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Interactive Outcome-Based Assessment Using Multimedia*

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In this paper we will attempt to describe how a self-paced interactive teaching method is used in a power electronics course, embodying many new presentational techniques. A discussion of the assessment objectives and outcome measurements over a period of 6 years will be given.

INTRODUCTION

DESPITE THE ROLE of computers in our educational environment and the extensive use of web-based resources, the instructional tools available to modern instructors are very limited. Moreover these tools are basically used with conventional teaching techniques, where the electronic presentation replaces the conventional blackboard and overhead projector.

The most used technique to present new material follows the 'flip chart technique'. If one wants to incorporate sound and animation it becomes very time consuming to produce and more so to maintain. It is certainly a good method of presentation, and students can flip through the presentation later and refresh their memory. Also they can usually branch to local testing modules and come back to the original stream of presentation. However this kind of instructional tool simply replaces the overhead transparencies (made more 'techy') but still achieves only 'one way' teaching termed as 'passive', where students only 'listen'.

Animation techniques in such presentations make it more comprehensive, especially when explaining a sequence of events such as a circuit in electronics. The inclusion of photographs of real equipment, for instance oscilloscope traces make the instruction more effective, but it is still limited to 'passive' learning.

PLATFORM

We have chosen the platform distributed by Asymetrix (ToolBook) as our development platform for several reasons. First it is very much user friendly, and one can use it to gain a sharply rising learning curve. Secondly, the highly object-oriented approach of the package allows extensive re-use of components, pages, animation modules, etc. Finally it is very flexible and uses a basic script oriented language. Debugging, testing, maintaining and expanding is very easy. If one needs much more support than the package allows, for instance in dedicated applications where one needs to simulate a system, direct C language modules can be produced, transformed into either spawned runtime modules, or made into DLL's (dynamic loaded libraries). The functions can be called directly from the scripting language assuring fast response. Because of the interpretive way the modules execute, one can easily step through sequences, check for accuracy or modify on-line, making the process of development very user friendly.

We have developed presentation templates with a library of script functions as well as a library of mathematically oriented functions such as Fast Fourier analysis, electrical circuit equations, etc., making the production of teaching modules very easy to develop rapidly. Typically once a module has been planned, organized, material gathered (which is a normal procedure for any presentation), it takes about two days to finish a 20-minute module and distribute to the class. Distribution is either done on CDs or downloadable from the course website. Files are in the order of magnitude of 1Mb as compressed files, hence even standard low-speed access network makes it rapidly retrievable.

Presentations rely on several combined techniques. The sequencing of the modules is synchronized with a sound track. Also, the sound track is synchronized with a 'comment field', so that you can either listen to the comments, or read them as you prefer, or both. You may also repeat either of them. Typically the developer will first type in the text of the comments, and when the module is finished, he will step through the module and read the comments and record them. These sound files, after editing, are invoked by the router program, which synchronizes the sound to the comments and the presentation sequences. It is important to understand at this point that the sequence of

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presentation need not be linear, like in a power point presentation. The examples shown in this paper will illustrate the self-paced 'active' learning path of a student.

PRESENTATION TECHNIQUES

Phase sequential description

Figure 1(a) shows a typical example of such method. Note the comment box at the bottom (the text seen actually is 'typed out' at reading speed). Clicking on the audio icon triggers the sound (also triggered automatically on page entry). When the hot words are clicked on, panels display the respective equations and solutions. When the button 'close switch' is clicked on, a stepped animation follows as shown by Fig. 1(b). Here one notices several information sources. The traces and color coordination is important (red voltage, blue current) and some of the box comments that appear during the animation in addition to the bottom comment (and voice) as if one would explain 'on the fly' a sequence of events. Figure 1(c) shows the progression as 'Continue' is pressed. The student can reset the presentation and step through it as often and as long as he or she wants until principles involved are thoroughly understood.

Interactive graphical presentations

After presenting the material using the sequential tree approach, a set of tutorials can be chosen by the student. Figure 2 shows a typical tutorial which should give a 'guts feel' for an RLC circuit excited with a step voltage. The student can interactively use a ruler and choose various parameters. He could also select a value and key it in. Immediately there is a response of the system he can see the circuit diagram with the corresponding elements, and the time response of the circuit is shown. The student will therefore 'play' with the values and get a feel for the various effects when varying the parameters. For instance, if one sets $C = 0$, the circuit shows only an L and R exponential rise, and labels it 'exponential' dynamically. This method of 'feeling the concept' is invaluable in many of the key elements of teaching general principles.

Laboratory support module

Figure 3(a) shows a screen where you may click on a list of equipment that will be used by the student. A picture of the equipment is displayed, and some comments, showing connections for instance, are indicated. Figure 3(b) shows the actual electrical diagram of the circuit as is appears in the laboratory book, and the experiment as it lays on the table. Using color-coded arrows, the wiring diagram is shown on both circuit and equipment. Finally Fig. 3(c) shows the expected oscilloscope traces to be observed and commented on in the laboratory. Typically students prepare their labs at home, and using this interactive display can familiarize themselves with the look of the equipment and the expected results. This allows them to use the laboratory time to fully concentrate on the engineering aspects and interpretations of results, rather than 'fight the equipment' during hours. Practically these three-hour laboratories used to drag out to as much as five hours because of the connections and equipment problems. Also, since the traces observed are always very much different from the theoretical mathematical responses the students used to spend a lot of time wondering whether their traces were actually correct or resulting from some wrong connection. With this multimedia support, labs never extend past the three hours, and are often finished ahead of time, and the laboratory reports are much better in engineering analysis content and student understanding.

