SOME COMPUTER-BASED LEARNING TOOLS FOR UNDERGRADUATE ENGINEERING AND TECHNOLOGY EDUCATION PROGRAMS: DEVELOPMENT, USES, AND EXPERIENCE

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Abstract

For several years, the first author has directed a program involving the development of graphical, interactive software for use by students in Engineering and Technology programs. The pilot project, sponsored primarily by two foundations, was oriented toward two-year, community-college institutions as well as four-year universities. It has involved the development of three major instructional packages, provided on CD-ROM media, and the building of a small consortium of participating user institutions. Additional work, involving other related technical areas, is currently being sought under new support.

The philosophy of the project, and the technical descriptions of the three modules developed thus far, are briefly presented. Some discussion of the specific languages, tools, and techniques employed in program development is given. Dissemination procedures as well as evaluation strategies, forms, and questions are indicated. Some experience gained in the implementation of the resulting modules is cited. References outlining the detailed technical development of the modules are also given.

Introduction

The senior author and his colleagues at New Mexico State University (NMSU) and elsewhere have developed a philosophy and a set of comprehensive instructional modules for graphically illustrating certain concepts fundamental to Engineering and Technology courses. The basic concepts addressed thus far, which underlie much of Electrical Technology and other branches of the field to a lesser degree, include vector concepts, steady-state ac network analysis, energy-conversion, and electromagnetic systems.

Three major modules have been developed, as follows:
  Vector Vision, which provides interactive instructional and problem-solving resources for introducing and reviewing fundamental vector and complex-number concepts for lower-division Engineering and Technology students

AC Insights Plus, which introduces many concepts critical to both dc and ac circuit analysis with an extended coverage of transformers and an introduction to rotating machines and related topics, and

Fields Insights, which addresses basic electromagnetic principles with some energy conversion material.

Each of these modules has been discussed in previous papers [1-5], several of which were prepared during the actual development of the modules.

The present brief paper addresses this topic from the perspective of the completed project. Some highlights of the experience in developing and using these instructional aids is presented. Based upon the acceptance of the work, suggestions are made concerning future modules.

Background and prior related work

Prior to beginning the development of this recent set of instructional aids, the authors acquired considerable experience at New Mexico State University in the development of very applied demonstration software for industry training programs and for academic use in electric power systems education[5]. These have included demonstration and analysis packages, incorporating interactive animated color graphics, for investigation of rotating ac machine behavior under a variety of unbalanced (as well as balanced) operating conditions, software for illustrating steady-state synchronous-machine behavior, Fourier analysis and the Fast Fourier Transform, and power-systems relaying.

More recently, the authors and their graduate-student colleagues have concentrated on the production of more sophisticated, user-friendly, microcomputer-based instructional aids which **enhance student performance and participation** in early engineering and technology courses, and **provide problem-solving resources** that students can use as they progress through succeeding courses. The original project sought to address the following areas:

1) basic vector analysis
2) steady-state ac circuit analysis fundamentals
3) vector analysis of steady-state ac circuits
4) steady-state electromagnetic device behavior (including coupled-coil operation)
5) introductory power-systems and utility-related concepts
Additional topics, such as energy conversion and conservation, have recently been added to this list.

Programming language and characteristics

The language chosen by the authors for their earlier, successful related software[5] was the C language, because of its extensive interactive and graphics-display capabilities. However, examination of recent multi-media usage, and recently-acquired equipment and software to perform this kind of development, led to the use of the Visual C++ ™ (rather than C++) language. Visual

C++ has advantages over C in its ability to create programs which function in a very windows-like environment, including display of quality still-life graphics, animated graphical sequences with audio capability, and interactive features such as "buttons", scrollbars, HELP screens, higlighted clickable text, etc. In completing the development of the modules, software including Adobe Premiere ™, Director 6.0 ™, Camcorder ™, and Lightwave 3D ™ were also used.

As the modules were being developed, several objectives were established, as follows:
- Windows-based appearance and operation
- An eye-catching, informative introduction
- Animated audiovisual presentation format where appropriate
- Interactive tutorial and problem-solving capabilities
- Full mouse-driven interactive capability for each part of every module
- Delivery on, and easy installation from, CD-ROM media

Instruction is accomplished through presentation of historical and technical information, graphical demonstrations, and mathematical exercises. Users may scroll through tutorial materials, work example problems with default data or enter their own numbers, compare results of parametric calculations, match their skills to some historical electrical problem solutions, etc.

