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Advantages and Disadvantages of Using Various Computer Tools in Electrical Engineering Courses

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***Abstract*—This paper discusses different computer tools used to help deliver, administer and teach the material covered in two basic undergraduate courses in Electrical Engineering. The computer facilities, programs, and tutorials developed are discussed; however, the paper concentrates more in analyzing the results of using these tools in the student learning process. The students' marks and the results of several student surveys, as well as the teaching staff's observations, are used to evaluate the usefulness of the different tools and determine their advantages and disadvantages. Some unexpected results regarding the actual students' use of these tools are also presented and thoroughly analyzed.**

Keywords: Computer learning, simulation programs, course administration, computers in lectures, student response.

I. Introduction

Computer tools to help professors and students alike in the teaching-learning process have become very popular in the past decade or so. Scores of articles can be found in the technical and popular literature referring to different software and hardware tools and the techniques to use them in learning environments [1, 2, 3], probably due to the great leap forward in the last few years in software and hardware development and their significant reduced costs. Most of these papers mention many advantages of using computer tools to improve the delivery of course material, and to presumably help students with their retention and understanding of this information.

In [4, 5, 6, 7, 8], for example, the authors discuss several software and hardware tools and how they are used, or could be used, to teach different aspects of Electrical Engineering. However, there is little reference in the literature to the possible disadvantages of using computer tools. In [4], the author comments on several possible pitfalls, which are also addressed in the current paper, concluding that the advantages fully outweigh the disadvantages. This conclusion, however, was apparently reached without direct feedback from the students. On the other hand, the authors in [7] mention that students replied very positively to on-line surveys regarding the usefulness of different computer tools; nevertheless, this conclusion was based on voluntary user surveys, rather than general student surveys. In [6], a particular software tool is said to have improved the student understanding of the course material, based on probable improved marks; however, very little data is given to support this conclusion.

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With all these ideas in mind, the authors of the current paper set out to use several commercial packages, which were easily accessible through the campus PC-network, to study the possible advantages and disadvantages of using these tools in the delivery, administration and understanding of two undergraduate courses. To determine the effectiveness and shortcomings of the computer tools, all students, regardless of their use of these tools, were asked to fill several questionnaires throughout the term. Furthermore, the students' performance was monitored and teaching staff's observations with regard to the students' use of the tools during tutorials were recorded, in order to help draw some conclusions. This paper reports the results of this study, with the intention of giving other colleagues a more realistic view of the benefits and limitations of using computers in the classroom.

Section II describes in detail the complete set-up of the test that was carried out, i.e., the courses, the software and hardware used, and the goals and means of using them. A brief description and comparison of the simulation packages used to develop several computer tutorials, and the reason for using them in the first place, are also discussed in this section. Section III presents and analyzes the surveys results, as well as the staff's observations and the students' performance in relation to their use of the available computer tools. Conclusions and recommendations are presented in section IV.

II. Description of the Study

From the current literature, three areas of application for computer tools in the classroom were primarily identified, namely, class administration, lecture delivery, and computer tutorials. In this context, the software, hardware, and mechanisms for their use are discussed in this section, considering the courses where these tools were used.

A. Courses

Two undergraduate courses were used as the "testing ground." These were, in chronological order:

1. *ME 269: Electromechanical Devices and Power Processing.* This is a second year, first term course for Mechanical Engineering students, to introduce them to basic ideas in magnetic circuits, electric machines and their controls. The material covered here is later used during co-op terms, when the students work mostly in industry, and in a third year course in control systems. The course has 3 lectures and a 2-hour tutorial class per week, with 3 lab sessions in the term. The class attending the last offering was made up of approximately 85 students.

2. *GEN E 123: Electrical Engineering.* This is a first year, second term, course for non-Electrical Engineering students, to introduce them to basic issues in linear and non-linear circuits. In Mechanical Engineering, it is a prerequisite for ME 269. The course has 3 lectures and a 1-hour tutorial class per week, with 4 lab sessions in the term. This course was offered to approximately 85 Mechanical Engineering students.