ASSESSMENT

Calculations

Commonly used assessment techniques implemented in learning packages include calculation questions. The student is given a simple problem, usually the application of an equation, and he has to perform calculations. The numerical answer is then compared with the solution computed by the builder of the software. This is rather limited in scope. The accuracy of the answer is usually not taken into account. For instance, if an engineering problem leads to a current of 2.5 A, the standard answer of 2.5342567 A is also accepted. This is actually worse than computing the wrong number, because the student does not get the feeling for number of significant figures. In fact, giving such an answer proves that he does not understand the problem. Furthermore, he knows only if it is 'correct' or not.

In our system we also use calculations; however the problem is streamed in steps. The student has to feed in the partial calculations and is guided along the way. When he gives a 'wrong answer', hints for correcting it are also given. For instance if he gives too many significant figures, he is told that that's what is wrong, and explained why it is wrong.

Standard packages will give you an assessment of 8/10 questions right! This gives a false impression of assessment. The two questions with the wrong answers may be the key ones, which prevent the student from understanding the whole concept. In our system, we do not care how many times a student repeats a portion of the problem, as long as he does it once correctly. Every time he has a new attempt at the same question, new parameters are given, so he has to repeat all the calculations and steps. He is not allowed to proceed to the next step until he has thoroughly proven that he knows the subject and understands the step. In this way,

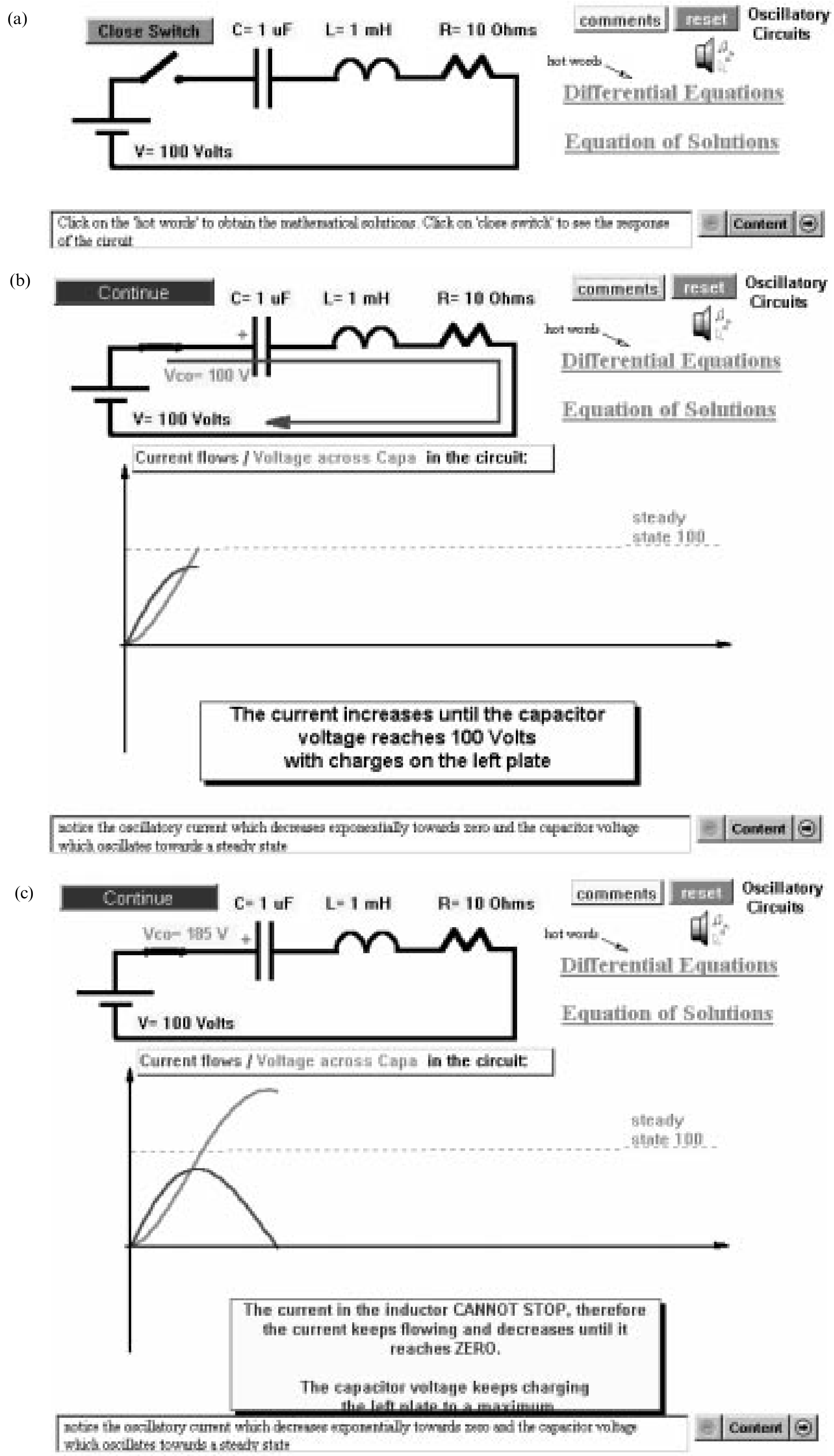


Fig. 1. Phase sequential presentation technique: (a) basic display; (b) first sequence display; (c) second sequence display.

