

Integration of Math and Physics into Electronic Engineering Technology Courses

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Abstract - The Electronic Engineering Technology (EET) Program plays an important role in the University of Southern Mississippi (USM). The EET program strives to create a learning environment that nurtures the development of critical thinking skills, and develops technology expertise. Traditionally, our courses in Engineering Technology, such as *Electrical Power*, tend to cover a lot of details from a technical point of view. Advanced mathematics as an analytical tool is typically not incorporated into instruction. This method has advantages, however, we have found that, without a solid understanding of science and physics behind the technology phenomena, it is not practical for the students to memorize easily all the technical information. The EET program at our university has just merged into the School of Computing, and is trying to improve the teaching-learning environment by incorporating more science and advanced mathematics into engineering technology curriculum. This paper discusses how higher-level mathematics and physics can be integrated into the instructional process of EET courses. As an example, this paper presents how we help the students to incorporate their knowledge and skills in algebra, calculus, geometry, trigonometry and physics into *Electrical Power*, which has long been a required course for EET in USM. This method has proven to be effective. Students have demonstrated a clear understanding of the technical information in the field of *Electrical Power* by the integration of higher-level math and physics.

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

1 INTRODUCTION

The instruction methods adopted for engineering courses and for engineering technology courses can be quite different. First, engineering and engineering technology curriculums have different objectives. Engineering courses have stronger requirements from theoretical views, while their engineering technology counterparts, at least higher-level engineering technology courses, focus on more practical applications and technical information. Secondly, engineering and engineering technology students have different levels of skills in mathematics and physics. Engineering students may feel comfortable with abstract theories after they have grasped higher-level mathematical knowledge. On the contrary, engineering technology students prefer hands-on skills. They usually do not have much knowledge in advanced mathematics and in-depth physics. This is especially true for some transferred students who do not have solid theoretical foundations in their lower-level 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. First, The students forget the technical information in later time easily, because the amount of information retained by students declines substantially after ten minutes [1]. Second, students know how things work but they do not know why things work. Students learn what they care about and remember what they understand [2]. Third, without appropriate requirements of logic reasoning and theoretical derivations, students take long time in

complete understanding of new concepts. This situation affects the outcomes of the course. Fourth, a course that gives emphasis to too many technical facts tends to isolate itself from other courses in the curriculum. The skills students have learned in this course and those in other courses cannot be effectively incorporate into each other. The isolation affects the outcomes of the whole curriculum.

Recently, we try to improve the outcome of our engineering technology program by teaching in a more analytical method. Our objective is to give students a clear understanding of electronics engineering technologies by appropriately integrating higher-level math and physics into EET courses. Described in this paper is our experience.

2 INTEGRATING HIGHER-LEVEL MATH AND SCIENCE INTO EET COURSES

In the practice of integrating higher-level math and science into electronic engineering technology curriculum, high-level courses are better choices than low-level ones. Junior and senior students have learned enough fundamentals of math and science, and are able to take more challenges in higher-level courses that are taught in a more theoretical way.

The steps of our procedure of delivering a major topic 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 [3]. The rule applies here. Relating new theory to what students have learned help them understand the theory.
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. 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.

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.

When higher-level math and science are to be incorporated into EET courses, instructors should pay attention to the levels of math and science that they will use. Prompt response to the feedbacks from the students is encouraged. A less “theoretical” way may decrease the method’s effectiveness, but a too many mathematical challenges may turn the practice into a disaster.

3 MATH AND PHYSICS INTEGRATED INTO *Electric Power* COURSE

Electric Power is inherently a typical electric engineering technology course filled with a lot of information from a technical point of view. Major topics include power generation, power transmission and distribution. More specifically, each of the following topics could be a separate 3-credit-hour course: electrical systems operation & control, electric drives, electrical machines, electric energy conversion, power electronics, high

voltage equipment and technologies, electrical installations in buildings, energy and environmental consequences, and power markets.

As an example presented here, we show how we teach electric power generators and motors with the integration of higher-level math and physics.

