Tests for Assessing Graduating EET Students

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Abstract

Several tests have appeared over the course of the past few years that EET students may qualify to take at or after graduation from their BET program. The FE or Fundamentals of Engineering test remains the standard for all graduating senior Engineering Technology students as well as for all disciplines of engineering and engineering technology. However, the test has not been encouraged by many disciplines, especially those in Engineering Technology. The latest test to become available is a test administered by SME especially for Associate or Bachelors of Electrical Engineering Technology students. The SME test has the opportunity to become the standard test for EET majors in the US.

The SME test has been created to give an outcome indicator for the ABET accreditation of the school’s program. Before automatically accepting this test, however, there should be a critical consideration given to the program’s ultimate goal of job satisfaction for the graduate and whether the SME test achieves this objective. Other tests may give some measure of outcome of the program that rivals the SME test. These include the CAP test from ISA and the Mechatronics test from Siemens. Both are geared to the manufacturing environment and a controls engineer. If the objectives of the program are found in the purpose of the test, then that test should be considered. If any test is to benefit the graduate, then the body of knowledge of that test should be included in the curriculum. The Mechatronics test offers promise of change toward a more world-accepted certification. In the meantime, the FE test must be encouraged with students properly prepared to succeed and the SME test is at best a test for the present accreditation process to view as to whether the program is meeting some basic level of learning.

Introduction

The four tests discussed are the Siemens Mechatronic Tests, the ISA CAP (Certified Automation Professional) Test, the SME (Society of Manufacturing Engineer) EET Test, and the NCEES Fundamentals of Engineering Exam (FE). The body of knowledge of each test has been gathered in a single document and may be viewed at the following:

http://www.eng.utoledo.edu/~wevans/Bodyknowledge.rtf
The four bodies of knowledge are found in this document at:

- Siemens Mechatronics Test Level 1: pg 1
- Siemens Mechatronics Test Level 2: pg 7
- Siemens Mechatronics Test Level 3: pg 19
- ISA Certified Automation Professional (CAP): pg 27
- SME EET Test: pg 45
- NCEES Fundamentals of Engineering Exam (FE): pg 55

Body of knowledge information can be obtained by visiting the website of the testing body. Body of knowledge information is the basis of building the test and provides the direction and content of the test. Bodies of knowledge and their associated practice tests can offer a starting point for preparation for the test.

### Siemens Mechatronic Tests

The three tests are:

- Level 1 – Mechatronic System Assistant
- Level 2 – Mechatronic Systems Associate
- Level 3 – Mechatronic Systems Professional

This third test is equivalent to a baccalaureate degree test in the United States. It has a job profile of an engineer. The body of knowledge document describes a Siemens Certified Mechatronics Systems Professional as one who “would carry out most of their work in an engineering office environment; however they may also carry out some of their work at production facilities, workshops, and service sites that use complex mechatronic systems.”

Such an individual would perform the task of design of a complete mechatronic system including mechanical and electric systems. Such an individual would be capable of program definition and creation of control systems capable of automating large systems of automatic machinery.

The desire of Siemens is to establish a test that allows certification world-wide with a standardized test. Instructors are trained at Siemens offices in Berlin. The introduction of this test in the US is intense in areas close to automotive plants that are transplants of German auto manufacturers. The automaker requires the mechatronic approach and the instruction is required at the local community college close to the plant. Whether the approach of establishing a mechatronic curriculum would be seen as a plus in attracting such an automotive plant in a particular locale has not been tried.

The idea of converting an established EET program into an approved mechatronic program would be difficult. And the faculty would have to completely buy in to the change. This has not happened at this institution and probably won’t. The idea probably will not go away, however, since Siemens is a very large company with influence worldwide. If this design of education
becomes popular in most other parts of the world, the US needs to be aware of it and seriously consider its adoption here.

If a comment by an Industrial Advisory Committee member from years ago had been followed, the mechatronic approach would have been modeled as industry asked for generalists with both mechanical and electrical skills to work with automation of machinery. The member suggested that those with both mechanical and electrical skills would be preferred in the manufacturing environment of their company. The suggestion was never given much consideration.