Usual Windows 95 ™ (or later) commands and procedures, such as minimizing, maximizing, or otherwise manipulating a window, may be invoked throughout the program. A HELP file is available at any time during module use. The software is designed so that students having a rudimentary knowledge of Windows 95 ™ may be able to navigate quickly and successfully through the entire package with little additional instruction (although many of these operations are also discussed in the HELP file). On-screen calculators, including one using reverse-Polish notation, allow the students to perform mathematical manipulations, including scalar addition, subtraction, multiplication, division, raising to a power, and complex-number calculations.

The modules use, where appropriate, the following:
- Real-time audio and video files and animated graphics
- Mouse-driven capability
- Display of still-life graphics
- Interactive questions and problem-solving sequences, with dialog boxes
- HELP files and animated HELP sequences
- Clickable text for ease of navigation cross-referencing and other purposes

Early versions of the modules in the series emphasized animated, audiovisual introductions. Comments from users have suggested that, while such presentations engage the students, the amount of disk space which they require (or the necessity of leaving the CD in its drive during program use) is a disadvantage. Consequently, the introductory animations were omitted in the final (electromagnetics) module. Animated video presentations find widest use in *Vector Vision* and are used in only the introductory material of *AC Insights Plus*. However, the latter, as well as *Fields Insights*, employs a considerable number of interactive examples, and the circuits module also contains animations of the sinusoid and rotating phasor.

Distribution of the modules is provided by means of CD-ROM. A **Setup** file is provided for each module, allowing it to be installed in a complete (including audiovisual files) or abbreviated (requiring the CD to remain in the drive) form. Several modules are typically provided on one CD.

Summary and content of completed modules

As mentioned earlier, the authors have completed three major instructional modules. Each of these, and especially the last two, have been revised and augmented extensively since the original descriptions have been published, partly in response to user critique. The modules are as follows:

Vector Vision provides interactive instructional and problem-solving resources for introducing and reviewing fundamental vector and complex-number concepts for lower-division Engineering and Technology students. It incorporates animated illustrative sequences, "talking-head" explanatory video files, audio messages, and graphical and analytical problem-solving capabilities. The software is designed for classroom and self-paced or demonstration use in mathematics, physics, engineering, and technology programs in two-year associate-degree-granting schools as well as in four-year institutions. *Vector Vision* is described in detail in reference [2].

AC Insights Plus is the largest and probably the most useful of the modules. *AC Insights Plus* is concerned with steady-state ac analysis, which represents the most wide-reaching of the concepts addressed in this group[3]. Primarily, this module provides interactive instructional and problem-solving resources for introducing and reviewing fundamentals of direct- and alternating-current circuit analysis. Primary topics addressed include, among other topics, the following:
basic electrical concepts
passive elements and sources
Ohm's Law
Kirchhoff's Laws
power (instantaneous, real, reactive, complex, apparent)
power-factor and power-factor correction
maximum power transfer
Thevenin's and Norton's theorems
power loss, efficiency, voltage regulation
multiple-source circuits
resonance
equivalence
star-mesh conversions
Other emphasis areas are included as well. The module begins with a discussion of units, prefixes, scientific notation, and powers of ten. This is followed by a direct-current review section, in which some of the fundamental laws, theorems, and concepts are introduced and explored. Major sections on transformer fundamentals (ideal, actual, and autotransformers), an introduction to electric power systems principles, and an extensive introduction to dc and ac rotating machines were added to later versions.

Fields Insights provides interactive instructional and problem-solving resources for introducing and reviewing fundamentals of electromagnetics. The approach and content were originally targeted to the freshman-sophomore level within the Engineering or Technology curriculum. As more material was added during its development, however, the relevance to junior and senior courses increased, as was the case with the *AC Insights Plus* module. It is structured so that the more advanced content may be omitted when used in a lower-division context.

Topics in *Fields Insights* include discussions of relevant SI and other units, definitions of a field, discussions of field quantities and mathematical dependencies, examples of field behavior such as gravitation, thorough discussions of electrical and magnetic laws and equations, and energy-related concepts.

Fields Insights is described in detail in reference [4].

Examples of module screen display

Because of space limitations, only two examples of module screen appearance will be presented.

Figure 1 shows part of an example, found in *AC Insights Plus*, illustrating one of Thomas Edison's early dc lighting systems. Students can change parameters and work through their "design" of this system, exploring possible alternatives and learning why the Edison interests chose particular lamp resistances, operating voltages, etc.

Figure 2.shows an illustration, found in *Fields Insights*, of the historical example of Joseph Henry's early nineteenth-century electromagnet. Students can recreate Henry's work (in a simplified setting), perform parametric studies, and compare the results. A discussion, outlining the historical and technical aspects of the problem, is first given. Following this, the interactive example allows students to explore the design of this historical device and to develop an appreciation of the validity of critical assumptions.