The electric power generators and motors are two of the major topics in *Electric Power* course. Students are easily confused by the miscellaneous technical information: AC generators, DC generators, AC motors, DC motors, to name a few, all having different configurations. A large fraction of class meet time is usually spent on how to help students learn effectively about generators and motors.

Surprisingly enough, the principle of electric generators and motors (and even transformers) is Faraday's law of induction, which is as concise as follows [4]:

- differential form:

$$\nabla \times \mathcal{E}(\mathbf{r}, t) = -\mu \frac{d\mathcal{H}(\mathbf{r}, t)}{dt} \quad (1)$$

- integral form:

$$\int \mathcal{E}(\mathbf{r}, t) \cdot d\mathbf{l} = -\frac{d\Phi_B(\mathbf{r}, t)}{dt} \quad (2)$$

where $\mathcal{E}(\mathbf{r}, t)$ is the electric field intensity; $\mathcal{H}(\mathbf{r}, t)$ is the magnetic field intensity, and $\Phi_B(\mathbf{r}, t)$ is the magnetic flux density.

Equations 1 and 2 are written in general forms. Do not scare off students with them because in most of the analysis of electric generators and motors, a simplified version works well. The simplified version, which students have already learned in *Physics* or/and *Circuit Analysis*, is the Faraday's law of induction.

In fact, the Faraday's law of induction is one of the four Maxwell's equations. Considering that the whole *Electric Power* course mainly deals with only one equation, the students will wonder how powerful the Maxwell's equations should be. The curiosity arose from this course inspires interests and motivation for further study.

The Faraday's law of induction in the differential form states that any time-varying magnetic field generates electric fields in the whole space.

The Faraday's law of induction in the integral form states that the electromotive force produced along a closed path is proportional to the rate of change of the magnetic flux through any surface bounded by that path. This applies whether the field itself changes in strength, or the loop cuts magnetic field lines. From the derivation, we can figure out two basis ways of generating electric power from mechanical energy: by rotating magnet inside a coil or rotating coil around a magnet. By this point, the students should be asked to and they will be able to construct simple models of electric generators.

The working principle of the electric generator is illustrated in Figure 1.

A most common equation to calculate the generated voltage of the generator is

$$V = Zn\Phi \quad (3)$$

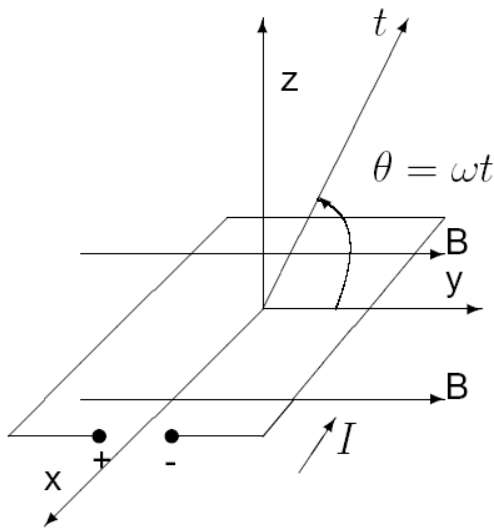


Figure 1: Demonstration of electric generator

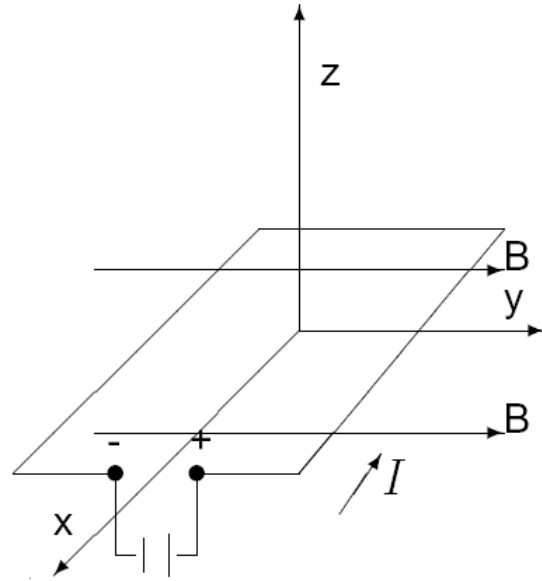


Figure 2: Demonstration of electric motor

where V is the effective voltage; Z is the total number of conductors on the armature; n is the speed of rotation, and Φ is the magnetic flux per pole.

