Engineering Technology Explained in Math and Science — A New Course

Zhaoxian Zhou
School of Computing, University of Southern Mississippi
Hattiesburg, MS 39406
zhaoxian.zhou@usm.edu

Abstract - A new teaching experience is presented in this paper. The author introduces purposefully more advanced analytical methods in his engineering technology curricula. The author integrates mathematical explanations and physical insights into technology courses such as *analog communication systems, digital communications*, and *electric power generation, transmission, and distribution*. This instruction improves the students' performance inside and outside of the classroom. Encouraged by responses from students, the author develops an new course, which serves as a technical elective, to present to the students the analytical methods. The paper describes how the course is developed and what content is included. Major questions that may be encountered during the educational practice are also discussed.

Keywords: Electronic Engineering Technology (EET), teaching method; mathematics; science

1 INTRODUCTION

The importance of mathematics and science will never be overemphasized in engineering and engineering technology education. The ability of mathematical analysis and physical understanding is considered a merit among engineers and technicians. However, major reports [1–6] have been released by highly respected U.S. academic, scientific, and business organizations on the need to improve science and mathematics education [7]. Although a great many of programs in engineering or engineering technology have strong curriculum requirements on math and science, it is perceptible that a gap exists between math/science education and engineering/technology education. In some cases, when a theory in math/science is taught, the instructor will not mention its particular applications into engineering/technology, and the students have no ideas how to apply the theory into the engineering and technical fields; similarly, when an engineering, especially engineering technology, course is taught, the students or sometimes even the instructor lack an advanced, analytical point of view. This is especially true in community colleges, one of whose objectives is to serve as a feeder to four-year universities. A number of recommendations [8] have been made to solve the issue, including increased communication between mathematics and engineering faculty, development of joint resources for problematic areas. In this paper, a new course integrating math and engineering and technology is proposed.

The Electronics and Computer Engineering Technology (ECET) Program in School of Computing, University of Southern Mississippi (USM) endeavors to improve the learning environment, nurture the development of critical thinking skills, develop knowledge and technology expertise, and inspire the students' interests in science, technology, engineering, and mathematics (STEM). Through this goal, the ECET supports the mission of the university and the college of providing the basic skills and perspectives essential for preparing graduates for effective participation in contemporary life.

The ECET program is taking actions to promote greatly its academic standing by offering more higher-level engineering and technology courses. Several electrical engineering courses, such as *electromagnetic fields and waves, digital signal processing, antenna analysis and design, signals and systems*, have already been

offered as a part of the effort. Because of the analytical nature of these courses, to achieve this goal, we require that students have profound mathematical skills. MAT280 (*differential equations*) is required for EET students, in addition to MAT167 (*calculus I*), MAT168 (*calculus II*), and MAT169 (*calculus III*) that are required for both EET and CET students.

The ECET program has an enrollment of economically disadvantaged students, first generation college students, and non-traditional students. A large number of students in ECET program are transfer students from local community colleges. A survey of the grades of students majoring in EET and CET taking MAT167, MAT168, MAT169 and MAT280 shows that during the five-year period from 2003 to 2007, the average GPA of 85 CET students taking courses MAT167, MAT168, and MAT169 is 1.32, and the average GPA of 167 EET students taking courses MAT167, MAT 168, MAT169, and MAT280 is 1.43, both are far below the university requirements. Details are tabulated in Table 1, where Ns stands for the number of students taking the course during 2003-2007. The unsatisfactory math performance has limited the student development in engineering and technology. The struggle in math skills in analytical engineering technology courses is one of the major reasons that account for student suspensions and dropouts.

Table 1: Math GPA of CET and EET students during 2003-2007

	MAT167		MAT168		MAT169		MAT280		Overall	
	Ns	GPA	Ns	GPA	Ns	GPA	Ns	GPA	Ns	GPA
CET	50	1.32	30	1.27	9	1.60			85	1.32
EET	77	1.25	54	1.44	27	1.63	9	2.22	167	1.43

Through the interactions with students, ECET instructors have found that a large number of students have difficulties applying fundamental science and mathematics into engineering and technology. Although the instructors spend a lot of time and effort each semester to review the fundamentals, the outcome is not always satisfactory. There are basically two major reasons. The first one is the students' unsatisfactory math performance stated above. For example, most transfer students do not have a solid foundation in mathematics education before joining a four-year university. Necessary help should be provided to these students for a smooth transition into the university community, and an appropriate solution to the problem is essential. The second reason is that a great number of students majoring in the engineering technology program are working students or returning adult learners. Time conflict forbids them from spending enough time for a solid understanding of prerequisite mathematical fundamentals. An efficient instruction method is clearly critical for student success, which is in turn a key to the achievement of the university goals.

