRF courses from a list.

We now view the students in our FRF IE courses in relation to the faculty operating under the successful FRF system. That is, just as the faculty have the freedom to pick and choose some subset from the universe of knowledge around which to build their courses, so we allow our students some limited freedom in picking and choosing from the universe of material that we present to them. This is our Theme B and our central justification for the pedagogical method we have labeled Theme A. Each is based on self-selection.

The FRF system was designed both to aid retention and to deliver academic content. Each course is designed to achieve these ends by very different methods and by faculty who are volunteers. Here we have attempted to describe our methods and how they now fit into the FRF system. We know that our student satisfaction survey results are much improved since the *Technological Survival* days and that retention is quite good. But what are the drawbacks?

We can see at least two. Each FRF course runs independently. There is, therefore, more expense in terms of faculty loading than there would be if common classes were scheduled for lectures or for other activities. Because each FRF course runs independently, there is little or no collaboration across disciplines. We the faculty, just like our students, are mostly self-selected into our various disciplines and sub-disciplines. This is undoubtedly based not only on our individual talents, but also, inevitably, on our weaknesses. The Division of Engineering's ultimate inability to engage across disciplines outside of engineering in the case of *Technological Survival* seems to us just another example of our human predilection to build walls. Although we may regret the loss of cross-disciplinary cooperation, the present FRF system works very well.

In the end then, what would we now choose for the course metaphor? Perhaps this: a sumptuous banquet. A table is laden with foods from everywhere. The guests are asked to sample everything possible; then, take what is most wanted and leave the rest behind. Whatever one guest leaves behind may be desired by another. There is no arguing with taste.

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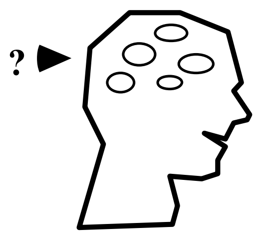
**Appendix A.**

**THINKING ABOUT THINKING**

Question: What is known about our problem solving and thinking processes? What can we discover by experimenting on ourselves?



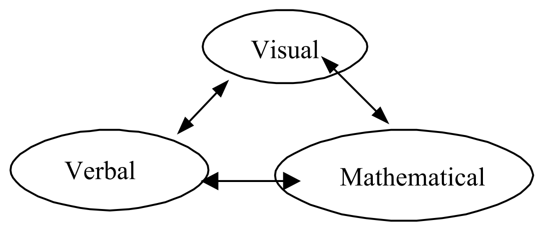




**Fig. 1a.** The Mind Is Compartmented - A Model of Mental Processes

**Fig. 1b.** Three (Independent) Ways of Thinking

**(a) The Dice Problem**

We know that if we throw an honest cubical die (with six faces), the likelihood of getting a particular number (say a five) is one in six, i.e., 1/6 = 0.1666..., or 162/3%. Question: If we throw two dice what is the likelihood of getting at least one five?

**(b) The Eskimo's Problem** [6]

**(c) The Monk Problem** [4]

**(d) The Euler Formula, V + F – E = 2**[2]

**(e) Pascal's Triangle**

**(f) Conscious and Unconscious Thought** [5]

Proceeding counterclockwise from the lower right in Fig. 2, we see that learning requires that we end up not knowing what we know! Can you offer an explanation for this peculiar "fact?"

| | Competent | Incompetent |
| --- | --- | --- |
| conscious | know that you know | know that you don't know |
| unconscious | don't know that you know | Don't know that you don't know |

**Fig. 2.** A Learning Paradigm

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