The University of Waterloo Engineering program is a co-op program, with students alternating between an academic term and a work term (4 months constitute a term), for a total of 6 working terms in industry and 8 academic terms on campus [9]; students are usually required to take 5 courses during their academic terms. The Mechanical Engineering undergraduate program has high admission standards, with a 1994 cutoff average of 86% in 6 high-school advanced

science courses [10], which is considered high in Canada. Therefore, the students participating in the study can be considered highly motivated.

The study was first carried out with the second year class (ME 269), and then, with what was learned, it was modified for the first year students (GEN E 123). The ME 269 students were compelled to use the computer tutorials and learn a simulation package by requiring them to do a project, which related to a transformer test done in the lab. On the other hand, the GEN E 123 students were motivated to use the tutorials and learn the simulation package by asking them to do an optional final project for extra marks, in a subject that was not covered in lectures.

B. Hardware

All of the software used for this study is available in the campus PC-network, known as WATSTAR. This is a DOS-based token-ring network with 1600 public and limited access terminals mostly dedicated to serve undergraduate students; 745 of these terminals are in Engineering [9, 11, 12]. WATSTAR has several ethernet gateways, so that it can reach and be reached through the Internet, mostly for e-mail and ftp purposes, although remote access to UNIX or other servers is possible through tcp/ip. It is interesting to highlight the fact that this network in Engineering, excluding operating system calls, is mostly used for Word Processing (43%), followed by mail (16%), and programming (15%); only 8% of the software activity is related to math and scientific applications, i.e., simulation. A class disk, which is typically dedicated read-only disk space in a WATSTAR server, was created to give students easy access to computer tutorials.

For presentations in class, a 486 PC-laptop and a LCD-screen were used mainly to discuss the simulation packages and computer tutorials, so that these could be directly linked to the subject presented in lectures. For the GEN E 123 class, tutorial sessions were run in a lab with computer screens in each workbench, which made the discussion of the computer tutorials and simulation packages easier to set up and follow than when using LCD-screens, as these have very specific demands on lighting. After the first experience with the ME 269 students, who were encouraged to use the simulation packages and computer tutorials on their own time, the GEN E 123 students were invited to work in a dedicated WATSTAR room during the tutorial sessions with the help of a teaching assistant. Since these tutorial sessions are typically dedicated to solving previously assigned problems with the help of teaching staff, the computer room was usually populated by students who had solved their problems in advance, i.e., the "top" of the class.

C. Software

In order to help with the administration of the course, and in particular with the communication between teaching staff and students, a news-group was created for easy access through WATSTAR. The news-group was chosen due its widespread use in Engineering, particularly Electrical Engineering, as this communication mechanism is less expensive than class e-mail lists, although is certainly less personal. This news-group was mostly used to let students know in advance of issues related to the course, such as course outlines, availability and mechanisms to access new computer tutorials, etc. In particular, the news-group was very useful in the assignment of problems with the corresponding answers, so that students could have extra time and a checking mechanism to work on these problems before tutorial

sessions. Students did not use the news-group to communicate with the rest of the class or with the teaching staff, using instead e-mail for these purposes, apparently due to the need of a more private medium.

Different simulation packages were chosen mostly due to easy accessibility through WATSTAR, and also due to their proven popularity and usefulness for introducing students to different subjects, e.g., [5, 7, 8]. A brief description of the three simulation packages and how and why they were used, as well as their shortcomings and advantages, follows:

1. *MATLAB* [13]. This is a powerful and versatile simulation software, very popular in industry and academia. It was originally designed for numerical analysis of linear control systems; hence, it is very well suited for numerical matrix manipulations. However, due to its flexibility in allowing direct programming and linking to FORTRAN and C routines, the package has grown immensely, with many added routines to allow numerical simulations of nonlinear systems as well.