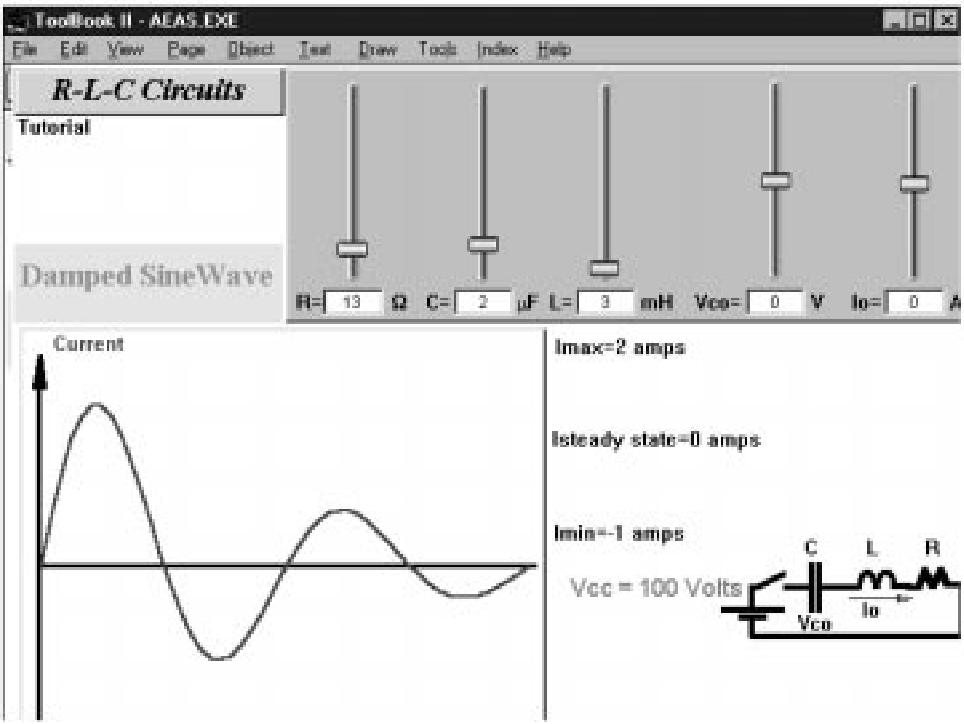


Fig. 2. Interactive tutorial with graphical interface.

you do not need a numerical assessment: everybody ends up ‘perfect’.

Multiple choice

This is a commonly used assessment technique, which of course makes marking large classes very convenient. In our experience, we have conducted many tests with this method and found it to be a complete passive assessment. The big problem is what does the student remember after the test? We have tried to give a multiple choice question, and when the student does not find the right answer, the correct answer is displayed (similar to all learning packages). A few days later exactly the same test is administered, but this time the order of the answers are randomly mixed. 8/10 answers become wrong because the students remember the correct sequence, say (c), but do not remember the meaning of the answer any longer. In a different set of studies, the test was given in the normal way, and immediately after, the students were given answers to some sample questions and were asked to state what the question was. Not one single student could remember any one of the questions. This should prove that multiple choice testing results in passive knowledge checking, it is often confusing, and to our judgement has very little pedagogical value. We have completely removed this technique from our methodology.

TRUE/FALSE

Again our studies in this field have resulted in a passive learning experience. If there is a sufficient number of questions, any student can obtain 50% by simply guessing. Using a little common sense will lead him in the 75% range, but after such a test if one tests orally for instance the student, it can be shown that the knowledge of the concept tested has no relation to the score obtained. It can work either way actually. Again we rejected such an assessment tool.

Value of scores

This brings the philosophical value of scores into perspective. What is the value of a score? What is the aim of the exercise?

If the aim of a learning module is to ‘mark’ a student, then it has no value in itself. If the score is the motivator behind the exercise to be done, then one fails a basic pedagogical goal. If we can motivate the student to learn, we do not need to mark him, because he will learn the material, and that is in itself the ultimate goal. All our techniques used strive to that effect: motivate the student, have him put the effort in the learning.

INTERACTIVE QUIZ

We have developed a series of techniques to invite the student to ‘play’ with a question, hence emphasize the motivation and stimulate his interest. Once he has done the exercise correctly (and he cannot proceed until he has the correct answer), he should fully understand the material and hence the pedagogical goal has been reached.

Graphical area identification

In Fig. 4, one wants to find out the precise point at which the thyristor stops conducting. When the