Siemens’ Mechatronics Curriculum includes core elements of mechanical engineering or engineering technology, electrical engineering or engineering technology and computer engineering or computer engineering technology. In the outline below, handlungskompetenz is translated as “decision-making and responsibility”.

The outline of the Mechatronics Curriculum designed by Siemens is as follows:

“Level 1: Siemens Certified Mechatronic Systems Assistant
After completing this level, participants will be considered intelligent machine operators with ‘Handlungskompetenz’. The emphasis is on efficient operation and troubleshooting.
Four courses cover:
• Electrical Components
• Mechanical Components and Electric Drives
• (Electro) Pneumatic and Hydraulic Circuits
• Digital Fundamentals and PLCs

Level 2: Siemens Certified Mechatronic Systems Associate
Level 2 certified people are technician-level workers with ‘Handlungskompetenz’. Systems management, investigation, repair and trouble-shooting are emphasized.
Six courses cover:
• Process control technologies
• Introduction to Totally Integrated Automation
• Automation systems
• Motor control
• Mechanics and machine elements
• Manufacturing processes

Level 3: Siemens Certified Mechatronic Systems Professional
Certified Mechatronic Systems Professionals are educated at the bachelor engineer level, with a focus on systems thinking and ‘Handlungskompetenz’.
Four courses cover:
• Mechatronics System Design
• Customized Automation Solutions with TIA
• Diagnostics, Control Systems and Optimization
• Dynamics of Machinery and Kinematics”

Siemens describes the approach used: “System Approach:

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The SMSCP curriculum is the result of the work of the core team of teachers at Siemens Technik Akademie Berlin, Siemens own elite international technical college. This team has developed a special teaching and learning approach over the last 25 years that always keeps the whole system in focus. This special set of didactic methods is called System Approach. The System Approach underlies the curriculum of the SMSCP, and it has been used with high effectiveness for the training of Siemens’ own students and workers in Germany. As a result, successful candidates learn how to work their way into and through a new system, and by means of the troubleshooting strategies which they learn, they are able to adapt their knowledge to new systems and situations.” To pursue a curriculum in Mechatronics, first consider the Siemens curriculum and contact the administrator for Siemens:

David Webb, Administrator  
Certification Programs  
Siemens Professional Education, Competence Area Berlin  
Siemens Technik Akademie Berlin  
Nonnendammallee 104  
13629 Berlin  
Phone: +49 (0)30 386 - 26042  
Fax: +49 (0)30 386 - 39200  
E-mail: david.webb.ext@siemens.com

In the world, Siemens may have the lead with universities in promotion of their curriculum and a standardized test. Examples include:

Nelson Mandela Metropolitan University, South Africa, has a Siemens Mechatronics Laboratory which opened in May, 2006.

Siemens established a joint effort with Singapore WDA – Singapore Workforce Development Agency - Nov. 19, 2008 for teaching of Mechatronics.

In the United States, three universities have established programs of Mechatronics at the baccalaureate level. Others have established two-year mechatronics degrees which primarily serve the needs of a local auto maker from Europe. It is not known to date whether the three baccalaureate programs are built on the Siemens model or encourage students to take the Siemens test. They are Chico State, Purdue University Calumet, and Southern Polytechnic. In their website, Chico State directly addresses the issue of student employment with a degree in Mechatronics:

“Mechatronics Engineering degree at Chico State, continues to be the only ABET accredited degree program in the US since 1998.

Employers Hire Chico MECA Graduates:  
Mechatronic Employers seek ABET accredited engineering graduates, as it ensures highly qualified candidates for employment. Chico State Mechatronic Engineering graduates, with an ABET accredited degree; generally start at $50K or more. The median Mechatronic salary for a fresh graduate may vary with the economy and the candidate's experience. They are employed for designing components or systems for automation. Following are some examples of
employers of Mechatronic Engineering graduates. They are hired for several purposes including automation of process industries; in medical industries (i.e., insulin pump for diabetic patients); designing robots for law enforcement; designing, building and testing autonomous flying machines for a various operations such as the ones flown in support of our soldiers in the gulf and for automation of farming.