   The major drawbacks of this program is its size and relative complexity; it takes some time to become familiar with its language and become familiar with several of the main routines needed for basic simulations. Equations must be handled in certain form and sequence, requiring the user to be familiar with the phenomena being analyzed, making it somewhat complex for inexperienced users. Furthermore, good comprehension of numerical analysis, linear algebra and linear systems is required, which makes it somewhat inappropriate for first year students, and sometimes difficult to understand for second year students. For these reasons, this package was only used for the second year class, i.e., ME 269.

   The University of Waterloo has a site-license for this program and related software, making it readily accessible through WATSTAR. The Department of Computer Services (DCS) gives regular introductory seminars to this package, so that students can easily learn the basics for its use in various courses.

2. *MAPLE-V* [14]. This is also a popular package, particularly at the University of Waterloo, where it has been developed and improved. As with MATLAB, this package and related software is also easily accessible on campus, with DCS giving regular seminars on its basic use.

   The program is a very powerful package, mainly designed to do symbolic computations. It is programmable and, therefore, very flexible. Its numerical capabilities are adequate; however, these cannot be considered its strong suit. One major problem is its complexity, particularly with regard to notation, which is somewhat inconsistent; it certainly takes a lot longer to master than MATLAB. Furthermore, as in MATLAB, problems have to be solved sequentially and in a given form, i.e., the manner and order in which the equations are solved makes a difference, requiring the user to be familiar with the subject under study; hence, it is not very adequate for freshmen students, at least not for certain simulation purposes. This program was only used in ME 269.

3. *EES* [15]. This is not a popular software, but it is certainly very adequate for simulation purposes. It was developed at the University of Wisconsin, as an "improvement" to an existent package called SOLVER-Q [16]. This short program allows the user to solve numerically sets of nonlinear and/or differential equations simultaneously,

with no regard to the order of the equations, which together with uncomplicated notation and simple to use pull-down menus makes it very easy to learn and use; the user simply inputs the equations practically as he/she would write them on paper, and proceeds to solve them through the use of menus. For all of these reasons, it was the preferred software by the ME 269 class, as reported below, and, consequently, it was chosen as the simulation package for the GEN E 123 group.

Although some programming can be done within the package, it is of very limited scope. Other major shortcomings are its limited graphics capabilities and its low reliability, i.e., it often crashes without apparent reason. Some basic knowledge of numerical methods is required, although not fundamental; for certain problems, it is important to understand how the program proceeds with its calculations in order to be able to obtain a reasonable solution.

As with MATLAB and MAPLE, the University has a site-license, which makes the program easily accessible.

For a detailed comparison of these programs and particular examples of their use, the interested reader is referred to [8, 17].

D. Tutorials

Based on the simulation packages described above, several computer tutorials were designed for each course. The main goal was to create self-contained tutorials that would allow the student to review important equations and concepts discussed in lectures, through personal unsupervised use and presentations in class. The tutorials below were developed for the ME-269 class in MATLAB, MAPLE-V, and EES to give students a choice of simulation package and to allow the teaching staff to determine the advantages and disadvantages of the different programs.

a. *Phasor analysis*: A simple R-L circuit was used to illustrate the advantages of phasor analysis versus time domain simulation.

b. *Transformer dynamics*: Energization of a loaded single-phase transformer without considering saturation. The parameters of the transformer are calculated from the open-circuit and short-circuit tests. In this case, the differential equations had to be converted to matrix form for MATLAB and MAPLE-V.

c. *Transformer saturation (project)*: Energization of an unloaded single-phase transformer considering saturation (in-rush currents). The core saturation was modeled by both a piecewise-linear function and a continuous nonlinear function. Piecewise-linear saturation produced some numerical problems in EES, and was impossible to implement in MAPLE-V. The data in this case was obtained from direct lab measurements.

d. *Transformer efficiency*: Efficiency versus load graphs were obtained for a single-phase transformer at different power factors. This problem was extracted directly from the textbook to give the students a sense of a useful direct application of the simulation packages.

e. *DC generator*: V-I characteristics of a dc shunt generator using a piecewise-linear saturation curve.

f. *Induction motor*: Steady state torque-speed characteristic of a three-phase induction motor.