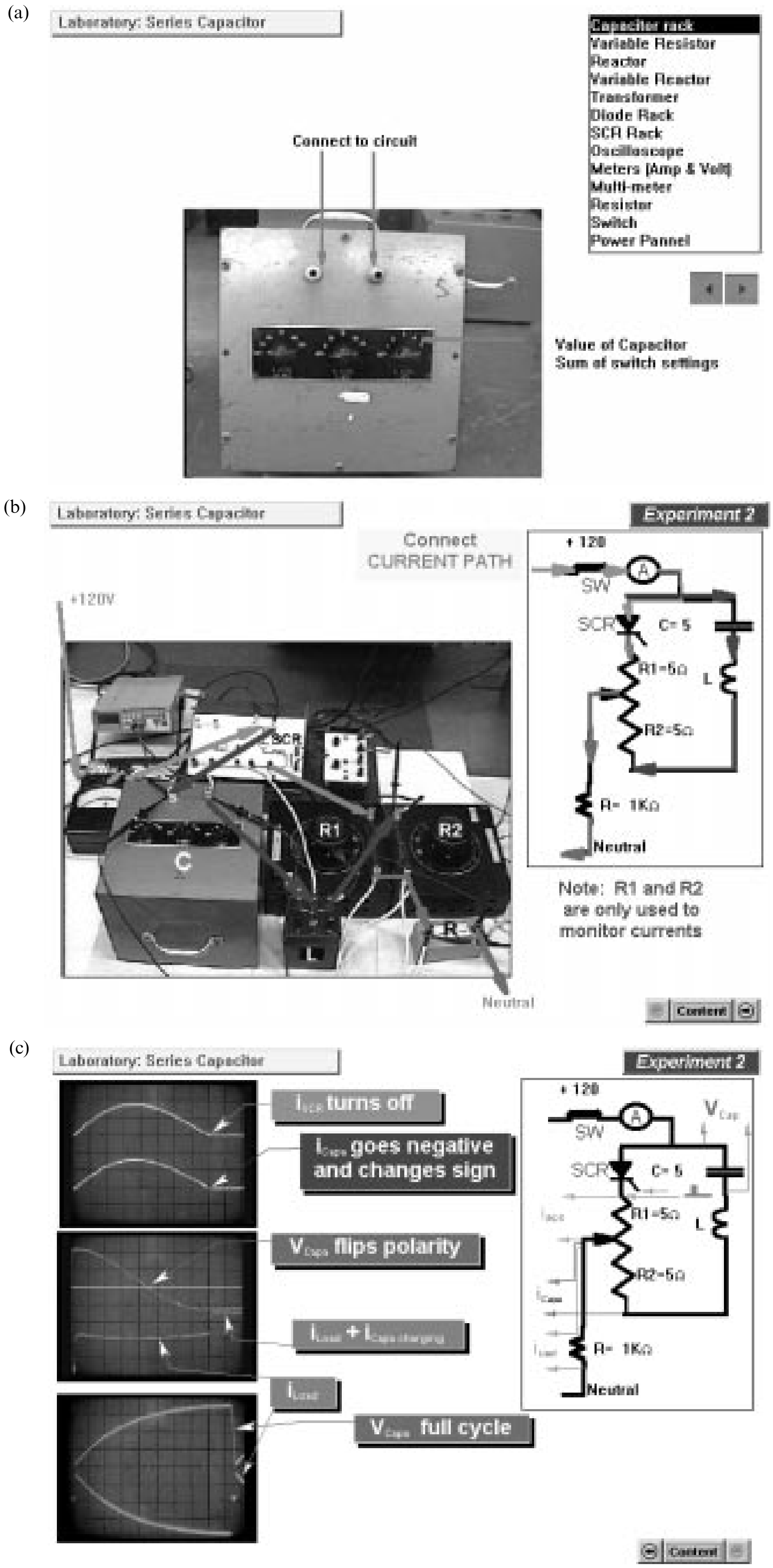


Fig. 3. Laboratory equipment support: (a) laboratory equipment; (b) wiring instructions; (c) oscilloscope typical display.

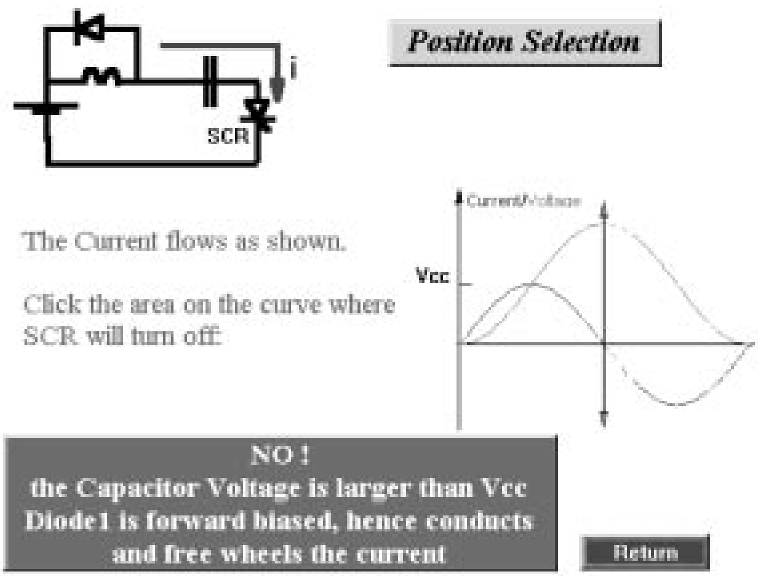
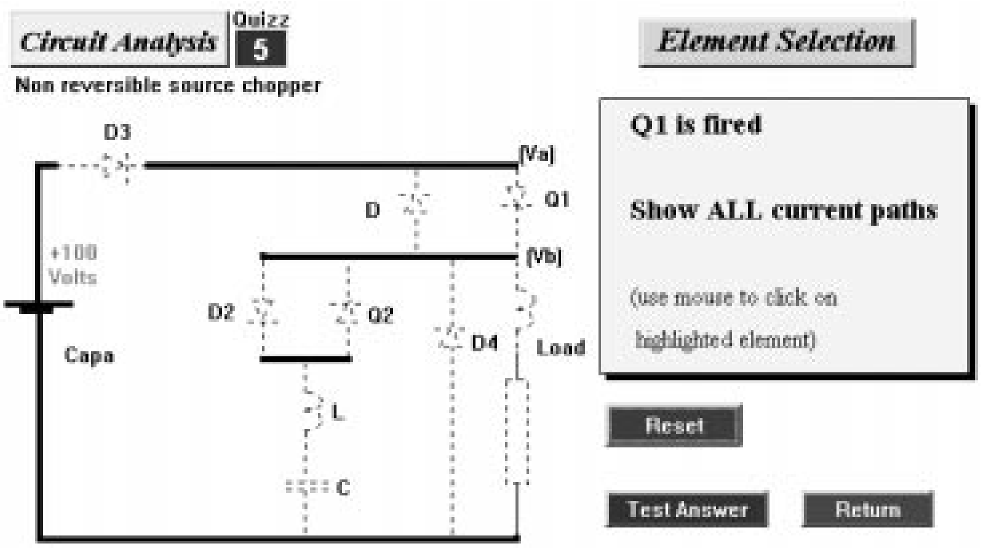