Purdue University Calumet recently received a large grant in support of Mechatronics Engineering Technology:

“PUC receives $613,000+ grant in support of mechatronics engineering technology program. Purdue University Calumet’s innovative mechatronics engineering technology program, which prepares students for high-demand jobs in the packaging machinery industry, has received a $613,862 grant from the National Science Foundation. The grant, entitled ‘Meeting Workforce Needs for Mechatronics Technicians,’ is the second the program has received from the National Science Foundation.”

A paper was presented by Prof. Glenn Allen, Southern Polytechnic State University, entitled: “Mechatronics Engineering – A Critical Need for this Interdisciplinary Approach to Engineering Education”. Southern Polytechnic is the third baccalaureate program offering a degree in Mechatronics.

Other than Chico, however, there seem to be no programs accredited in Mechatronics. A look at the ABET programs of accreditation does not list Mechatronics at this time. Shown below is the list from ABET’s website of available programs for accreditation:

ISA’s CAP Test

The CAP test emphasizes the business aspect of automation more than other tests. Planning a project, cost-estimating and development of strategies based on financial models tend to be featured. Also unique to this test is areas of computer skills such as database modeling and networking. This test is unique in that a professional controls engineer might be more able to take this test as a career step after working in industry a few years. This test is a stretch for a senior in EET even with a good grasp of programming and general controls engineering skills.
EET programs tend not to be able to afford the equipment to provide experience in these areas. Equipment cost and maintenance of such systems is a constant drag on budgets and are not easily afforded or maintained.

This test is not my favorite as it is not a necessarily good test concerning technical skills. It rewards practical skills which is good but leaves little room for the technical side of the engineer’s skills. While no data is available as to numbers of engineers taking the CAP test, it is a relatively new test and ISA is believed to be promoting it in hope that it will be a standard of acceptance of engineers in the controls industry whether electrical, mechanical or other type of automation engineer. It may be hoped to be considered by ISA as an equivalent to the PE, especially among controls engineers.

The CAP Associate Program\(^3\) was launched in March 2007 and is targeted at seniors in an engineering or engineering technology program wanting to work in a controls industry. ISA describes the objective of this test in the following statement on the ISA website:

“The Instrumentation, Systems and Automation Society (ISA) has launched a CAP Associate recognition program for students interested in working in the automation field. The CAP Associate program provides recognition of the student's interest and knowledge of automation. ISA will offer a CAP Associate exam, and students who pass the exam will receive one year of “work experience” credit toward ISA’s Certified Automation Professional (CAP) certification program requirements. CAP applicants who have a four-year technical degree must document five years of experience in automation.\(^4\)

ISA’s CAP certification program offers qualified automation professionals a chance to prove their knowledge and skills through a comprehensive examination focused around the key areas of automation.

Encouragement

‘By giving students the opportunity to get ahead of the game by taking an exam like this, we’re encouraging them to pursue a career in automation and receive a respected recognition for their education up to that point,’ said Vernon Trevathan, vice president of ISA’s Professional Development Department. ‘In today's job market, certification is a powerful tool, and they’ll be one step closer to earning the CAP designation.”

The CAP Associate exam\(^7\) consists of 75 multiple choice questions. The same body-of-knowledge as the CAP exam is included in the test. Technical categories include:

“basic continuous control;
basic, discrete, sequencing, and manufacturing control;
advanced control;
reliability, safety, and electrical;
integration and software;
deployment and maintenance;
work structure.”
Paul Darnbrough PE, CAP, in the article from ControlGlobal titled “Professional Engineers or Certified Automation Professional, Which Certification is Best?” answers many questions pertaining to choosing a proper test. His perspective is either the FE or CAP test.

Darnbrough argues for the need for professional credentials. First is the need for safer design and improved standardization and efficiency. He also argues for the need that employers have for some assurance that the employee is adequately qualified for the task required. He believes the PE is the primary credential in the US. He cites legal aspects of the PE as the only person with authority to sign and seal engineering drawings. He then discusses the CAP from ISA as the alternative to the PE. He argues for both as a general rule with the PE as the license of primary importance but the CAP as a suggested goal for the automation professional. Two charts from the article summarize the difficulty of obtaining the licenses and the benefits of the two licenses:

<table>
<thead>
<tr>
<th>TABLE 1: PE VS CAP</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>How Hard Are They to Get?</strong></td>
<td></td>
</tr>
<tr>
<td>4-Year Engineering Degree</td>
<td>Required</td>
</tr>
<tr>
<td>Other 4-year Technical Degree</td>
<td>Not accepted</td>
</tr>
<tr>
<td>2-Year Technical Degree</td>
<td>Not accepted</td>
</tr>
<tr>
<td>Work Experience Required</td>
<td>6 years</td>
</tr>
<tr>
<td>Application Process</td>
<td>Hard</td>
</tr>
<tr>
<td>Cost (filing, exam, study)</td>
<td>&lt;$1,000 initial</td>
</tr>
<tr>
<td>Exams Required</td>
<td>PE and PE</td>
</tr>
<tr>
<td>Difficulty of Exams</td>
<td>Quite difficult. Two exams, each of long duration</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 2: PE VS CAP, BENEFITS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PE</strong></td>
<td><strong>CAP</strong></td>
</tr>
<tr>
<td>Accepted across U.S.</td>
<td>No, state-specific</td>
</tr>
<tr>
<td>Recognized worldwide</td>
<td>No</td>
</tr>
<tr>
<td>Legal recognition</td>
<td>Yes, in most cases</td>
</tr>
<tr>
<td>Industry Acceptance</td>
<td>High</td>
</tr>
<tr>
<td>Peer Recognition</td>
<td>High</td>
</tr>
<tr>
<td>History/Tradition</td>
<td>Over 100 years</td>
</tr>
</tbody>
</table>

Darnbrough states:

“My position as control systems engineering manager at KDC Systems has rarely called for me to stamp electrical drawings, but I constantly apply engineering principles in our work. Core members of our controls group include Mechanical PEs and Canadian PEs, and they bring exceptional value to our work.

I don’t hold a PE in control systems, but a former colleague of mine does. Control senior technical editor Dan Hebert, PE, says, ‘I passed the California Control Systems PE exam in the
mid-1990s. I found the exam to be difficult, but quite fair, as it tested for real-world practical experience rather than theoretical knowledge.’”

Darnbrough concludes:

“‘I obtained a Louisiana Electrical Engineering PE a few years later. Because of comity, I only had to take a simple exam concerning principles and practices, with no technical test required,’ adds Hebert.

‘I wanted to get a PE because of its industry-wide recognition. I also needed it so that I could get licensed in other states,’ says Hebert. ‘For me, the benefits of the PE have exceeded the time and trouble required to obtain the certification.’”

The CAP test may be a test that automation professionals may desire but not at the University of Toledo. The test would require too much effort in too many advanced areas. The FE is to be encouraged but the CAP or CAP Associate test is too much for this EET program to achieve.

**SME’s EET Test**

This test has been recently created to be used as an assessment tool for EET program performance. It can be used for assessment at the two year associate level or at the four year baccalaureate level. The structure of the test seems to infer that four year students will tend to perform very well with two year students performing at a somewhat less favorable level. The body of knowledge closely parallels that of the curriculum at this university and will probably be a required part of the senior experience at some time in the future.

At this time, the faculty has decided not to pursue encouragement of this test among graduating seniors. This may change, however, in the future.

**NCEE FE Exam**

This test is familiar to most and is the one that we all should most closely identify with. This test has been around for many years and tests the entire four year experience for engineers and engineering technologists. A problem for this university is that most EET majors do not take this test and the results would probably not be very good. This is not to say that many students couldn’t succeed at the test but more preparation and work would be required, especially at the senior level to prepare students for the test. It is an interesting fact that the MET (Mechanical Engineering Technology) program has a review course for the FE exam but the EET program does not. The course is not required but an elective. It is not very popular with the students, however, and is not viewed as a priority among MET students. The most motivated Engineering Technology students with the FE are the Construction majors (CET). They report a 30 to 40% interest in taking the test with approximately 50% success in passing the test. Anecdotal pass rates among all engineering and engineering technology students at the University of Toledo ranges from 60% to 90% with 70 to 90 students taking the test each half year.
A white paper from NCEES describes the use of the FE exam in assessment. ("Using the Fundamentals of Engineering (FE) Examination as an Outcomes Assessment Tool").

Conclusions include:

“Engineering programs should seriously consider using the FE exam subject-level performance data as part of their program assessment, with proper regard for the caveats described.