Based on feedback from students and teaching staff of ME 269, only EES was used to develop the computer tutorials described below for the first year GEN E 123 class, as this was the preferred simulation package due to its simplicity and short learning curve, with enough computational power to handle the type of simulations required.

a. *Nonlinear equations*: The parametric solution of a set of nonlinear equations was used to introduce the main features of the simulation program, including tables and graphics, during a tutorial session.

b. *KVL and KCL*: Voltages and currents of a textbook resistive circuit were calculated for dc and ac voltage sources.

c. *Differential equations*: A textbook R-L-C circuit was used to set up and solve the corresponding differential equations, for dc and ac sources, assuming zero initial conditions.

d. *Circuit transients (optional project)*: An R-L-C dc circuit out of the textbook was used to obtain the voltages and currents for a series of switching events.

e. *Superposition*: A resistive circuit from the textbook was used to demonstrate the principle of superposition with an ac voltage source an a dc current source.

f. *AC circuit*: An R-L circuit was used to demonstrate the advantages of phasor analysis versus time domain analysis.

g. *Active filter*: The output signal of an OPAMP band-pass filter was calculated at different frequencies for a square-wave input voltage. The input signal is modeled using a finite number of terms of the corresponding Fourier series.

h. *AC/DC rectifier*: An ac/dc rectifier bridge was solved using the basic nonlinear equation of a Ge diode to obtain the voltage in an RL load with capacitive filtering.

III. Surveys

To determine how the computer tools were being used and whether these were actually helping in the understanding of the course material, students were asked to answer several questionnaires throughout the term. The ME 269 class was given three surveys, at the beginning, middle and end of the term, whereas the GEN E 123 group was asked to fill out only two, one at the beginning and one at the end of the course. The final questionnaire for the ME 269 class is presented in the Appendix, to give the reader a clear picture of the types of questions being asked.

The surveys for both classes were rather similar. The first one concentrated on determining the students previous knowledge of software and computers, with particular interest in their familiarity with and use of communication and simulation packages. The questionnaire included a question on the students expectations of the use of these packages in the course, to later compare with their actual observations and use of these tools. Table I shows the students' answers to the main questions in the survey; observe the higher rate of response from the second year students, which

TABLE I

Results of initial survey in %

	ME 269	GEN E 123
Participation	90	46
Familiar with WATSTAR	90	76
Familiar with e-mail	68	75
Familiar with news-groups	23	33
Familiar with EES	0	0
Familiar with MATLAB	2	5
Familiar with MAPLE-V	6	15
Simulation packages were helpful	88	91
Computer used for word processing	61	67
Computer used for programming	13	20
Computer used for data analysis	19	6
Computer tools would be helpful	90	100

the authors believe should have no bearing on the final results. Several important conclusions can be drawn from these results. First, the majority of the students were familiar with the hardware, and a relative large number of them were used to computer communications. Few students had used simulation packages before, and these few considered this type of software useful. Computers were mostly used for word processing, which agrees with the actual use of WATSTAR on campus, as indicated before. Finally, the great majority of the students felt that using the news-group and simulations packages in the course would be helpful.

The results of the final questionnaire are summarized in Table II for both courses. Notice again the higher response from the second year students. Interesting conclusions can be extracted from the students' answers, some of them somewhat unexpected given the apparent positive disposition from the students towards the use of computer tools in the course, as demonstrated on the first survey. First of all, familiarity with the hardware from their exposure to it through the course significantly improved, particularly for the first year students who were also exposed to the network in other courses. One can also observe that a significantly larger number of second year students than first year students used the news-group, although only slightly more than half of both classes thought that it was useful. However, these results could justify the use of news-groups in a regular basis in future courses, since it does not require much time from teaching staff. Furthermore, it is clear from the surveys' results that more ME 269 students used the simulation packages as opposed to the first year class, which could be reasonably attributed to the simulation project which was compulsory for the ME 269 class and only optional in GEN E 123. Notice the clear preference of the second year students for EES, even though no one was familiar with this software; this could be credited to its relative simplicity, which was the main reason for choosing this package for GEN E 123. Half of the group that used

the simulation packages the most, i.e., the ME 269 class, considered these programs helpful, as expected; the majority of GEN E 123 students felt that these programs were not helpful, but at the same time they were not very familiar with the packages and tutorials. The surveys' results also show that very few students planned on using the simulation packages in the future, which is rather inconsistent with both their initial and future expectations of these programs.

With regard to the computer tutorials, more second year students were familiar with at least one computer tutorial than the first year students, which is to be expected due to the different requirements in the project, and it is also consistent with their use of the simulation packages. Also, about half of the ME 269 class thought that the computer tutorials were interesting and helpful, whereas a lower number of GEN E 123 students felt that the tutorials were helpful; this difference could again be attributed to the distinct use of the simulations packages by both classes. Finally, a relatively large number of students thought that the computer demonstrations and discussions in class of the tutorials were interesting, with a smaller number of students thinking that it was useful. These results were somewhat surprising, given the apparent attractiveness of computer presentations, assuming that the presentations were well structured and properly delivered; however, the results could be explained based on the students' preference for trying to solve the problems on their own, at their own pace.

Notice that a relatively large number of students complained of lack of time to use the computer tools, whereas only a small group indicated no interest in them. This might justify the marked difference between the actual students' use of the computer tools and their past and future expectations, and brings out the issue of a probably overloaded curriculum.

It is important to mention that an intermediate questionnaire was given to the second year students before the project was due, and the results indicated significant less familiarity with the simulation packages and tutorials than what it was observed in the final survey. This might also help explain some of the differences one sees between the results of the final survey for the ME 269 and GEN E 123 classes, since this survey was carried out for the first year class before the optional project was due.

In addition to the surveys, the teaching staff tried to monitor the students' performance in relation to their use of the simulation packages, based mostly on observations and project marks. These results were inconclusive, i.e., it was not possible to directly tie final marks to the use of the simulation packages. Nevertheless, the "top" students, which were people with marks above 90% and represented about 10% of the class, demonstrated interest in the computer tutorials and consistently used the simulation packages throughout the term; however, one could not conclusively argue that their performance would have been any less stellar had they not used these programs.

To finish this section it is appropriate to mention that a significant number of person/hours were dedicated to preparing the tutorials and setting up some of the hardware and software used in this study. To give the reader an idea, the computer tutorials took a person an average of approximately 6 hours to set up and check. Thus, if one considers the time expended in marking the simulation projects, preparing the computer presentations in class, and supervising the use of the programs, the cost/benefit ratio most certainly becomes an issue when considering the use of these tools. In the study presented here, research and funding were important motivational factors that are not always present. Moreover, one should not forget that these tools also require extra time from the students, particularly

TABLE II

Results of final survey in %

	ME 269	GEN E 123
Participation	73	60
More familiar with WATSTAR	71	92
Use WATSTAR in other courses	47	96
Use of news-group	70	44
News-group was helpful	56	51
Use of EES	82	60†
Use of MATLAB	5	—
Use of MAPLE-V	21	—
Plan to use simulation package in the future	10	16
Simulation packages were helpful	50	21
Familiar with at least one computer tutorial	79‡	60†
Computer tutorials were interesting	46	50
Computer tutorials were helpful	55	37
Class demos were interesting	60	54
Class demos were helpful	44	50
Lack of time to use simulation tools	40	54
Not interested in using computer tools	8	9
Future use would be helpful	84	83
Tools should be used in other courses	66	74

† Estimate based on optional final projects turned in.

‡ Tutorial closely related to required project.

in learning the simulation packages and familiarizing themselves with each tutorial.