2 Integrating Higher-Level Math and Science into EET Courses

Our traditional instruction methods put the weight on hands-on skills. Almost every EET course has a separate, corresponding laboratory course or a laboratory session embedded in the course. We have found that our students, even transferred students who do not have solid theoretical foundations are able to learn the technical information easily. However, shortcomings have been found in the instruction method. The lack of higher-level skills in math and physics degrades the outcomes of our instruction. Since 2005, we have introduced purposefully more advanced analytical methods in our engineering technology curricula. Higher-level mathematical explanations and physical insights are integrated into technology courses such as *analog communication systems*, *digital communications*, and *electric power generation, transmission, and distribution*. The typical steps of our procedure of delivering a major topic in *electric power generation, transmission, and distribution* are described as follows.

1. Step 1: concise, theoretical statements are proposed. The theoretical statements are usually higher-level conclusions of other pertinent courses that the students have already taken. Johann Friedrich Herbart suggested that instructors should first prepare the pupils to be ready for a new lesson, and associate the new lesson with ideas studied earlier [9]. The rule applies here. Relating new theory to what students have learned help them understand the theory.

2. Step 2: once the theory is proposed, every effort should be taken to explain the physics behind the theory. Practical examples are usually used to help the students in the understanding of the theory.

3. Step 3: after the students completely understand the theory (and natural derivations of the statements, if any), the technical information can be delivered in a way that is easy and straightforward.

This instruction improves the students' performance inside and outside of the classroom. One direct benefit of this instruction method is that the students know how things work and know why things work. Students will be able to grasp new emerged technologies quickly, and even be inspired to propose their own new ideas and solutions. Paper [10] reported the student skills in math and physics, illustrated the instruction method, and summarized the outcomes and evaluation of the teaching method from a senior course *electric power generation, transmission, and distribution* that adopts this method. The statistical report suggests that the students have a better understanding of engineering technology problems from this new teaching method than from traditional teaching method. The students have increased interest to engage in lifelong learning processes, have further exposure to other EET areas, and enjoy the learning experience. The instruction method has better learning results than traditional ones.

3 PROPOSED COURSE

With the experience in the recent three years, the ECET faculty has felt a significant need to improve the students' performance in math courses. However, the nature of the student enrollment determines that the traditional ways for improvement of math skills such as traditional tutorial services in math classes do not work. One of the reasons is that in most of the traditional math classes, engineering and technology applications are merely integrated into the abstract mathematical concepts. However, bridging the gap between math and engineering technology curricula has been proved to be able to improve students' performance effectively [10].

Encouraged by responses from students, we have developed a new course that serves as a technical elective to present to the students the analytical method. Unlike any traditional course in science, technology, engineering, or mathematics, the proposed course is a comprehensive integration of all related topics, with a target of junior, senior and graduate students in engineering and technology. The prerequisite of the course is a junior standing, which means the students have already had basic concepts and skills in circuit analysis, along with mathematical fundamentals. The highlights of the course are described as follows.

- First, the course is concise and efficient. Only the science and mathematics that is necessary to the corresponding engineering and technology curriculum is covered. This is beneficial to the working students and returning adult learners who suffer a time limitation.

- Second, the course is comprehensive and helpful. Any major science and mathematics skills that are necessary to the engineering and technology curriculum will be covered. This greatly relieves the burden when the instructors teach any engineering and technology course.

- Third, the course is open to future needs. Topics in science and mathematics could be easily added corresponding to any change in the engineering and technology curriculum; new engineering and technology applications could be easily updated with the corresponding science and mathematics topics.

The content of the course includes typical topics that are mostly encountered in electrical and computer engineering and technology courses. These topics usually demand harsh mathematical and science requirements on students. Several examples are listed below.

- Topics in *algebra*: complex numbers, eigen-functions, Euler's identity, polynomials, vector analysis. These topics are most likely found in *electrical power*, *electromagnetic fields and waves*, *digital signal processing*, and *digital communications*.
- Topics in *calculus*: Taylor's expansion, integrals, and differential equations. They are mostly encountered in *communications* and *electromagnetic fields and waves*.
- Topics in *linear algebra*: matrix manipulation, which is needed in discussion of error detection and correction schemes in *digital communications*.
- Topics in *special functions*: Bessel functions, Dirac function, and Sinc function. These functions are helpful in understanding some concepts in *digital signal processing* and *communications*.
- Topics in *transformation analysis*: Fourier transform, Laplace transform, and z-transform. A complete understanding of these transformations is an essential skill in *advanced circuit analysis*, *digital signals and systems*, and *digital signal processing*.

