# The Fundamentals of Engineering (FE) Examination as an Outcomes Assessment Tool for Engineering Technology Programs

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Abstract

Increased assessment in engineering technology and engineering programs is now in vogue. The Technology Accreditation Commission of the Accreditation Board for Engineering and Technology (TAC of ABET) has developed new TAC of ABET Engineering Technology Criteria 2000 (ET2K). Accredited engineering technology programs will be required to have plans for "continuous improvement" and evidence that the results are applied for ongoing program improvement. Continuous improvement of programs is closely linked with Total Quality Management (TQM) principles. Further, the criteria require that engineering technology programs demonstrate achievements by "student outcomes assessment." Each institution is left to determine the methods that it uses to demonstrate achievements for each program. Student outcomes assessment evidence for engineering technology programs may include "nationally-normed subject content examinations" according to the new criteria.

The Fundamentals of Engineering (FE) examination is an obvious potential student outcomes assessment tool. The National Council of Examiners for Engineering and Surveying (NCEES) prepares the FE and Principles and Practice of Engineering (PE) examinations. NCEES is working with academia to encourage the use of the FE examination to help engineering programs satisfy the student outcomes assessment required by the new EAC of ABET Engineering Criteria 2000 (EC2000). Could the FE examination also be successfully employed as an outcomes assessment tool for TAC of ABET programs? What impact could an increase in engineering graduates taking and presumably passing the FE examination have on the career potential of engineering technology graduates? This paper explores these and other issues related to outcomes assessment using the FE examination emphasizing Electrical/Electronic(s) and Mechanical Engineering Technology programs.

## Introduction

Self-assessment of engineering and engineering technology (ET) programs is now receiving increased emphasis. New TAC of ABET Engineering Technology Criteria

2000 (ET2K) call for institutions to do more student outcomes assessment. The institutions are left to decide on the assessment tools they use to measure student performance. Student outcomes assessment evidence may include "nationally-normed subject content examinations." [1]

The Fundamentals of Engineering (FE) examination, prepared by the National Council of Examiners for Engineering and Surveying, is an obvious potential assessment tool [2]. NCEES is exploring ways to work with academia to heighten awareness of using the FE examination to help programs satisfy the outcomes assessment required under the revised ABET 2000 criteria. A NCEES white paper has been prepared addressing this issue for EAC of ABET programs [3].

The FE Examination

The NCEES examinations are used universally by all states in the US as well as by other related government jurisdictions. Thus, these examinations are identical across the US, making them an ideal benchmark for comparing the academic attainment levels of US graduates of engineering and ET programs. Some states do not allow ET majors to take the examinations. Most states, however, allow ET majors within twelve months of completion of degree requirements to take the FE examination as long as they are in an ABET-accredited program.

The FE examination is an eight-hour examination testing basic engineering concepts and mathematics. The morning session examination is currently the same for all engineering disciplines/majors. The afternoon session currently varies by discipline. The pass rate in October of 2000 for first time examination takers from EAC of ABET programs was 77 percent for electrical discipline examinees and 87 percent for mechanical discipline examinees [4]. For the total takers in Electrical/Electronic(s) Engineering Technology (EET) programs and Mechanical Engineering Technology (MET) programs, the pass rates were 46 percent and 46 percent, respectively [5]. There is much less participation in the testing by ET majors than by engineering majors, and ET majors are currently less successful at passing the FE examination.

The FE examination results provide a potential benchmarking tool for university ET programs. Note that the overall score, however, does not identify specific areas of weakness. Students taking and passing the FE examination should be off to a better start in their professional careers than those lacking the EIT designation indicating that they have passed the FE examination. Personal observation shows that if the process toward becoming a licensed professional engineer does not begin early in one's career, then the likelihood of one eventually becoming licensed diminishes. Further, as one progresses in their professional career, professional licensure is often expected for higher level engineering positions with greater responsibility and income. In fact, licensed professional engineers can expect salaries 15 to 25 percent higher than those who are unlicensed [6].