IV. Conclusions

A detailed description of a study to determine the advantages and disadvantages of using simulation software in Electrical Engineering courses has been presented. The tools used to administer and deliver lectures, and help students in their understanding of the course material have been discussed, and, most importantly, the students' observations on the effectiveness of these tools and their actual use of them are reported and analyzed in detail.

Although one could argue that the survey results presented here show a relatively good acceptance from students of computer tools in the classroom (40–50% range), it is clear that the majority of the students seem to shy away from using them for a variety of reasons, but particularly due to a probably overloaded curriculum; students seem to prefer standard ways of lecture delivery over new mechanisms that require some extra work. The surveys show that there is a significant difference between students' and teaching staff's expectations of the benefits and use of computer resources in the teaching-learning process, and what it actually goes on in the classroom. These results also demonstrate that the students' use of simulation tools do not just happen voluntarily as one would expect, on the contrary, students have to be academically compelled to use them.

Based on the study results and the authors experience, one should consider carefully the use of simulation packages in Engineering courses. The costs, in terms of time and resources, have to be weighed against all probable benefits, taking into consideration the large initial investment.

Appendix

Final survey for second year students (ME 269):

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1. Do you feel more comfortable now with WATSTAR?  (Circle one.)

   YES          SOME            LITTLE          NO


2. Did you use WATSTAR in any of your other courses?

                YES             NO

   If yes, which course(s) and what program(s):_____________________
   ________________________________________________________________


3. For ME-269, which one of the following packages you used?
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	NO	LITTLE	SOME	REGULARLY
a) NEWS:	0	1	2	3
b) EES:	0	1	2	3
c) MATLAB:	0	1	2	3
d) MAPLE:	0	1	2	3

4. Do you think that the use of the news-group helped to improve the communication with the Prof. and/or the administration of the class?

   YES SOME LITTLE NO

5. Which one of the following simulation packages did you use for the project?

   EES MATLAB MAPLE

6. After using these programs, which simulation package you liked the most (circle ONE):

   EES MATLAB MAPLE

   Because (circle your choices):

   a) User friendly

   b) Simple to understand

c) Powerful (speed, graphic capabilities, etc.)

d) Easily available

e) Used in other course

f) Plan to use it in the future

g) Others:_____
_____

7. Did the use of these programs help you in better understanding the material discussed in class?

YES SOME LITTLE NO

8. Are you familiar with any of the following tutorials?

	NO	LITTLE	SOME	YES
a) Phasors (I)	0	1	2	3
b) Transf. dynamics (II)	0	1	2	3
c) Transf. efficiency (III)	0	1	2	3
d) DC generator (IV)	0	1	2	3
e) Induction Motor (V)	0	1	2	3
f) Transf. Saturation (Proj.)	0	1	2	3

9. In general, you think that the tutorials were (circle one for each

category):

	NO	LITTLE	SOME	YES
a) Understandable	0	1	2	3
b) Useful	0	1	2	3
c) Interesting	0	1	2	3
d) Challenging	0	1	2	3
e) Related to course	0	1	2	3

10. Did these tutorials help you understand better the material discussed in class?

YES SOME LITTLE NO

11. Were the class computer demos interesting?

YES SOME LITTLE NO

12. Were these demos helpful in clarifying the material discussed in class?

YES SOME LITTLE NO

13. What were the major difficulties you had regarding the programs and tutorials ? (Circle your choices.)

a) None

b) Lack of time

c) Too many programs

d) Too many tutorials

e) Difficult access to a computer

f) WATSTAR too slow

g) Not interested

h) Others:_____
_____

14. Do you think that continuing the use of all these resources in future ME 269 classes would be:

HELPFUL SOME LITTLE WASTE

15. Would you like for the Profs. to use these resources in other courses in a regular basis?

YES SOME LITTLE NO

16. Any additional comments and suggestions would be appreciated. We are particularly interested in hearing any ideas that you may have about how to improve the use of all these resources for future classes.

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