A more detailed equation for the generated voltage can be derived from equations 1 and 2, and be given as

$$v(t) = \omega B_0 A \cos \omega t.$$

This equation not only gives the amplitude of the generated voltage, but also states the polarity of the output voltage, and the phase relationship between the output voltage and the rotation (such as neutral zones). The polarity of the output voltage can also be determined by right hand rule (Lorentz's force), but it is not as systematic as the above-mentioned method.

The Faraday's law of induction in the integral form also states the negative of the rate of change of the magnetic flux through the area enclosed by a closed path equals the electric voltage applied along that path. This is the working principle of electric motors, whose model is described as in Figure 2.

The analysis of electric motors is similar to that of electric generators. Therefore, electric generators and electric motors are in essence the same. They work under the same principle and are able to play both roles theoretically.

There are many other engineering technology issues in *Electrical Power* into which math and/or physics can be incorporated. For example, the relationship between phase and line voltages and currents can be well explained by trigonometric equations or by vector analysis. The details are not presented here.

4 EVALUATION OF THE INSTRUCTION METHOD

The proposed instructed method has been adopted for two semesters in USM. A student survey has been completed recently to evaluate the performance. Nine feedbacks are collected from the class, fall semester, 2006. Each question has five choice that are scored one to five, respectively, standing for “strongly disagree”, “disagree”, “neutral”, “agree”, and “strongly agree”. Thirty-two questions classified into three categories are on the questionnaire. The survey results are analyzed in figures 3, 4, and 5. Average scores and standard deviations are plotted in the figures.

4.1 On the student skills in math and physics

The survey questions are:

1. Before taking the course, I thought high-level math and science (physics) skills are necessary for EET curriculum.
2. Before taking this engineering technology course, I expected extensive math and physics in the course.
3. Before taking the course, I thought I have enough skills in math and science (physics) for the course.
4. In the course, more algebra, calculus, geometry, trigonometry and physics are presented than I expected.
5. After taking the course, I think high-level math and science (physics) skills are important for EET curriculum.
6. After taking the course, I think I need more skills in math and science (physics).
7. After taking the course, I think I will learn more skills in math and science (physics) if given a chance.

The responses are plotted in Figure 3. We see that several major changes have happened after students taking the course.

- Comparing responses to questions one and five, we see that the score increases from 3.5 to about 4.4, while the standard deviation decrease. This means more students have recognized the importance of higher-level math and physics to the EET curriculum.
- While the responses to question “the course is math- and physics-extensive” before taking the course are mixed, students agree (with a score of 3.7) that more math and physics are presented than they expected.
- Students have the same level of confidence (a score of 3.6) on their skills in math and physics before and after taking the course. However, almost all students agree or strongly agree (a score of 4.2 and a small deviation of 0.7) that they are willing to learn more math and physics if given a chance.