A program will gain the most from using the FE exam as an assessment tool if it requires all students to take the exam, particularly the discipline-specific PM exam, and if faculty establish specific goals for their programs.”

Websites abound with information encouraging students to adequately prepare for the FE Exam. The following from the North Carolina State engineering website is not unique. It advises:

**“How should students prepare for Fundamentals of Engineering Exam?”**

1. Select electives at NC State that support the exam. In most engineering programs, students can choose electives, many of which support the FE exam. Examine the list of topics covered on the exam (PDF). Then select electives in these subject areas. Get help from your adviser.
2. Take the FE preparation course E 490.
3. Take one or more trial examinations. The National Council of Examiners for Engineering and Surveying (NCEES) offers a free mini-exam and a longer diagnostic exam. A more extensive exam is offered by PPI. The most economical trial exam is at www.eitexam.com, which offers 3-month access to an exam with problems and solutions for only $10.
4. Get a copy of the *Fundamentals of Engineering Supplied-Reference Handbook* and become familiar with it. The *Reference Handbook* is supplied to FE exam takers at the exam. Many questions on the exam concern topics covered in this handbook. Ordinarily, the handbook is furnished to students in E 490. The handbook can be purchased at the NC State Bookstores or directly from NCEES or PPI. Sections from the handbook can be downloaded free from NCEES, but it is normally cheaper and more convenient to get a copy of the book. The E 490 course teaches you how to use this handbook.
5. Study one of the many preparation manuals available from NCEES, PPI or Kaplan for the general and discipline specific exams. NC State is a PPI sales partner. This means that you can buy PPI education products for a 20% discount. To take advantage of this program, visit http://www.ppipartner.com/WN580.
6. Be sure to take the right calculator into the exam. Some calculators are banned.”

Articles written for other ASEE conferences attest to the fact that encouragement is needed to motivate students to take the FE. Also expressed is the discouragement when students tend to skip this important test.

Moore, Thornton and Skeith write:

“The remainder of this paper is focused on what computer engineering students can and should do to prepare themselves for FE registration at different stages of their academic
experience and how they can be encouraged to do so. Students should be reminded that it is never too late to start preparation for registration and that the earlier that one starts this process, the better their chances for success.”

Students at the University of Toledo’s EET program are not encouraged to take the FE exam. The test is seen as too difficult and students are discouraged by peers from taking the test. Only as students graduate and find that many jobs encourage the FE do they become motivated and take courses that more adequately prepare them for this test. The curriculum is in need of changes to more adequately prepare students for the test. A recent IAC meeting in the EET program discussed this problem and possible remedies were mentioned.

Summary

To require students to participate in a test as graduating seniors is the question. Do we require a test or not? Which test is best for our students?

From the body of knowledge and opinion of this individual, the ISA CAP test is the least desirable test. The Mechatronics test from Siemens is intriguing but not practical unless the curriculum is significantly changed. The ability to change may be limited due to the limited resources of teaching and support staff. If at some time in the future, the student population served is reduced to unacceptable numbers, Mechatronics may be an answer. It would be better to change before a crisis but many times, change only happens after a catastrophe is upon the horizon. The Mechatronics test and curriculum does deserve our consideration, however. The Mechatronics test may emerge as an alternative to the FE test and definitely has merit. The Mechatronics curriculum may offer better training for the FE as well, giving the student a bonus of achieving both the Mechatronics certification as well as professional registration after successfully obtaining the FE.

The SME EET test has definite merit and will probably be the choice of the faculty if the decision is made to establish a test for assessment purposes. It is built to fit within the present curriculum. It makes sense. It will probably be the test used and this faculty member will be supportive of its implementation if desired by the faculty as a whole.

The FE test is also a good option if the faculty is convinced that a favorable result is achievable. It has been popular for a long time and is the standard by which all other tests and certifications are measured. It will not go away but may be too difficult and require too much of a stretch for EET students to take as a group. Individual EET students should be encouraged to pursue the FE since it is preferred by most engineers and gives the highest recognition an EET student could achieve.
Bibliography

[1] www.eng.utoledo.edu/~wevans/Bodyknowledge.rtf


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