FE Examination Subject Coverage

The NCEES provides a listing of the subjects covered and the percentage weights of their coverage for the morning session of the FE examination. These are listed in the attached Appendix. A more detailed listing, including the morning session topics covered within the subject areas, can be found at the NCEES Web site [7]. All FE examinees from all disciplines take the same morning portion of the FE examination.

For the afternoon FE examination session, testing is available in five specific disciplines as well as a general discipline. An examinee takes the examination in one selected discipline. EET majors most appropriately would take the electrical discipline FE examination. The electrical discipline examination subjects covered with their percentage weights are listed in the Appendix and at the NCEES Web site [8]. Similarly, MET majors would most appropriately take the mechanical discipline examination. The mechanical discipline examination subjects covered with their percentage weights are also listed in the Appendix and at the NCEES Web site [8].

EET and MET programs are the most common ET programs and represent a great number of ET graduates. EET programs often lack many courses pertinent to the morning FE examination session subjects. On the other hand, MET programs generally provide most, if not all, courses pertinent to the morning FE examination session subjects. The current program specific curricula requirements of TAC of ABET accreditation criteria are surely a factor in this disparity [1]. Technical course work in EET programs "must include the fundamentals of electricity/electronics and principles of circuit analysis." MET programs, however, must specifically "include topics in materials, statics, dynamics, strength of materials, fluid mechanics, thermodynamics, and electric power or electronics." All of these MET program topics are subjects in the morning session of the FE examination that all FE examinees must take.

Taking the FE Examination

Problems and questions can arise with students taking the FE examination especially if care is not taken to prevent them. For instance, are all students required to take the FE examination? To obtain a representative sample, all program students approaching graduation should be required to take, but not necessarily pass, the FE examination if it is to be used as an outcomes assessment tool. What about student examinees who have not yet completed or even taken some subjects on the FE examination? Also, are the students sufficiently motivated to do well on the examination, especially if it is required for record only? The white paper recommends that engineering students be given an exit questionnaire to help establish their perception of their preparedness to take the examination. This procedure seems equally applicable to ET students. The students can be asked to list any pertinent courses that they had not taken or were taking at the time they took the examination. Further, the white paper recommends that assessment be

based on data from several examination administrations – not just one. This must be a long-term endeavor. In fact, it would be a continuous process in the context of TQM.

The examinee is allowed to use the *FE-Supplied Examination Reference Book* only. No other textbooks, handbooks, etc. are generally allowed for use during the FE examination. A pristine copy of the *Reference Book* is supplied at the examination administration, and the examinee may not use a personally owned copy. Personal copies are available from NCEES for study/review. A copy of the book can be found at the NCEES Web site [9]. Generally no other books may be used during the FE examination. The FE examination is generally more nearly a closed-book examination even though the *Reference Book* is available.

Using FE Examination Results for Outcomes Assessment

State licensing boards issue *Report 5 Summary* reports to engineering schools in their states. This report summarizes the results for students from a particular university who took the FE examination and compares these results with similar results for both national and state examinees. It breaks down the examination results by subject such as chemistry, computers, dynamics, electric circuits, etc. State licensing boards can issue similar reports generated for ET students/programs. NCEES already produces a similar report for TAC programs. It is called *Report 5A Summary*. The white paper suggests the possibility of modifying the *Report 5 Summary* to improve outcomes assessment. So, presumably *Report 5A Summary* could also be similarly modified.

Through *Report 5 Summary* (or *Report 5A Summary*), the NCEES makes FE examination data available to a university on the success of its student examinees as a group. It does not provide data on each individual student. The question arises on what to do with the examination data once it is obtained. Outcomes assessment is expected by TAC of ABET to be used in a continuous improvement program. Would universities publish examination data and advertise the success of their programs? What if a university's students scored much lower than ET or engineering students elsewhere? Any true assessment with meaningful "nationally-normed" benchmarks has this risk. The FE examination is a benchmark for measuring knowledge attainment in prescribed subjects, and direct comparisons of results are possible.