Dissemination, use, and evaluation

As stated earlier, the original primary objective in developing this program of instructional modules was to supplement and enhance education in Technology programs, primarily at associate-degree-granting institutions. Accordingly, partnerships were formed with more than a half dozen institutions [1,2] for the use and evaluation of the work. Other institutions ultimately elected to participate as well, including several four-year and advanced high-school programs. The material is also in use in electrical engineering, technology, and physics programs at the authors' university.
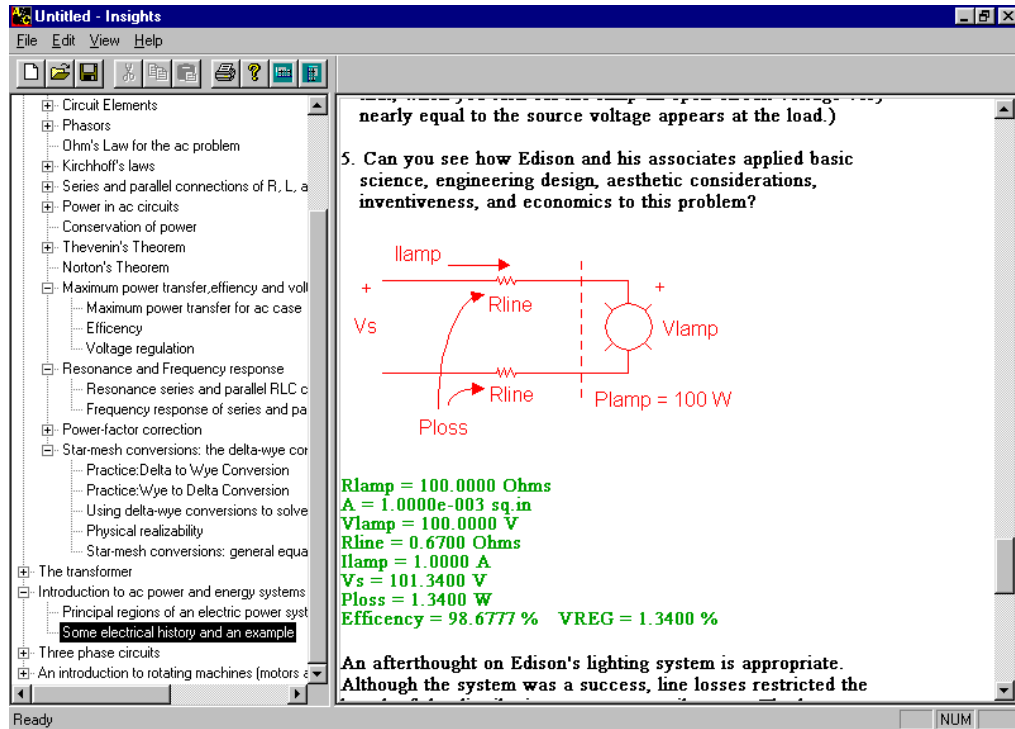
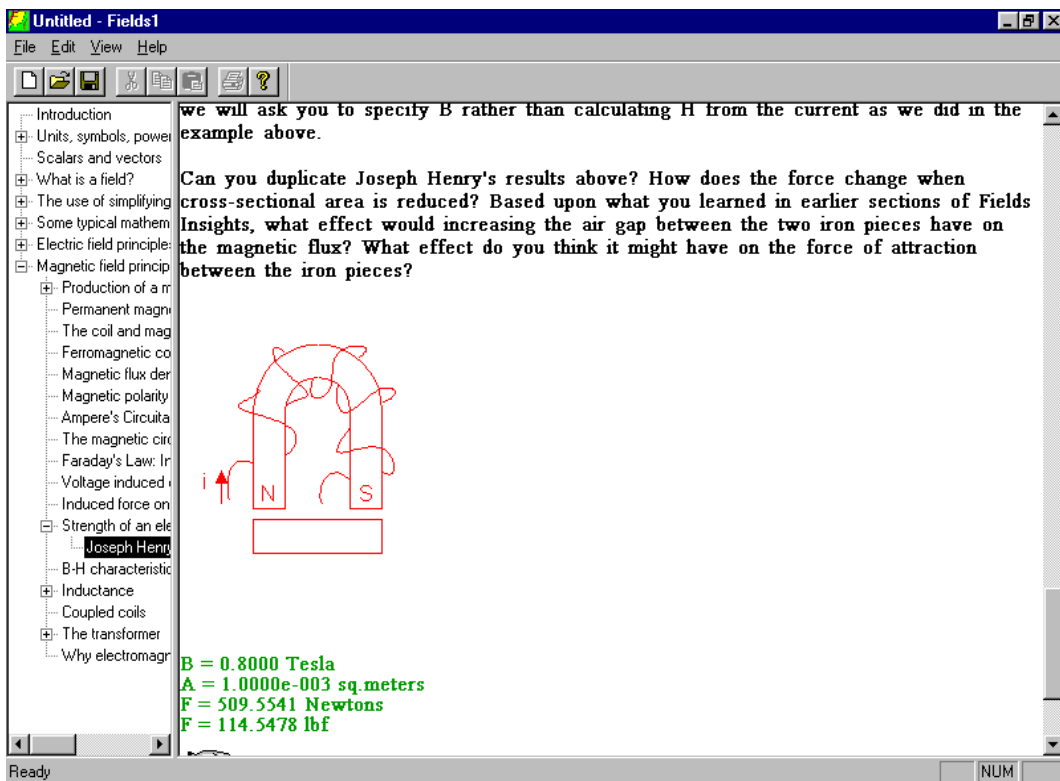**Figure 1. Interactive example of Edison system.**

