Curriculum Integration Using Case Study Approach for the Enhancement of Technology and Engineering Education

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Abstract

Integrating physics, mathematics, and communication skills in engineering and technology education is one objective of the three-year NSF-funded grant titled "The South-East Advanced Technological Education Consortium, SEATEC." The consortium is a collaborative effort of five different teams across Tennessee. Each team includes multi-disciplinary faculties, industry partners, university partners, and high school tech-prep teachers. The current paper describes an innovative approach to curriculum development and delivery that improve engineering and technology education and revive student interests in pursuing these programs. A description of how curriculum integration using the case study approach can be used as a promising method for the enhancement of technology education is also discussed. Finally, a sample case is given and examined. The authors are members of two of the SEATEC teams, and teach in 4-year electrical engineering technology programs.

I. Introduction

Integrating physics, mathematics, and communication skills in engineering and technology education is very essential in today's technologically driven world. Technologists and engineers face increasingly complex applications that require an interdisciplinary team approach. In the face of this fact, companies currently encounter the new challenge of staying technologically current or risk falling behind the competition! The implementation of a new technology, however, is often slowed down by the unavailability of experienced workers. In order to address the increasing demand for a skilled workforce, a process is needed for the development and dissemination of a technology-based education curriculum that is both readily accessible and responsive to innovation and industry needs. As a result, a coalition of five two-year technical colleges in Tennessee with representatives from four-year universities, secondary schools, business and industry, and government institutions in Tennessee, Kentucky, and Alabama was formed. A grant proposal titled "The South-East Advanced Technological Education Consortium, SEATEC" was submitted to NSF for funding. The grant was funded for three years (about $1.8 million) with the following goals:

1. To provide national leadership for the development and implementation of case-based instruction in technology and engineering education.
2. To provide opportunities for continuous and appropriate professional development of participating faculty.
3. To assess the effectiveness of the case study approach in teaching technology-related curriculum.

4. To nationally disseminate information related to SEATEC activities, materials, and results, including outcomes of the use of case studies in field-test setting.

II. The Evolution of SEATEC

The current SEATEC effort to develop the case study method in technical education began as an outgrowth of a previous NSF-funded grant titled TEFATE (Tennessee Exemplary Faculty for Advanced Technological Education). SEATEC, like TEFATE, is a consortium developed by a partnership of five two-year colleges in Tennessee with representatives from four-year universities, secondary schools, business and industry, and government entities in Tennessee, Kentucky, and Alabama. The TEFATE project had several important components: interdisciplinary faculty teams, partnerships with business and industry, faculty internships in industry, and DACUM studies to structure a curriculum development effort in telecommunications technology education. Each team included: two-year faculty members from electrical/electronic engineering technology, information systems, English, mathematics, and science (usually Physics); one Tech-Prep partner from a local high school; an engineering technology faculty from a four-year university; and an industry partner. The TEFATE development teams explored ways in which faculty could learn to bring the workplace into the classroom, and to develop problem-based learning materials from a broader interdisciplinary approach.

One of the most exciting outcomes of the TEFATE project was the development and the use of case studies in science and technological education. The teams discovered that there were few models for the use of this method in science and technological education, although many examples existed in disciplines such as business, law, medicine, and education with very positive outcomes. This discovery led to a focused effort to learn more about the development and implementation of case studies and to refine this method for use in teaching technical content. The interdisciplinary development teams at the five two-year colleges began to adapt situations encountered during site visits and internships in industry into actual case studies to be integrated into the courses that they teach. The TEFATE project created twenty-five case studies, and began field-testing them in their courses. During this process, numerous challenges emerged and several crucial issues were identified. As a result, the work of TEFATE has been continued with the SEATEC project, a more structured effort to define the case study model for use in technological education.

III. SEATEC Activities

Year one of SEATEC began with the Fall 1998 Workshop which focused on implementing case studies in technological education, the effective use of cooperative education and case studies, and integrating multimedia in the classroom. Two professional development forums titled "Characteristics of an Effective Case Study" and "Strategies for Using Case Studies in Teaching and Learning" were conducted during the winter of 1999, at Peabody College at Vanderbilt University. Case study samples were presented and used in the two forums. Participants were able to experience the benefits of using case studies and to practice cooperative education first hand. The forums were followed by knowledge mining activities led by the Learning Technology Center (LTC) at Vanderbilt http://peabody.vanderbilt.edu/ctrs/ltc/ in which SEATEC faculty members shared their thoughts with the experts, industrial partners, and other members. Finally, eight new case models were presented at the 1999 Summer Workshop, which bore the fruits of this activity-filled year. More cases are being developed.

IV. Field Testing and Assessment

For the purpose of constructive assessment of the SEATEC approach to curriculum development, the Learning Technology Center (LTC) http://peabody.vanderbilt.edu/ctrs/ltc/ at Vanderbilt University was contracted to assess the effectiveness of the case study approach in the technology curriculum. The plan includes a literature survey, a procedure for evaluating case studies, assessing the progress in case study model development and, ultimately, assessing the effectiveness of this approach. The twenty-five cases developed under the previous TEFATE grant were posted on the web and also printed for dissemination. Each SEATEC team identified the courses where field-testing will be conducted and formal assessments are being conducted. In the meanwhile, informal evaluations were conducted throughout the year. These preliminary evaluations indicated very positive results by both students and faculty. Furthermore, assessments are currently being performed at community colleges and four-year universities across Tennessee, Alabama, and Kentucky. A National Advisory Committee was also formed to monitor the progress in meeting this objective.

Initial field-testing instruments indicated that students often feel as if they are employees at the job site in which the technical problem is taking place. Since case-based instruction is student-centered, students have more responsibility for their own learning, thereby allowing instructors to spend more time facilitating than lecturing. Students graduate with marketable skills and virtual industrial experience. Employers who have participated with SEATEC in the case writing process are enthusiastic about the graduating new workforce who is trained in problem-based and case-based learning using an interdisciplinary approach, with critical thinking and problem solving skills, and who possesses the required communication tools.

Finally, SEATEC members who have published several papers and presented at various international, national, and regional conferences are disseminating the preliminary results of this creative method. A web site has also been created, to electronically disseminate materials related to the grant and available at: http://www.nsti.tec.tn.us/SEATEC/

V. Case Study Essentials

The TEFATE and SEATEC teams discovered that a variety of approaches and emphases might be taken in the production of a case study. The TEFATE study identified five key general components:

1. A “set”—a brief story line intended to get the reader's attention and generate interest in the case itself;
2. A background narrative—to provide a historical context and also situate the problem and the rest of the case in a real-world workplace context;

3. A problem to solve—appropriate for the reader's situation, which could be small and very specific or larger and more general. This is the issue that the reader must analyze in order to identify the problems and develop possible solutions;
4. Questions for the student to answer—to promote additional critical thinking and also to guide the analysis that the readers and student groups must conduct;
5. An instructor's guide—to provide comprehensive support for the teacher through instructional strategies, possible solutions, alternative problems to solve, and tailored support material based upon the content areas and the intended student level of the problem and material contained in the case.

The twenty-five initial case studies of the TEFATE project contained each of these components. Some cases were brief, specific, and limited in terms of student activities; others were more lengthy or open-ended.

In their recent investigation, the SEATEC group has continued to recognize these key general components. Furthermore, in order to increase quality, consistency and appropriateness for technology education, the teams agreed to adopt an additional checklist of the required components for the case studies that were presented and refined in the 1999 Summer Workshop. These included:

1. Objectives of the case to be clearly stated;
2. Assessment suggestions to be included;
3. “Real” business application to be clearly made;
4. Mathematics component must be present;
5. Science component must be present;
6. Technical writing/oral presentation component must be present;
7. A Technical focus for the case is required;
8. Identification of target audience, student group, course or class topic to be given;
9. Instructors guide to be present and complete;
10. Suggestions for extending case to be given.

Cases developed in 1999 have shown increased quality and sophistication. Several cases are being developed into multimedia and are being extended to address problems in related fields. Additional subject areas are being also explored for the development of future cases. These may include topics and problems associated with basic physics such as basic heat transfer and energy conservation, forces and motion, etc. The new cases are also undergoing additional review and field-testing and are available for dissemination.

VI. An Example of Integrating Physics Into Technology Curriculum Using the Case Study Approach

To illustrate a case study product developed through these projects, one of the early TEFATE cases will follow as an example. It was selected for this paper because of its application of a basic principle of physics, that of uniform straight-line motion. This principle is applied, however, to a more advanced topic: reflection of waves. Several electrical topics play a role in the case, also. The case serves as a good vehicle for students in a two-year electrical technology program to practice these principles of physics, with other integrated multidisciplinary extensions (math and English). This particular case is tightly structured as a model of good troubleshooting practice, though it could be modified with “break-out” points for class discussion if desired. The “Problem” section of this case is located in the “Questions” section at the end of the narrative.

<u>Transmission-line Fault Location: A Case Study</u>

Bill looked up from his workbench in the electronics shop to see Joe, the college’s head electrician, walk in, followed by Dan, the Director of the Computer Center.

“Oh-oh. There must be trouble somewhere for you two to visit like this,” Bill said, greeting them. “Yep,” replied Dan. “We know you always enjoy a challenge, and we have a good one for you. We’ve got to have a remote computer terminal working by tomorrow over in the Student Center, and we just found out that it doesn’t work. The setup worked fine last semester, but when we plugged everything up to the underground data cable there was no response this time. We know the terminal equipment is good because it works fine using a different data cable to another building. Joe thinks that the underground cable has been cut or broken somehow.”

“How have you determined that, Joe?” Bill asked.

“By using an ohmmeter and a terminating resistor on the far end”, Joe replied. “Instead of seeing the resistor’s 50-Ohm value plus a few Ohms for wire resistance, we have a very high resistance, several hundred thousand Ohms. I figure that the cable has been cut and the little continuity that we do see is due to moisture in the ground supplying a poor path across the ends of the wire. But I can’t figure any way to determine where the break is without digging up the whole 800-plus feet of cable, and we don’t have time to do that. Besides, that would make a real mess, and my boss would have a fit! If we could just know about where to dig, we could splice the break in time. Is there any way you could figure where the problem is?”

Bill thought for a minute. He knew that if the line had a dead short, he could make a rough guess using an ohmmeter and the measured resistance from each end; but with an open, the results wouldn’t be precise enough for a determination. But there was a way to answer the challenge: send a pulse of current down the cable, and measure the time required to see the “reflection” of the pulse come back to the source after it encountered the broken end of the cable. The concept is called *Time-Domain-Reflectometry*: just as a ball bounces off a wall or a beam of light off a mirror, a pulse of current will “bounce back” from an open or shorted transmission line (there’s no reflection from a properly terminated line). If the Velocity of signal travel in the cable is known, and the travel Time can be measured, then calculating the Distance can be done using the familiar $D = V \times T$ formula. Fancy instruments are available to do this directly, but the college didn’t own a “Time-Domain-Reflectometer”, so something would have to be improvised.

“OK”, Bill replied; “I can do it. Help me carry the pulse generator and oscilloscope over to the Computer Center.”

Once there, Bill connected the pulse generator to the cable’s connector and hooked the ‘scope across the same point using a “Tee” and short leads. He set the generator to send a very fast-rising 5-Volt pulse down the cable. Sure enough, the oscilloscope showed the initial pulse followed by a strong reflection of nearly the same amplitude in 1.2 microseconds. Pointing to the reflection, Bill announced, “there’s the problem, just 1.2 microseconds away!”

“How far is that in feet?” asked Joe. Bill grinned. “I thought you would want to know that! Well, we know that signals in wires travel somewhat slower than the speed of light; in fact, every cable has a “velocity factor” that gives its speed rating as a percentage of the speed of light, c, which is 186,300 mi/sec. This is standard coaxial Ethernet cable with a velocity factor of 66%.”
Bill whipped out his pocket calculator.
“We have to convert the miles/second to feet/second by multiplying by 5280 feet per mile. Also, the distance to the fault is found by using half the measured time on the ‘scope, since the pulse has to travel that distance twice, both down and back.”
After punching in the numbers, Bill announced, “that means your fault is about 390 feet from here.” Joe pulled out his map of buried cables on campus and studied it closely, figuring out where 390 feet away would be.
Suddenly, he snapped his fingers. “I know! That’s right where the grounds crew replaced a section of broken sidewalk last month! They must have dug too deep and cut the cable!”
“Let me know if that’s what you find,” Bill said, packing up the equipment. Two hours later, Bill’s telephone rang. “I’ll buy you a cup of coffee tomorrow morning,” Dan said. “That was it, and the problem is repaired!”

<u>Questions for the Student</u>

1. Explain how Dan used good troubleshooting principles to narrow the scope of his problem to the buried cable.
2. Illustrate and explain how Joe knew that the cable was open using an ohmmeter.
3. Why couldn’t the location of the fault be accurately determined using an ohmmeter?
4. If the cable fault had been a dead short, how could an ohmmeter be used to determine an approximate location?
5. Draw a diagram illustrating Bill’s equipment setup and the cable-fault situation.
6. Verify Bill’s result of 390 feet with your own calculations.
7. Reduce the calculations required in case this problem were to be solved repeatedly; i.e., derive a simple formula that gives the distance to a fault in feet if the velocity factor of the cable and the total pulse travel time, in microseconds, are known.
8. Suppose that the velocity factor of the cable is unknown. How could the problem be solved if another piece of the same type cable, of known length, is available?
9. Suppose the velocity factor of the cable is unknown and no other cable is available for comparison, but both ends of the cable are accessible and its total length is known. How could the distance to the fault be found?
10. Suppose Joe had called back and said: “My boss said I can’t dig up that new sidewalk unless I can prove to him that the problem is there. I saw what you did but don’t understand it well enough to explain to him. Can you write a memo for him explaining why you think that the fault is there?” Write a memo to the Director of Buildings and Grounds explaining your determination, using technical facts to justify your position, but with enough explanation that a non-technician can understand them.
11. In the lab, use a long spool of coax cable and the test equipment available to duplicate this experience.

Instructor's Guide to Transmission-line Fault Location Case

Case Overview: this Case describes an actual incident involving a severed underground cable that had to be repaired rapidly. Only general electronic test equipment was available, but the technologist was able to provide a solution to the problem, which the Case describes. Though the theory behind the solution is quite technical, the explanation is presented in a manner suitable for Associate-level students. The complete solution (except for final calculations) is presented in the Case in an attempt to model successful technical problem solving for the student. The Case ends with a number of questions and exercises for the student.

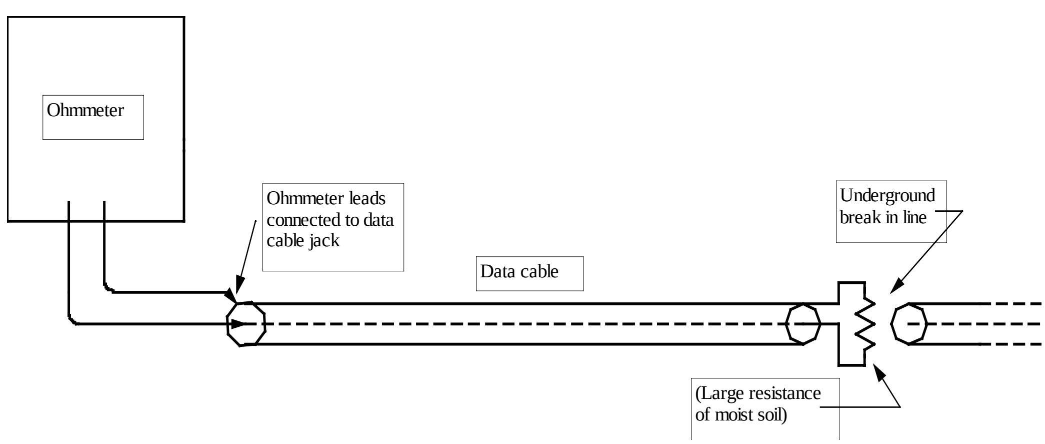
Learning Objectives:

1. The learner will apply, through a practical problem, the basic principles of signal propagation through cables.
2. The learner will observe good troubleshooting principles in practice.
3. The learner will utilize algebra and physics in the solution of data communications troubleshooting.
4. Application of basic test equipment will be reinforced for the learner.
5. An opportunity to practice Technical Writing will be provided.

Courses and Levels: This Case is intended for use in Electrical and Computer Engineering Technology courses at the Associate and Baccalaureate level. Ideally, the student should have studied the theory of Transmission Lines before reading this Case, but it is presented in a manner that it can be understood even without this background. A math background of algebra is needed.

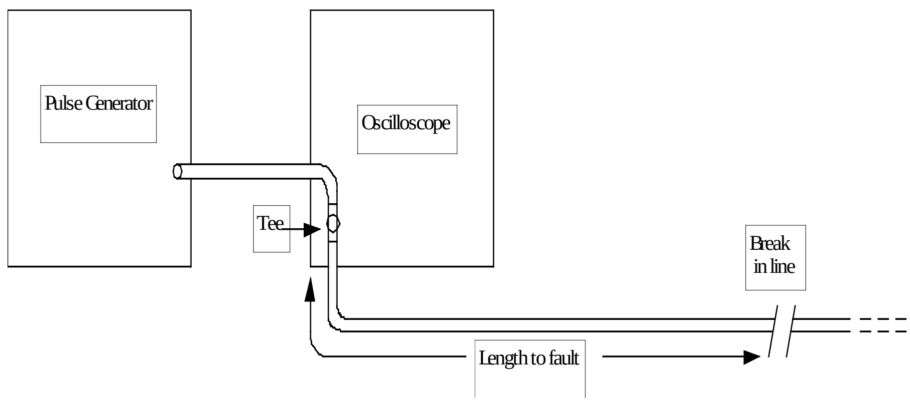
Solutions to Some Student Questions

- *Illustrate and explain how Joe knew that the cable was open using an ohmmeter*. With a 50-Ohm terminator across the remote end, a good cable's resistance as measured with an ohmmeter should be 50 Ohms plus the cable wire resistance, which can be accurately found in reference manuals or simply estimated to be a few Ohms, less than another 50 Ohms certainly. A shorted cable would read considerably less than 50 Ohms. An open cable would ideally read infinite Ohms, but moist soil can provide a path of a few hundred thousand Ohms. Illustration:



- *Why couldn't the location of the fault be accurately determined using an ohmmeter?* Theoretically, if one knew accurately the soil resistance, that value plus the wire resistance would provide a method of estimating distance to the fault. However, the soil resistance isn't accurately known, and in fact will likely change as ohmmeter current causes migration of copper ions from the end of the wire through the soil! Even if that weren't a factor, a few hundred thousand Ohms of soil resistance compared with a few Ohms of wire resistance would produce a meaningless difference.

- *Draw a diagram illustrating Bill's equipment setup and the cable-fault situation.*



- *Verify Bill's result of 390 feet with your own calculations.*
  D = V x T = VF x c x $T_{total}/2$ = .66 x 186300 mi/sec x 1.2 x 10^{-6} sec/2 x 5280 ft/mi = 390 ft

- *Reduce the calculations required in case this problem were to be solved repeatedly; i.e., derive a simple formula that gives the distance to a fault in feet if the velocity factor of the cable and the total pulse travel time, in microseconds, are known.*
  D = VF x c x $T_{total}/2$ = VF x 186300 mi/sec x $T_{total}/2$ x 5280 ft/mi x 1 sec/10^6µsec
  D (ft) = 492 x VF x T_{total} (µsec)

It is hoped that the reader will grasp the interdisciplinary approach of the case-study method for enhancing technology education, which can be refreshing to the student and an effective tool for the instructor.

The full case and its solution as well as supporting materials are available from SEATEC for dissemination (http://www.nsti.tec.tn.us/SEATEC/)

VII. Summary

SEATEC will continue to address the need to increase the number of technologically prepared workers by creating models for the development and delivery of work-based case studies to be used in engineering and information technology programs. SEATEC will become a resource for technological educators in two-year colleges, high schools, and universities by collecting and disseminating models for development and implementation of case studies in technology education. Students in these programs will benefit through exposure to case studies developed by inter-disciplinary faculty teams who have identified real-world problems during industry internships and site visits. These teams will provide students with exciting work-based problems that introduce and reinforce new technological applications, as well as build foundation knowledge in mathematics and science. Educators in other technical fields, such as basic physics education, are encouraged to apply the lessons that SEATEC is learning to develop case study problems focused on their disciplines.

VIII. Acknowledgements

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