Assessment of important issues introduces uncertainty and even fear. This could be either beneficial or detrimental to the image of a university's ET programs. Knowledgeable parents, potential students and employers may begin asking how a program's students fare on the FE examination. A few engineering programs already require a passing grade on the FE examination for graduation, and more may follow. Other universities require that their students take the examination for record only. At least initially for an ET program, it seems more realistic to require a grade for record only. Later, after a history of student results is established and analyzed, requiring the

attainment of a certain grade for graduation might be considered, possibly after some curriculum fine-tuning as a part of continuous improvment.

The white paper does not endorse using the entire FE examination as an assessment tool, and it addresses only engineering programs – not ET programs. However, the logic presented for engineering programs is applicable to ET programs. The overall score on the FE examination is too broad for identifying and addressing specific instructional subject area strengths and weaknesses. Different programs have different emphases, and the white paper authors do not intend that the FE examination to determine the curriculum content of programs, which would tend to force programs to be similar. Instead, they suggest that the faculty of a program establish predetermined FE examination goals for subjects that can be used individually for assessment after scores are available. Grading scores can be obtained by topic, institution and major with the cooperation of the state PE Board based on *Report 5* (or *5A*) *Summary* reports. Students should be required to take the appropriate discipline-specific afternoon portion of the FE examination for their discipline/major. Both electrical and mechanical discipline specific afternoon portions are available. The white paper suggests comparisons with peer institutions.

It is easy to see why the white paper authors prefer not to become involved in dictating the emphasis or content of academic programs. The FE examination content, however, can serve as a guide for the development of curricula. At least, it is worthy of consideration by engineering and ET faculties. The content of the FE examination is developed based on the knowledge skills attainment expected of competent engineers by a group of experienced engineers. That should serve as an excellent benchmark for aligning academic programs with the needs of employers in general. Everyone would have a clear understanding of the objectives of the programs, including faculty members and employers. Linking curriculum content to that of the FE examination should also help prevent personal agendas (realized or not) of faculty members, possibly serving their own self-interests, from unduly influencing academic programs. It would allow easy identification of instructional subjects that were inconsistent with program objectives and encourage careful consideration and justification of any deviations. Fewer than half of the problems on the FE examination need to be answered correctly in order to pass. Thus, there is some flexibility for emphasizing selected instruction areas while still maintaining a major thrust in the FE examination subjects. If the emphasized instructional areas include subjects covered on the FE examination, then students would be expected to excel in those subjects counterbalancing weaker performance in subjects in other areas receiving less emphasis. The FE examination, however, would help enforce checks and balances between the curriculum implicitly dictated by the FE examination as determined by external experts and one expounded by ET faculty members, hopefully with input from local industry. Deviations from the FE examination subjects would need to be tempered by the reality of differing opinions of external experts.

It is important to evaluate student performance in each of the subject areas of the FE examination. After all, the faculty is also being "graded" on the achievement of their students as determined by others. Weak instructional areas need to be identified objectively (quantitatively) so that they can be targeted for improvement. Otherwise, improvement efforts become unfocused and disorganized. This would be handled as a continuous process improvement effort consistent with TQM principles. TAC of ABET requires that programs "have plans for continuous improvement and evidence that the results are applied to further development and improvement of the program." [1]

ET Instruction and the FE Examination

If the overall FE examination is chosen as an assessment tool, consideration should be given to orienting the curriculum instruction to the subjects covered on the FE examinations for the respective disciplines. As already mentioned, it would make the instructional goals of the program very clear to the faculty and to outsiders. If this is selected as an assessment outcome to be measured, then it should guide ET programs' curricula. Some consideration should also be given to the respective PE examinations, which should academically be fairly consistent with the FE examinations for the electrical and mechanical disciplines. MET programs probably more closely fit the FE examination coverage than typical EET programs. The most obvious weak area in the MET program at my university is that no heat transfer course is required, although one is offered as a technical elective. Another weak instructional area is ethics, but it counts only two percent of the FE examination grade (four percent of the morning grade). Some believe that this unique area can be handled pretty well with the limited material in the *Reference Book* possibly along with limited coverage in a seminar-type course. For the EET program at my university, the deficiency list includes fluid mechanics, materials science/structure of matter, and mechanics of materials, statics and thermodynamics as well as ethics. With the exception of ethics, all of these subjects are currently taught in our MET program. Most EET program subject deficiencies mentioned here are introduced in physics, but depth and breadth of physics instruction for most students in these areas is inadequate for the FE examination. Physics covers many topics so the coverage of any one topic is necessarily brief. It also typically does not present material with an application approach.