The proposed course has several anticipated impacts.

- The course has direct and instant impact on the students in our EET and CET programs. From our two-year instructions, it is expected that the course is able to improve the ECET students' academic performance, and the ECET program will function more efficiently in providing students with a broad education that is founded on analytical principles and processes combined and implemented with modern technology.
- As stated above, the course has direct impacts on the working students, returning adult learners. This course offers them an efficient method to improve their science and mathematics foundation, which in turn, will improve their academic performance in engineering and technology.
- The course affects place-bound students and true distance learners. By various distance education methods, the course could be of benefit to any one who is interested, as well as enrolled students. The course helps nurture life-long learners.
- The course is a multidisciplinary course. It is able to get all STEM students involved. The course inspires the science and mathematics students' interests in engineering and technology through practical applications of theories. On the other hand, various engineering applications enhance the students' understanding of abstract topics in science and mathematics.

The outcome of the course will be evaluated by both direct and indirect methods.

- The course can be evaluated indirectly by various surveys. Two types of surveys will be conducted: student survey and instructor survey. The course evaluation criterion of USM will be used to evaluate the student learning outcomes. The evaluation results along with students' feedback during the teaching of the new course will be assessed. Reviews, comments and suggestions will be collected and analyzed from users within the USM community.

- The course can also be assessed directly through the student performance. The instructor will evaluate the student performance on the application of science and mathematics knowledge into engineering and technology courses. The performance of students that take the proposed course and that do not take the course will be analyzed.

4 CONCLUSION

In this paper, a new teaching experience is presented. The experience of integrating more advanced mathematics and science into engineering technology curricula is discussed. A new course is proposed that will effectively improve the mathematics and science performance of electrical and computer engineering technology students. The course covers most of the theories that have included in the ECET curricula. For the purpose of conciseness, the course covers only the topics that are likely needed by ECET students. The major topics are discussed in the paper. The course has positive impacts on the working students, returning adult learners, place-bound, and time-bound students. This course offers them an efficient method to improve their science and mathematics foundation, which in turn, will improve their academic performance in electronics and computer engineering and technology.

References

[1] "Keeping america competitive: Five strategies to improve mathematics and science education," The Education Commission of the States, Tech. Rep., 2005.

[2] "Tapping americas potential: The education for innovation initiative," The Business Roundtable, Tech. Rep., 2005.

[3] "Statement of the national summit on competitiveness: Investing in u.s. innovation," The National Summit on Competitiveness, Tech. Rep., 2005.

[4] "Waiting for sputnik," the Center for Strategic and International Studies, Tech. Rep., 2005.

[5] "National defense education and innovation initiative, meeting americas economic and security challenges in the 21st century," The Association of American Universities, Tech. Rep., 2006.

[6] "Rising above the gathering storm: Energizing and employing america for a brighter economic future," The National Academy of Sciences, Committee on Science, Engineering, and Public Policy, Tech. Rep., 2006.

[7] C. M. M. Jeffrey J. Kuenzi and B. F. Mangan, "Science, technology, engineering, and mathematics (stem) education issues and legislative options," Congressional Research Service, The Library of Congress, Tech. Rep., May.

[8] K. Willcox and G. Bounova, "Mathematics in engineering: Identifying, enhancing and linking the implicit mathematics curriculum," in *Proceedings of the 2004 American Society for Engineering Education Annual Conference and Exposition*, Salt Lake City, UT, June 2004.

[9] M. D. Merrill, “First principles of instruction,” *ETR&D*, vol. 50, no. 3, pp. 43–59, 2002.

[10] Z. Zhou, “Integration of math and physics into electronic engineering technology courses,” in *ASEE Southeast Section Conference*, Louisville, KY, April 01-03 2007.

Biography

Zhaoxian Zhou received the B. Eng. from the University of Science and Technology of China in 1991; M. Eng. from the National University of Singapore in 1999 and the PhD degree from the University of New Mexico in 2005. All degrees are in Electrical Engineering. From 1991 to 1997, he was an Electrical Engineer in China Research Institute of Radiowave Propagation. In the fall of 2005, he joined the School of Computing, the University of Southern Mississippi as an assistant professor. His research interests include electromagnetics, radiowave propagation, high performance computing and numerical analysis. His teaching interests include communications, electromagnetics, antennas and propagation, electric power, and signal processing. He is a senior member of IEEE and a member of ASEE.