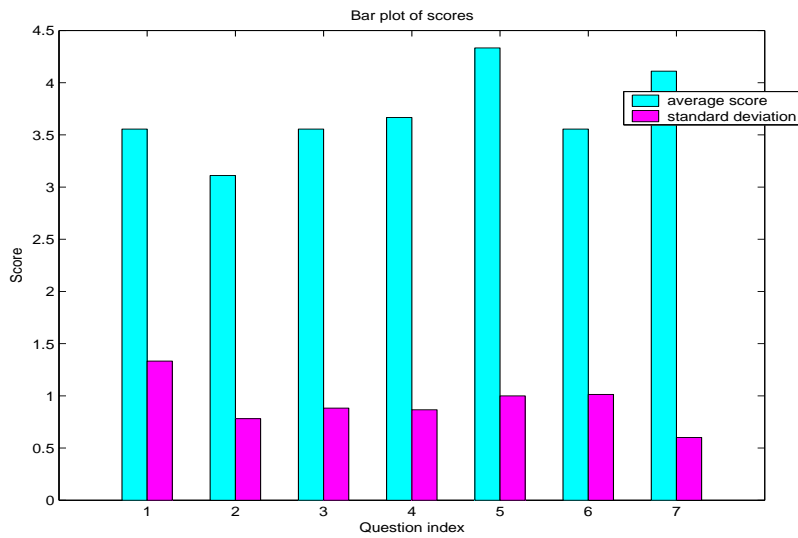


Figure 3: On the student skills in math and physics

4.2 About the instruction method

Twelve questions have been proposed to ask the students about how we adopted the new instruction method in the course. The questions are

1. The instruction method distinguishes itself from traditional ones in the sense that, when main topics are delivered, theory and principles are introduced first, followed by technical information.
2. I find that the theory part in the instruction method is difficult to understand.
3. I think that the theory part in the instruction method helps understand the technical information better.
4. The instructor relates practical applications to theories, and vice versa, for better understanding of both.
5. The instructor devotes time for recitation or asking questions designed to check student understanding of material (interaction between teacher-student/student-teacher)
6. There is less emphasis placed on information transmission and greater emphasis placed on developing student skills.
7. The students are involved in more than passive listening in classroom (e. g., practical problems are discussed in classroom).
8. The students engage activities outside of the classroom (such as experiments, after-class reading, discussing).
9. The instructor encourage after-class reading, through classroom examinations, homework, etc.
10. The instructor promotes student motivation through challenging topics.
11. Examination questions involve comprehensive other than simple tasks.

12. The students are involved in higher order thinking (analysis, synthesis, evaluation)

The responses are plotted in Figure 4. Responses show that

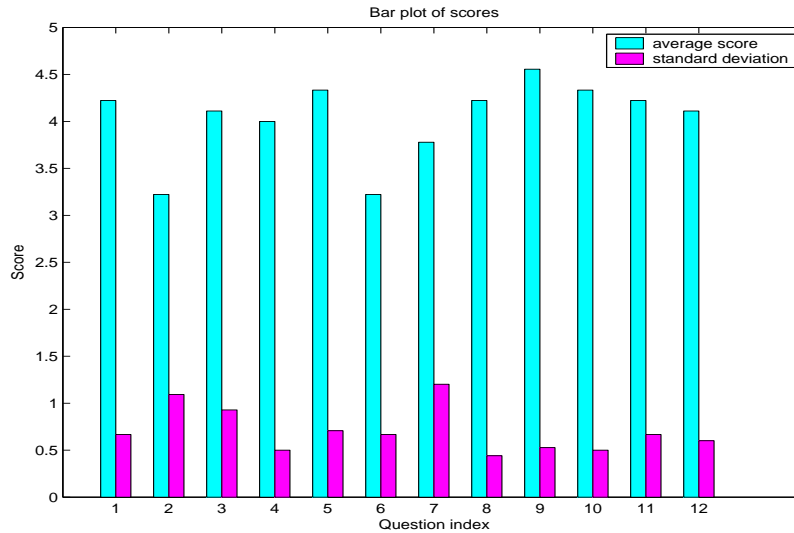


Figure 4: On the instruction method

- Almost all students agree or strongly agree (with a score of 4.3) that the instruction method distinguishes itself from traditional ones; that the theory helps understand the technical information better (with a score of 4.2); that practical examples are related to abstract theories (with a score of 4.1); that challenging topics have been chosen to promote their motivation (with a score of 4.3); and most importantly, they are involved in higher order thinking (with a score of 4.2).
- Students agree that they have engaged activities outside the classroom (with a score of 4.4). However, some of them still feel the need to put the emphasis on developing student skills other than information transmission (with a score of 3.3). This is true and we would improve it in the future by activities such as field trips to power plants. Students do not learn much just by sitting in class listening to teachers, they must relate what they are learning experiences and apply it to their daily lives [5].
- It seems that most of the students feel comfortable with the understanding of theories imposed by the method (with a score of 3.3). This may be because we put more emphasis on physical explanations rather than requirements of mathematical strictness.