The common lack of balance found in the curricula of EET programs with respect to the FE examination coverage is obvious. It is allowed by the TAC of ABET criteria [1]. Thus, some may conclude that the FE examination is thus not suitable for assessing EET programs. Others may argue that EET programs are not providing the knowledge base expected of engineers (or engineering technologists). For EET programs, NCEES expectations and the TAC of ABET criteria are somewhat inconsistent. Some programs as they are now constituted are not as suitable as others for using the entire FE examination as an outcomes assessment tool. That, however, does not mean that many subjects, especially those covered in the afternoon, would be appropriate for outcomes assessment using the FE examination.

The common lack of balance in EET programs with respect to the FE examination could be improved with minimal curriculum changes. MET students typically take an EET course to meet TAC of ABET requirements. On the other hand, EET students are not required to take any usual MET courses to meet TAC of ABET requirements. Most of the subjects lacking in EET programs would be covered in the core curriculum of a traditional EAC of ABET program of the past. The concept of core curricula seems to have diminished over the years, as the number of credits (hours) required for graduation has been reduced. Many current EAC of ABET programs do not cover the full breadth of the traditional core engineering courses. Examinees who have not had all of the core subjects can pass the FE examination, but they are at a disadvantage. EET programs might be broadened and improved by incorporating a couple of well-designed MET or general ET courses into the EET programs. These would be designed to address the usual deficiencies identified in EET programs relating to the FE examination. Ideally EET students would take a course in each subject deficiency mentioned, but that would require about six additional courses excluding ethics at my university. There are less severe alternatives that might improve the situation for EET students. For instance, a thermal/fluid science course could be developed and required for EET students. This would include survey coverage of thermodynamics, fluid mechanics and heat transfer. Similarly, a survey course in engineering mechanics could be offered encompassing statics, strength of materials (mechanics of materials) and dynamics. The two survey courses would, of course, lack the depth of the courses taken in these areas by our MET students.

A concern is that program instructors may feel that under the pressure of outcomes assessment, they must push their students excessively forcing them to produce more to pass their course than the credit hours for the course reasonably require. An overly zealous faculty member would essentially be stealing student time from a fairer faculty member. After all, faculty members are competing to some degree for students' time. It all comes down to each instructor's sense of fairness, conscience and professionalism. It is impossible to have a good program without these characteristics in faculty members. Care needs to be taken to insure that these characteristics are not punished. The faculty as a group must take the blame for poor performance. After all, the faculty as a group should run each program. Of course, courses can be taught where there is little learning due to poor instruction. But, problems can arise from a myriad of other complicated and interrelated factors too. These include too little emphasis on the subject in terms of credit hours, students being poorly prepared to take the course, a student population inherently more gifted or interested in some areas than others, weak students in general, poor teaching facilities, poor teaching schedules, a poorly planned curriculum, unidentifiable statistical aberrations, etc. Faculty members should not be automatically evaluated individually on outcomes assessment results unless the problem very clearly lies with that faculty member alone. Otherwise, continuous improvement will likely be degenerate into continuous finger pointing. The continuous improvement process must be insured in the

context of TQM principles. That means the faculty members do not work in a state of fear, but rather in one of cooperation in attaining changing common goals.

A question immediately arises if ET students are to take the FE examination. That is, should students be provided with an "extra" review class(es) dedicated specifically and solely to preparation for the FE examination? Is such "help" even needed? If so, should students be given college credit for successfully completing a review class? Should credit for the review class dictate that the student pass the FE examination? There may be resistance from university administrators, funding agencies especially for state-supported institutions or accrediting bodies to giving college credit for review courses. It is possible that some special preparation could be provided in a course having a more general and palatable description such as Engineering Ethics and Practice.

The FE examination is a potential choice as an assessment tool to measure student performance. It is based on the knowledge and skills qualified practicing professional engineers believe that new graduates should have. ET and engineering students are generally competing for many of the same jobs. More employers may demand that students demonstrate similar skills by possessing the EIT designation especially if EAC of ABET programs increasingly expect their students to take the FE examination. It may become an obvious and measurable distinction if many engineering majors become EITs based on outcomes assessment requirements imposed upon them by their university programs while few ET graduates obtain this designation.

## Conclusion

The NCEES examinations are fairly applied and intended to encompass material that practicing professionals believe engineers should know at two relatively early stages in their careers. PE status is a lofty but achievable goal for many ET graduates in most states. Early steps toward achieving that goal can be encouraged and complemented by using the FE examination as part of an outcomes assessment strategy.

Other commonly suggested outcomes assessment tools have obvious detracting elements. Student portfolios and employer questionnaires are very difficult to objectively compare and evaluate. The FE examination most closely meets the "nationally-normed subject content examinations" mentioned in the new TAC of ABET Engineering Technology Criteria 2000 (ET2K). Program curricula should be consistent with the outcomes assessment methods selected. Therefore, the assessment method selected should meet the needs of the students both for maximum effectiveness of instructional time and for measuring truly meaningful outcomes. The FE examination fits these criteria well.

No doubt there will be ongoing discussion and debate among engineering and ET faculties on how to best handle ABET mandated outcomes assessment. The NCEES seems flexible in its willingness to help serve these needs. Engineering and ET faculties around the country may develop many ideas. Novel ideas may be developed by

organizations like NCEES or professional societies like ASEE, ASME and IEEE. Maybe new standardized examinations will appear. ET university faculty members need to continue to monitor, discuss and evaluate ideas for satisfying the new TAC of ABET outcomes assessment requirements as well as participate in the generation and development of ideas. This is a prime area of importance to ET programs and the future success of the graduates of these programs.

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Appendix, FE Examination Subject Coverage

Examination Morning Session Subjects and Their Percentage Weights [7]

| **Subject** | **Percent** |
|---|---|
| Chemistry | 9 |
| Computers | 6 |
| Dynamics | 7 |
| Electrical Circuits | 10 |
| Engineering Economics | 4 |
| Ethics | 4 |
| Fluid Mechanics | 7 |
| Materials Science/Structure of Matter | 7 |
| Mathematics | 20 |
| Mechanics of Materials | 7 |
| Statics | 10 |
| Thermodynamics | 9 |

Afternoon Electrical Discipline Examination Subjects and Their Percentage Weights [8]

| **Subject** | **Percent** |
|---|---|
| Analog Electronic Circuits | 10 |
| Communications Theory | 10 |
| Computer & Numerical Methods | 5 |
| Computer Hardware Engineering | 5 |
| Computer Software Engineering | 5 |
| Control Systems Theory & Analysis | 10 |
| Digital Systems | 10 |
| Electromagnetic Theory & Applications | 10 |
| Instrumentation | 5 |
| Network Analysis | 10 |
| Power Systems | 5 |
| Signal Processing | 5 |
| Solid State Electronics & Devices | 10 |

Afternoon Mechanical Discipline Examination Subjects and Their Weights [8]

| **Subject** | **Percent** |
|---|---|
| Automatic Controls | 5 |
| Computer | 5 |
| Dynamic Systems | 10 |
| Energy Conservation & Power Plants | 5 |
| Fans, Pumps & Compressors | 5 |
| Fluid Mechanics | 10 |
| Heat Transfer | 10 |
| Materials Behavior/Processing | 5 |
| Measurement & Instrumentation | 10 |
| Mechanical Design | 10 |
| Refrigeration & HVAC | 5 |
| Stress Analysis | 10 |
| Thermodynamics | 10 |

Information contained in these Appendix tables can be found at the NCEES Web sites listed in the Bibliography.