Fig. 4. Graphical interaction for position detection.

(a)



(b)

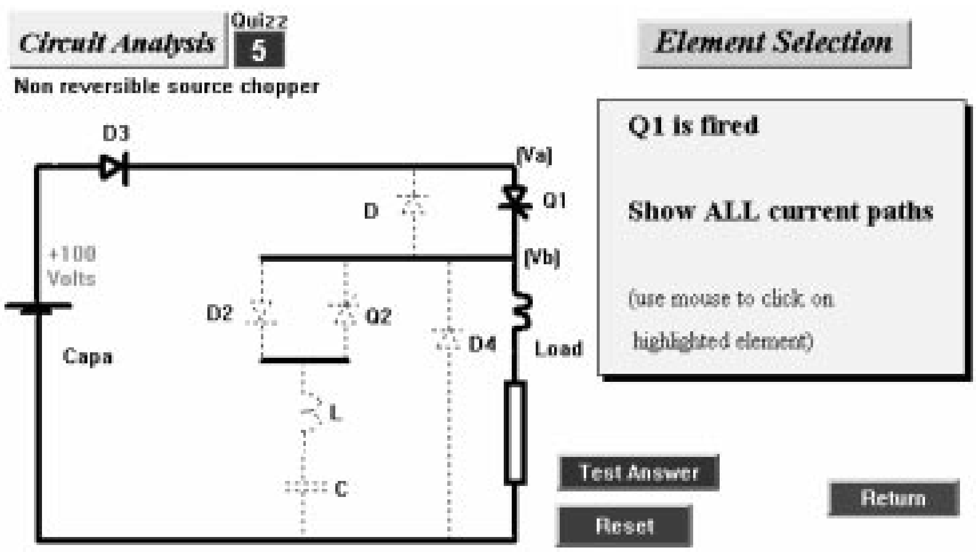


Fig. 5. Selecting a path: (a) graphical interaction for element detection; (b) path selection with elements.

(a)

(b)