Figure 2. Example: Interactive calculation of electromagnet strength.

The work has thus far been distributed on CD-ROM only. Since the effort has heretofore been considered developmental, progressively more complete, expanded, and corrected versions have been issued, in many cases modified or augmented in response to user comments and needs. The latest (Spring 2001) versions of the modules are distributed by an NSF-chartered consortium and are available for a small processing fee (see **Availability** below).

As the work progressed, more detailed and useful evaluation instruments were progressively developed. Appendix A shows, for example, a student evaluation form for the *AC Insights Plus* module. Similar forms were developed for the other modules, for assessing both student and instructor use. Comments obtained through these forms and through other feedback were continually used during the ongoing development/improvement process of module development.

Current plans call for developing similar modules in related areas, including energy conversion, conservation, and efficiency. The experience gained through conducting this project over a three-year period has been rewarding and, hopefully, useful for future efforts. The authors welcome comments from educators and others concerning the work already done or new possible directions for future related efforts.

Availability

The modules are available on CD-ROM from
MATEC
2323 W. 14th Street, Suite 402
Tempe, AZ 85281

Acknowledgements

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3. Howard A. Smolleck, Nadipuram R. Prasad, Barbara Powell, Bhargava Jayanti, Shakir Manshad, Sashadry Divakarla, "Development and use of a software learning tool for instruction in alternating-current fundamentals", <u>Proceedings of the Sixth Interamerican Conference on Engineering and Technology Education (Intertech 2000)</u>, June 14-16, 2000, Cincinnati, Ohio (on CD-ROM).

4. Howard A. Smolleck, Nadipuram R. Prasad, Barbara Powell, Bhargava Jayanti, Shakir Manshad, "An interactive instructional module for electromagnetics instruction for electrical engineering and technology curricula", <u>Proceedings of the Fourth International Conference on Engineering Design and Automation</u>, July 30 - August 2, 2000, Orlando, FL (on CD-ROM).

5. H. A. Smolleck, "The effective use of interactive computational demonstrators in electric power engineering education". <u>Proc. of the ASEE/IEEE Frontiers in Educ. Conf.</u>, Nashville, TN, Nov. 11-15, 1992, pp. 480-488.

HOWARD A. SMOLLECK received his BS, MS, and Ph.D. from the University of Texas, Arlington. From 1974-79 he was on the faculty of Old Dominion University, Norfolk, VA, and since 1979 has been with the Department (now the Klipsch School) of Electrical and Computer Engineering at New Mexico State University, Las Cruces, where he currently holds the rank of Professor. Dr. Smolleck's primary area is electric power systems. He is a member of Tau Beta Pi, Eta Kappa Nu, Alpha Chi, and is a Registered Professional Engineer.

BHARGAVA RAM JAYANTI was a graduate students in the Computer Science Department at New Mexico State University. His background is in Computer Science and Civil Engineering. Mr. Jayanti has recently accepted employment as a program development specialist at AMDOCS in Richardson, TX.

Appendix A
Student evaluation form for *AC Insights Plus*

Date_____
Course prefix and number_____   Name of your school_____
Major _____
How many engineering technology courses have you completed? _____

*The software package **AC Insights Plus** was designed primarily to help you learn alternating-current concepts in a meaningful, enjoyable way. It was intended, where appropriate, to supplement the material presented in the text and in the lecture, and to allow you to review at your own pace and help you do some of your homework calculations.*
Please answer the following questions by circling your best assessment for the scale given in each case. Your responses will help us improve the design of this and related products.