4.3 Outcomes and evaluation of the teaching method

To assess the outcomes of the instruction method, thirteen questions are proposed. The questions are

1. The students have the ability to analyze 3-phase circuits through calculations.
2. The students have the ability to analyze problems concerning load power flow.

3. Students have the ability to evaluate alternate design solutions through transmission line parameters and modeling.
4. The students have the ability deal with applications involving transformers
5. The students have the ability to apply creativity in the design of power system solutions.
6. The students have the ability to identify and solve power system applications and related problems.
7. The students have learned sufficient course content.
8. Student motivation is increased by the imposed challenges.
9. The students have further exposure to areas related to electronics engineering technology though this course.
10. The students recognize the importance of, and have an increased interest to engage in lifelong learning processes.
11. The students enjoy the learning experience.
12. The instruction method has better learning results than traditional methods.
13. The students prefer this instruction method than traditional methods.

The feedback is plotted in Figure 5. Data analysis show

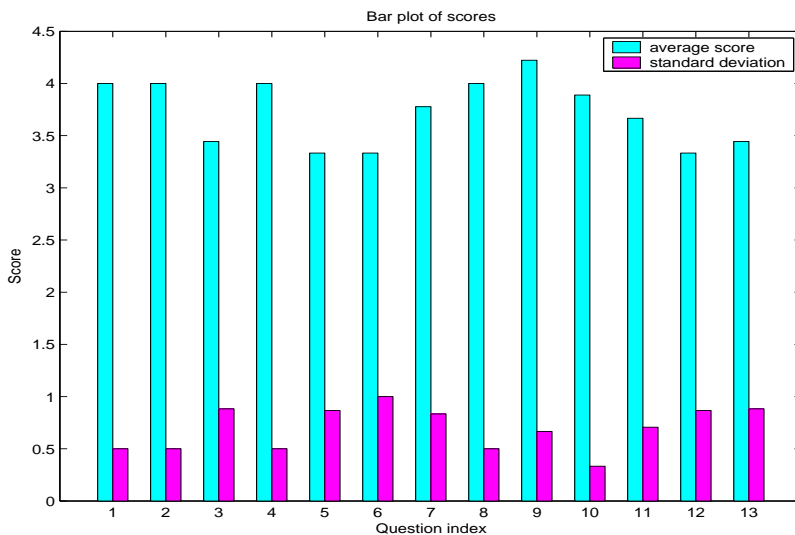


Figure 5: Outcome and evaluation of the teaching method

- Feedbacks to major course topics (questions one to six) show that most students have confidence (with a score of 4.0) on analysis problems (questions one, two, and four), however, students are less comfortable (with a score of 3.4) in design applications (question three, five, and six). This is because skills of analysis rather than synthesis are benefited more from the integration of higher-level math and physics.

- Students have learned sufficient contents (with a score of 3.8). This is satisfactory considering that the topics in our course usually will be covered in more than one module in some other universities.
- Students agree that they have their motivation is increased in the course (with a score of 4.0). They have an increased interest to engage in lifelong learning processes (with a score of 3.9).
- Students agree or strongly agree (with a score of 4.2) that they have further exposure to other EET areas though this course.
- On average, the students enjoy the learning experience (with a score of 3.8); they prefer this instruction method than traditional methods (with a score of 3.4), and they agree that the instruction method has better learning results than traditional ones (with a score of 3.5).

5 CONCLUSION

In this paper, we present the procedure how we adopt a new method to teach a senior course *Electrical Power* in the University of Southern Mississippi. By this method, math and physics are incorporated into an electronic engineering technology course. A 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.

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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.