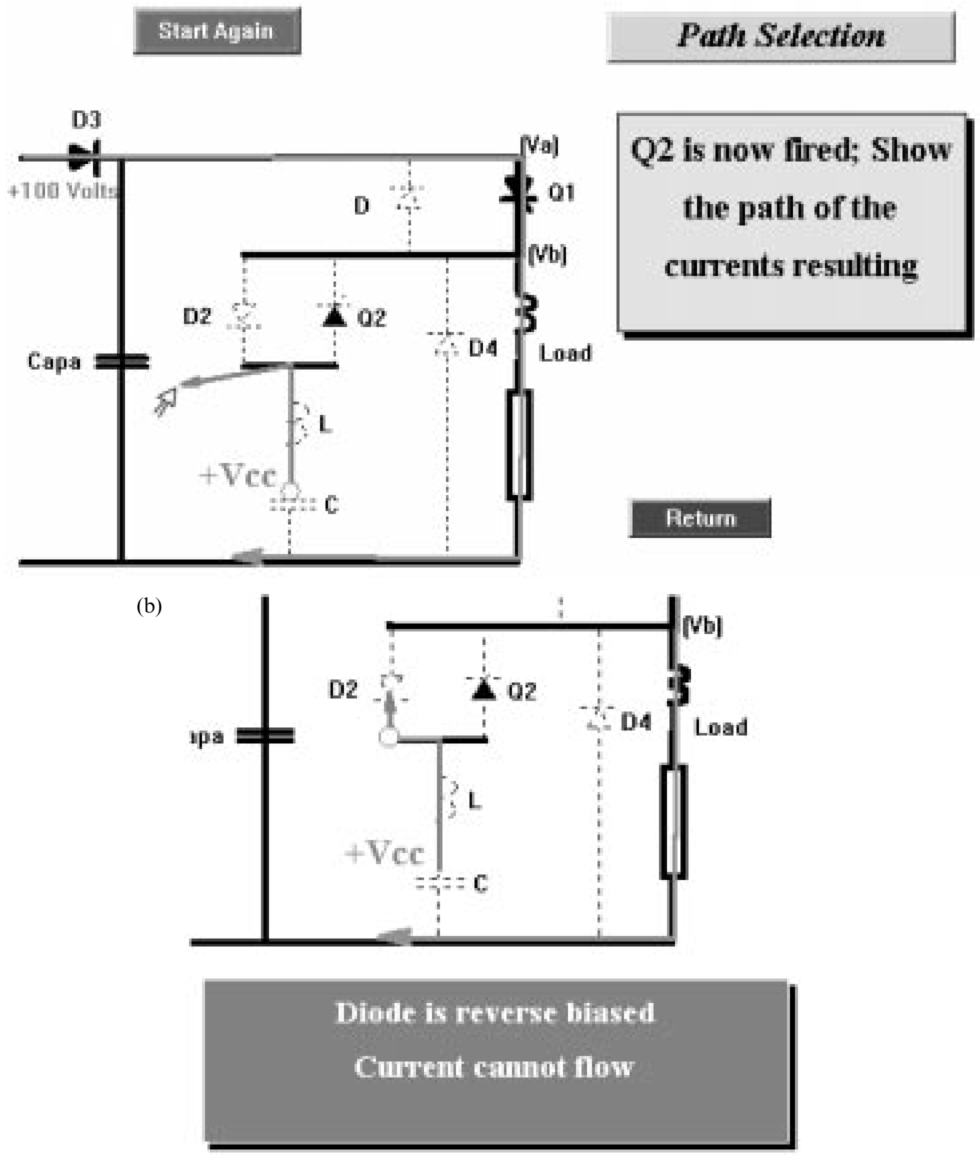


Fig. 6. Interactive graphical path drawing: (a) interactive path selection with arrows; (b) instant feedback on error.

mouse is brought within the area of the curve, a vertical hair-line is attached to the mouse. When clicked, the assessment comes back, giving a hint to why the answer was wrong. In this case the correct answer is at the intersection of the current and voltage curves.

Element selection

Figure 5(a) shows a typical circuit to analyze according to the sequential method taught in the presentation. We would like to test whether the student has understood the principles of sequential power electronics circuit analysis. When the mouse is positioned over an element, the contour highlights as light gray. When the mouse is clicked over the shape, the contour is highlighted as black. This allows the student to actually pick elements, and here for instance show a current path as seen in Fig. 5(b). When the answer is tested, a message displays again more information, for instance 'another path exists'.

Path selection

Figure 6(a) shows a circuit and the student is asked to draw a path. When the student grabs the end of the red arrow, the next arrow is shown, and a direction can be selected for the next segment. Releasing the mouse actually causes the next segment to be highlighted by an arrow. Figure 6(b) shows what happens on the next segment. An immediate feedback is provided and the reason for the error is given. The student can now back off by clicking in the circle and deleting the wrong segments.

Expert system

Figure 7(a) proposes a diagram that was used in the regular presentation. A specific question is asked, requiring a full English sentence. When the expert engine is clicked on, Fig. 7(b) shows the organization of the screen. The student is asked to give a written composition, for instance he will key in 'a surface'. The verification will give a hint

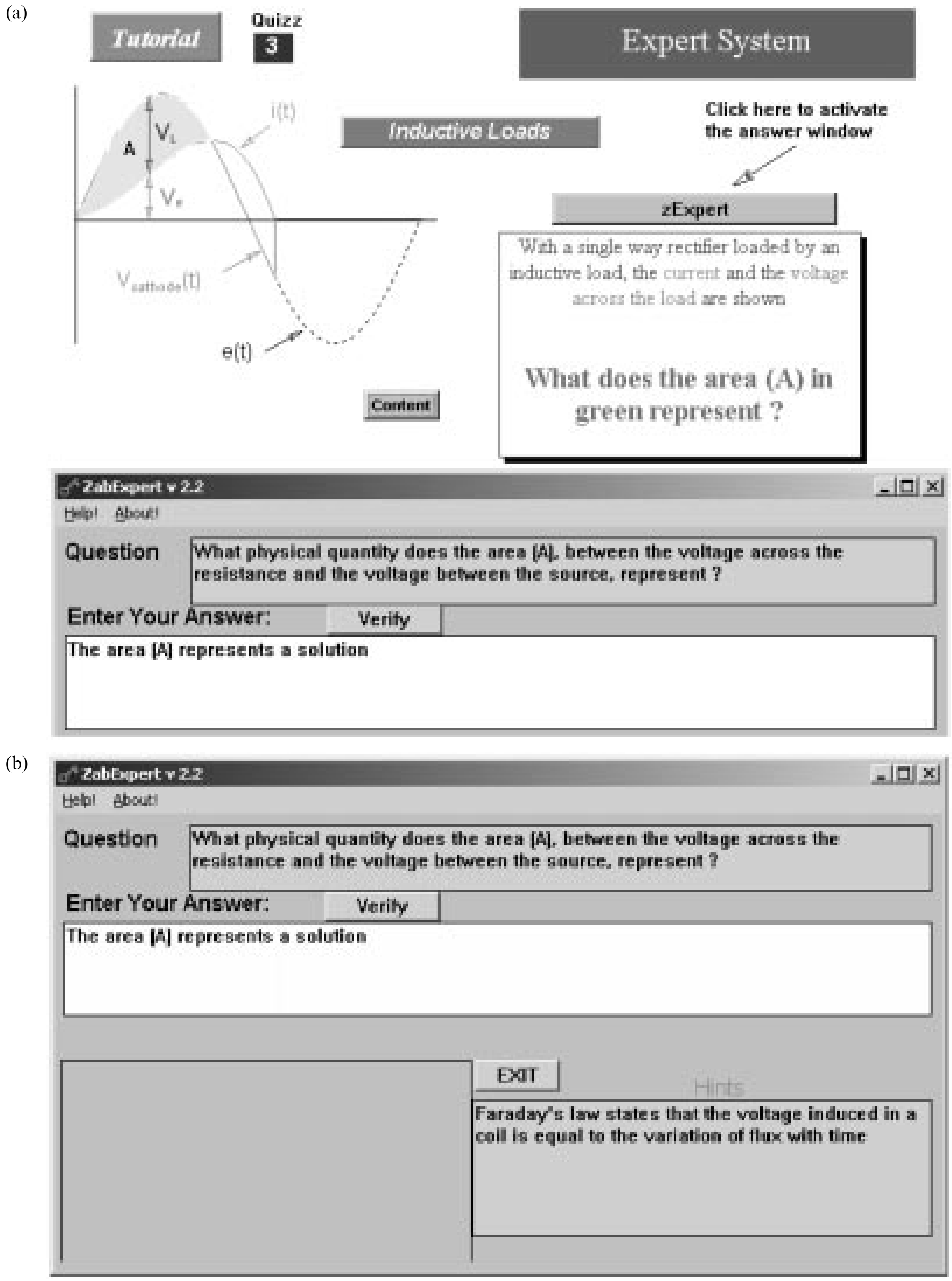


Fig. 7. Expert engine: (a) initialization of expert answer; (b) expert answer shell.

as shown, and the student keeps trying to reword his answer according to the guidance that he receives from the hints. The hints are graded from vague to more precise, until finally the correct word to use is in the sentence. As an example the series of hints guiding the student who has everything wrong is the following:

- Hint 1: 'Faraday's law states that the voltage induced in a coil is equal to the variation of flux with time.'
- Hint 2: 'The area is the time integral of a voltage.'
- Hint 3: 'The word [flux] must be included in the answer.'
- Then 'flux' is added.
- Hint 1: 'The area is considered positive because e(t)> Vr(t).'
- Hint 2: 'The word [stored] must qualify "flux".'
- Then 'stored' is added.
- Hint 1: 'The flux is stored somewhere?'

- Hint 2: 'Think of the mathematical definition of a flux.'
- Hint 3: 'The flux of a vector is the scalar product of the vector across a given area.'
- Hint 4: 'The word [field] must be included in the answer.'
- And so forth, leading to the 'perfect answer': 'The flux stored in the magnetic field.'

The expert engine also provided with a spell checker to allow some leeway in correcting typing errors. There is also semantic checking. Words cannot simply be keyed in any order. Grammatical analysis permits a 'decent' sentence to be written and detected. The engine was written in 'C' and is driven by an instructor created script file, which of course is encrypted so students cannot simply open the file and find the answers. Contrary to expectations, the scripting does not require any knowledge of the expert engine. There are some very simple rules to follow, and the instructor prepares the series of hints by order of clarifying functions. A wizard actually can guide the instructor in order to produce automatically the script file.

This expert engine has been thoroughly tested with people knowing the subject matter and also those without knowledge. It took a maximum of three minutes for the knowledgeable people to arrive at a correct answer (two full sentences were required as the answer), well formulated, in correct English. It took an average of 10 minutes for non-initiated people to arrive at a correct formulation, although they did not understand much of the meaning, and were relying most of the time on the last hint (which word to use).

When a student uses this expert engine to answer a complex question, the intensity of the effort to produce the answer and 'beat' the machine is such that no one tested ever forgot the answer, and always remembered the question, hence the concept tested was well imbedded in the student's memory.

PERFORMANCE

Each of the techniques implemented has been assessed. With the intelligent calculation the student must perform the calculations and the method is checked along the way using partial answers given. In fact, the 'hidden' path of the method is dictated by the creator of the module. This way method, accuracy of the calculation and format of the answer are checked.

For the graphical interfaces, the students get an immediate feedback. Results are not shown. The student is lead to the solution, and each step is checked on line and progress towards the correct answer is monitored.

These combined methods allow a complex, animated, voice-directed problem-solving technology. Figure 8 shows such a complex design problem. For instance the student is asked to find the optimum angle, alpha, leading to suppression of the first, third, fifth and seventh harmonics. Each time a new angle is selected, the time curve is updated and the frequency spectrum redrawn. Not only will the student arrive at a good engineering optimization, but in the process will acquire a 'feel' for what Fourier analysis is all about, and will relate time response to harmonic content not

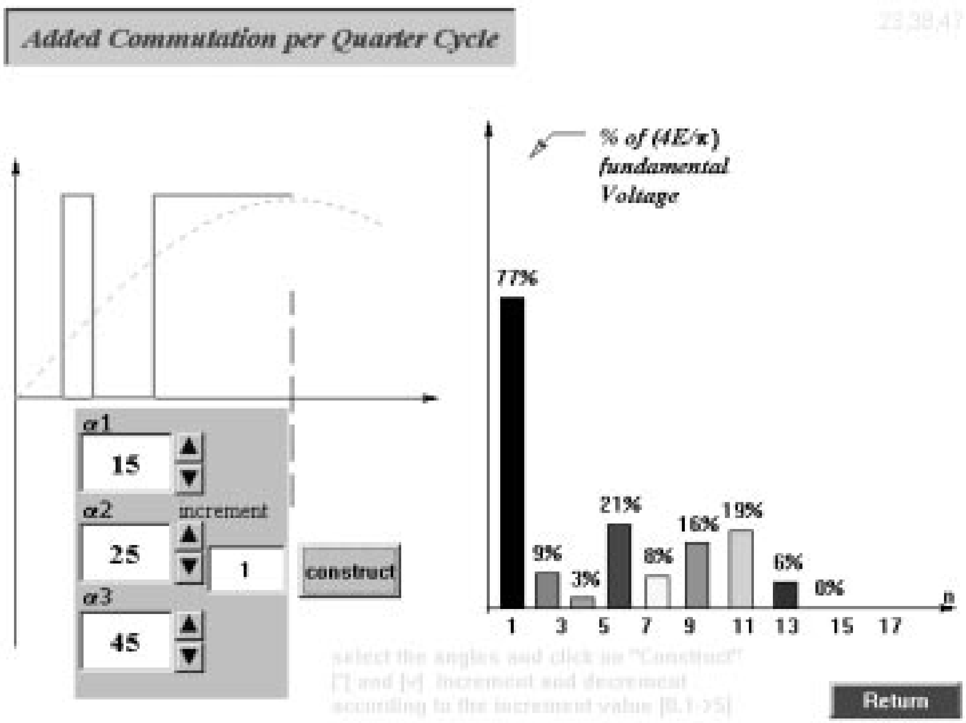


Fig. 8. Interactive design problem.

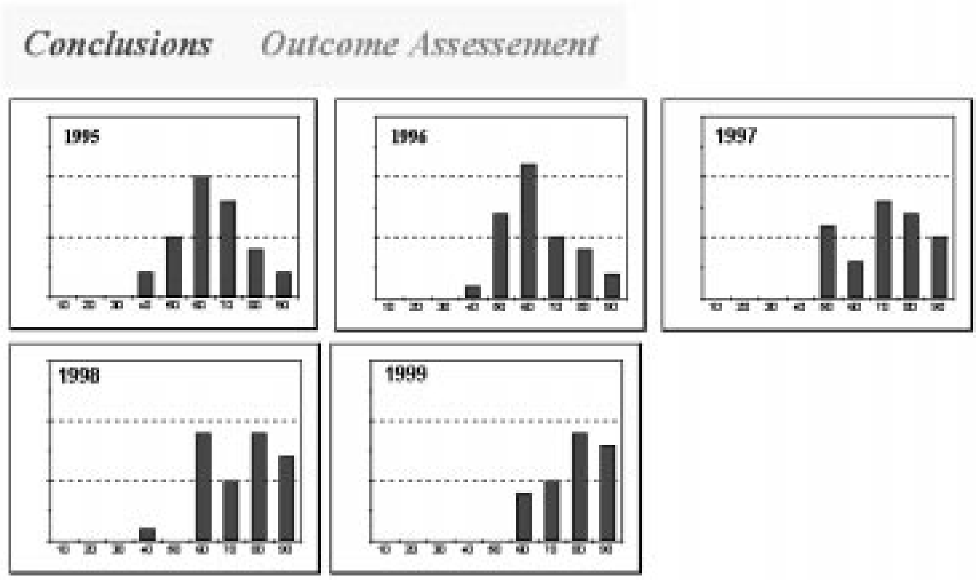


Fig. 9. Performance assessment.

just as a mathematical exercise, but with a practical feel for the method.

CONCLUSIONS

Present techniques offered by instructional packages are often very limited, namely multiple choice testing, TRUE/FALSE testing and basic calculations. The presentation techniques are limited to flip chart-style sequential formats. Even animations and voice support follow the flip chart method.

We have developed a series of new techniques with intelligent calculation and with feedback that actually checks the method as well as the format of the answer. We have developed graphical interactive design and interactive drawing techniques, through which the students can actively learn and test their skills. Each step is checked and the feedback will guide the student with why he is not correct and gives him progressive hints.

Finally a powerful expert engine has been developed where the student has to provide a complex English sentence (or several) to a question. Grammatical syntax and spelling is checked, and the student is constantly guided with hints in increasing focus to guide him towards a correct answer.

All these methods are combined in modules that are distributed over the Web or on CDs, and the student can work at his/her own pace. Because of the inherent goal of self-motivation and active learning experience, there is no need to perform marked testing. In fact all students should eventually arrive at the correct solution, each at its own speed of learning.

A Power Electronics course was chosen as a pilot project. The outcome assessment presented in Fig. 9 showing the grade distribution of the students in the course over the years is the marks that they obtained in a final examination of three hours, with conventional questions of new circuit analysis, intelligent questions on principles and design questions. In 1995 only one preliminary module was introduced to see how students react to this new teaching. The results are the expected 'bell curve' that we all are happy to achieve. Over the '96 and '97 years, 80% of the modules were actively developed and put in place. One can see a definite distortion of the results shifting in the high marks. In '98, the modules were polished up according to the feedback of students (the previous version did not duplicate voice and comments), and finally in 1999 more design modules were added (such as the harmonic spectrum optimizer) and the results were even more pronounced. In fact in the years 2000 and 2001, the questions asked at the exams were so difficult that even the teaching assistants could not properly answer the questions. 80% of the students achieved A or A+, all but one were above 75%. But the impressve outcome assessment was that all students really understood the principles, had an excellent engineering feel for them, and were able to utilize their knowledge in a wider engineering environment, not just confined to standard questions regurgitated from their notes. They all could use their knowledge intelligently and learned to integrate it in other areas of engineering and science.

The success of this method has been so overwhelming that students have asked to implement this scheme in other courses.

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