General observations on *AC Insights Plus*
1. How easy was it to start up the program and navigate through it?
very difficult 1   2   3   4   5 very easy

2. ***AC Insights Plus*** is organized in a modular fashion so that the user can pick and choose only those specific topics where he/she needs review. Is this more or less helpful than a comprehensive review where you must sit through all topics in some specific order?
not nearly as good as 1   2   3   4   5 much better than
the strict order approach   the strict order approach
3. How helpful were the interactive problem examples in providing interest/motivation?
not helpful 1   2   3   4   5 very helpful

4.How helpful were the interactive problem examples in providing an understanding of the concepts?
not helpful 1   2   3   4   5 very helpful

5. When accessed from the outline, each topic has an accompanying text section where a summary of the topic is provided. Did you read most of these?
1 yes   2 no

6. Was the text provided in each of these summaries helpful in your review or did you rely solely upon the interactive examples?
text most helpful 1   2   3 both helpful   4   5 interactive examples most helpful

7. How useful to you was the built-in Reverse-Polish calculator, with stacked entry capability?
not helpful 1   2   3   4   5 very helpful

8. How useful to you was the "standard" built-in calculator?

not helpful 1   2   3   4   5 very helpful

9. How useful was the dc circuit review for you?
not useful 1   2   3   4   5 very useful

10. How helpful do you feel a workbook would be for segments of this software in providing sample exercises in tutorial fashion?
not helpful 1   2   3   4   5 very helpful
The following questions are about your background in vector and complex number mathematics.
11. Have you ever performed complex-number addition and subtraction in a math or technology class before this one?
1 yes   2 no

12. Have you ever performed complex-number multiplication or division in a math or technology class before this one?
1 yes   2 no

13. Have you ever used polar-to-rectangular or rectangular-to-polar conversion in any of your classes before this one?
1 yes   2 no

14. What was your background in trigonometry before using AC Insights Plus?
no background1   2   3   4   5 very complete

For the topics below, please rate whether you feel the topics are covered adequately in AC Insights Plus or should be further developed.   The rating will be 1-5 where 1= needs more development such as more examples, etc., and 5 = the topic is very well clarified for the purposes of review. Circle the zero (0) if the topic doesn't apply to your studies or if you didn't read it.
15. DC review
1   2   3   4   5   0

16. Units, powers of ten, prefixes
1   2   3   4   5   0

17. The sinusoid (including animated display), rms quantities
1   2   3   4   5   0

18. Rotating phasors (including animated display)
1   2   3   4   5   0

19. Ohm's and Kirchhoff's laws
1   2   3   4   5   0

20. Power, reactive power, power factor
1   2   3   4   5   0

21. Transformers
1   2   3   4   5   0

22. Introduction to electric power systems
1   2   3   4   5   0

23. Introduction to three-phase systems
1   2   3   4   5   0

Relation of *AC Insights* to your education
24. Value to this course:
not useful 1   2   3   4   5 very useful

25. Value in enhancing your interest in the subject:
not useful 1   2   3   4   5 very useful

26. Relevance to your engineering or technology education:
irrelevant 1   2   3   4   5 very relevant

27. Overall, AC Insights added to my knowledge of electric circuits:
strongly disagree 1   2   3   4   5 strongly agree

28. AC Insights increased my interest in this course:
strongly disagree 1   2   3   4   5 strongly agree

29. AC Insights increased my interest in the engineering/technology area:
strongly disagree 1   2   3   4   5 strongly agree

30. AC Insights helped motivate me to continue in my present studies:
strongly disagree 1   2   3   4   5 strongly agree

31. I think that a software package like this one should be a part of each of my technical courses:
strongly disagree 1   2   3   4   5 strongly agree

32. Approximately how many hours did you use AC Insights outside of class? _____ hours total

Summary comments on AC Insights Plus
Please rate AC Insights in terms of each of the statements below:

33. Attractiveness, general appearance:
very unattractive 1   2   3   4   5 very attractive

34. Timeliness of the development of this product:
unnecessary 1   2   3   4   5 very timely

35. Mode of presenting material within AC Insights:
uninteresting 1   2   3   4   5 interesting

36. Quality of content:
poor 1   2   3   4   5 excellent

37. Quality of production:
poor 1   2   3   4   5 excellent

38. Your overall rating of AC Insights:
poor 1   2   3   4   5 excellent

39. Please feel free to give us any suggestions for improving or enhancing AC Insights:

40. Are there other classes where you think that a software package of similar format would be of value to you? Please list those classes, if any: