DEIC: Web-Based Materials to Teach Digital Electronics

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Abstract – The paper describes a Web-based Digital Electronics Interactive Course (DEIC). DEIC transmits knowledge to the students by means of static text, figures, tables, and by interactive simulation of some digital circuits. It also offers different kinds of interactive tests with prompt feedback for self-assessment. Students' surveys show that they found the software easy to use and felt it helped them improve their skills and understanding.

Keywords: computer-based learning, digital electronics, self-assessment, interactive simulation

I. INTRODUCTION

In our days, technology is everywhere. Since the early days of computers, learning through computer-based environments has dramatically increased [1]. Students and teachers now expect their educational experience to include the use of current Web technologies and engaging learning interactivity. Web-based simulations, Web-based classrooms, and Web-based tools can provide a dramatic benefit for teaching and learning.

All this activities are possible since we have ubiquitous personal computers with Web access and Web browsers. We will be able to do better things, to provide students with deep learning; we will be able to move beyond the limitations of a traditional classroom since we have now access to learning opportunities such as:
- interactive course materials;
- simulations, multimedia, visualization;
- homework and quizzes.

In addition we can access this features any time and any place, since they involve site-independent learning (distance education) – through courses that are delivered largely or entirely online.

Deep learning may be facilitated by interactive simulation; static text-based information may serve as enrichment or preclass assignment; and a video-on-demand presentation could be a postclass reinforcement activity.

As this development becomes more of a reality, we will need to redefine existing educational pedagogy, commonly accepted learning theories, and the role of the professor, which have all driven our traditional education delivery system. These changes will involve, among other things, a major shift in pedagogy from a teacher-lectured-centered environment to a learner-centered/learning-style environment [2].

In recent years, there have been important changes in education, both in terms of curriculum content (what is taught) and in the delivery of material (how it is taught) [1].

The prestigious IEEE Transactions on Education magazine devoted in 2005 a special issue on Web-Based Instruction containing no less than 25 papers.

A Web-based educational tool for digital signal processing tools is described in [1]. In addition, the paper presents an exploratory study about the improvement and validation of this tool. An adaptive testing system that generates tests for assessment that are tailored to each student appears in [3]. A discussion of the author's use of WebCT environment to deliver a sophomore Electric Circuit Theory Course to undergraduate students at the Texas A&M University, College Station campus is presented in [4]. The OASIS tool containing a large question database and server-side program that delivers questions, marks student responses provides prompt feedback, and records students' activities was developed and implemented in the University of Auckland, New Zeeland [5].

Textbooks had traditionally been the fundamental tools for the Digital Electronics course, so the learning process was somehow static and inefficient. The need was great for developing and delivering quality, up-to-date educational material based on new technology and associated pedagogical advantages, such as interactivity, enjoinment and instantaneous feedback.

The result of a collaborative work between the Bases of Electronics Department of the Technical University of Cluj-Napoca and the "Edmond Nicolau" Electrotehnic Group School of Cluj-Napoca, consists of a Web-based Digital Electronics Interactive Course – DEIC. DEIC transmits knowledge by means of static text, figures, tables and data sheets and by the possibility to simulate the operation principles of digital circuits. It also offers the self-assessment

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possibility; different types of tests that provide prompt feedback to the learners being available.

II. DEIC – DIGITAL ELECTRONICS INTERACTIVE COURSE

The Digital Electronics Interactive Course (DEIC) has been designed using the HTML language and Java and JavaScript languages (Fig. 1). It can be run in an internet browser being adequate for use in traditional classrooms or in asynchronous and non-eyewitness active self learning courses to engage students in active reinforcement of the concepts acquired in class.
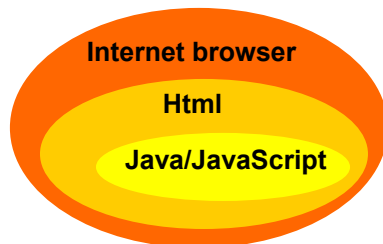

Fig. 1. The DEIC structure

A. The DEIC content

The course deals with active and interactive study of logic gates, combinational circuits, and sequential circuits. The course Web page allows the instructor to make available all course-related materials in a very accessible way. Table 1 shows a synthesis of all materials and their available format. Some material is in .pdf format for easy downloading and printing.

In general, for each topic the learner can access the following materials: theoretical aspects, experiment, data sheets of the discussed integrated circuits, a number of proposed problems as assignment, test for knowledge reinforcement and/or self assessment, and working sheets.

The chapter of logic gates contains the following types of gates: OR, AND, NOT, NOR, NAND, and XOR. The decoders, multiplexers, demultiplexers, adders, and magnitude comparators are presented in the chapter of combinational circuits. The sequential circuits chapter treats the flip-flops (RS, JK, and D), counters, and registers.

waveforms, and datasheets. The learners are welcome to run attractive experiments by simulation. To facilitate the comprehension of the circuits operation, these experiments highlight the operating principle of the studied devices eliminating the details and second order effects. They are interactive applications: the mouse action on graphical element leads to modification in color of some graphical elements or in the appearance of new graphical elements.

A very useful tool in the learning process is the interactive assessment test. This kind of test is primarily appreciated for its prompt response on the correctness of the answers provided by the learner. The waiting time and the involvement of a teacher to check the answers, specific to traditional tests on paper are fully eliminated.

DEIC proposes a diversified spectrum of tests:

- closed evaluative questions and answers tests, specific to computer-based assessment [6]:
  - tests with multiple choosing items where the learner chooses a correct answer from the proposed ones for each question or utterance. Two versions are implemented in DEIC: 1) all items of the test are available scrolling the display, with the possibility to return to a previously solved item to change the initial answer, and 2) each item of the test is individually presented with no possibility to return to a previous item;
  - tests with alternating answers items containing statements that have to be appreciated as being true of false, with no possibility to return to a previous item;
- opened evaluative questions and answers tests:
  - filling gap tests; that kind of test being among the very few kind of tests that admits a quick and objective control.

B. The graphical user interface

The graphical user interfaces of DEIC look like the one presented in Fig. 2. The title window allows the user to browse all the DEIC content, the window being present in all the application screens. For instance, the user can select one chapter to be studied. According to the selected chapter, the corresponding hyperlinks are displayed in the content window: sub-chapters, interactive tests, proposed exercises and problems, respectively working sheets (last ones only

Table 1

The theoretical aspects are introduced through the medium of static text, circuit symbols, truth tables,

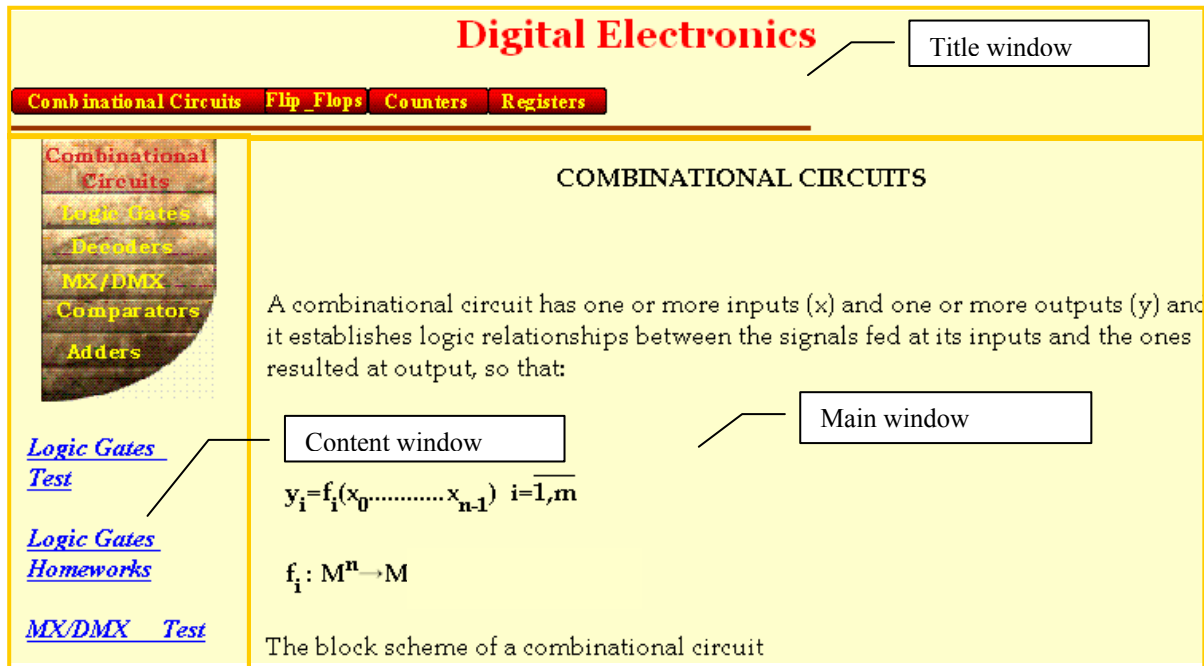|	Theoretical aspects		Experiment	Test		Proposed problems		Data sheet		Working sheet
	pdf	html	java	pdf	Java/JS	pdf	html	pdf	html	pdf
Logic gates	X	X	X							X
Combinational circuits	X	X	X	X	X	X	X	X	X	X
Sequential circuits	X	X	X							X

Fig.2. The graphical user interface of DEIC

in .pdf format). The experiments, tests, and theoretical aspects are displayed in the main window.

C. *A lesson in DEIC*

For the illustration purpose we will present in the following the *RS* flip-flop lesson in the flip-flops chapter.

The lesson can be efficiently learned using its associated working sheet. In the case of *RS* flip-flop the learner is invited as a first step to study the theoretical aspects (circuit symbol, description of the operation, truth table), as one can see in Fig. 3.

At the second step, the learner has to fill in the working sheet with experimental results, obtained by simulating the behavior of a *RS* flip-flop. Fig. 4 shows
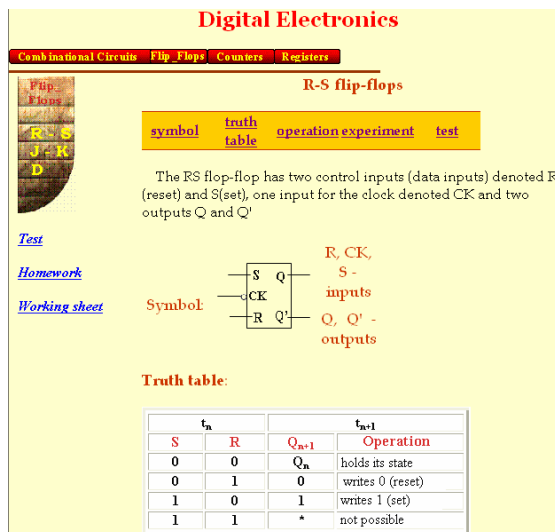

Fig. 3. The screen of the RS flip-flop lesson

the Java applet used for simulation. The *R*, *S* and *T* (clock) inputs are sensitive to the mouse action. The logic state of any input can be altered by a mouse click on the corresponding green circle. The current
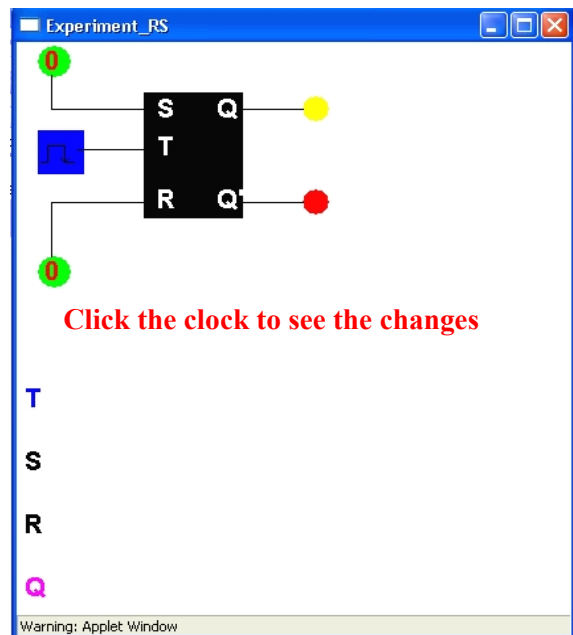
logic state is written inside of that circle. For an efficient graphical communication, the yellow color is used to represent the *logic 0* state, while the red color is used to represent the *logic 1* state at the output. As a special case we used the mauve color at the output in the case when the forbidden state is present at the input ($R=S=1$).

According to the combination of logic states presented at the input, the output of the flip-flop keeps its previous logic state or changes its logic states (and implicitly the color of the graphical components representing the outputs) by clicking the *T* input. Simultaneously, some waveforms representing the time evolution of the inputs and output will be drawn

Fig.4. The window to simulate the *RS* flip-flop

in the same window (see Fig. 5). All these events happen synchronous with the action of a mouse click on the clock input (*T*), signifying the apparition of a

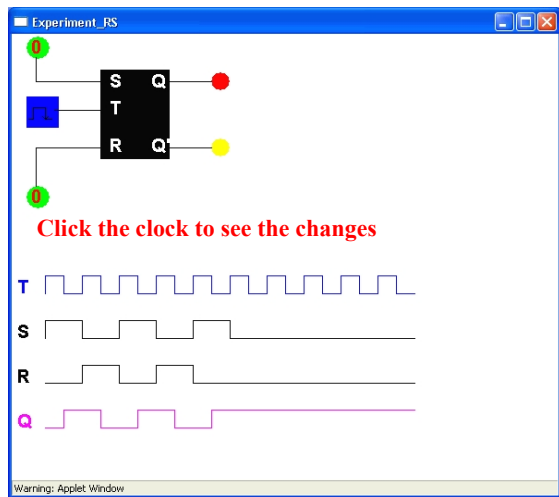falling active edge of the clock signal. Each action on the *T* input is equivalent with a clock period.

Fig. 5. Operation of the *RS* flip-flop. Waveforms.

The third step in the working sheet requires running the simulation and completing the waveforms at the *Q* output for specified inputs waveforms. The final step in the working sheet asks the learner for a text description of the *RS* flip-flop operation.

The features, the absolute maximum rating, the electrical characteristics, and the connection diagrams of the integrated circuits complete the picture on the real behavior of the circuits.

One proposed test for consolidation and deepening the knowledge is the one with multiple choosing items, containing 10 items. This test was implemented as a Java application. One single question is displayed on a certain time (Fig. 6.), the learner having the possibility to choose the correct answer. Once a question is solved and one passes to the next one there is no possibility to return to a previous question. To the end of the test, the number of correct answers is displayed. At every new running of the same test the
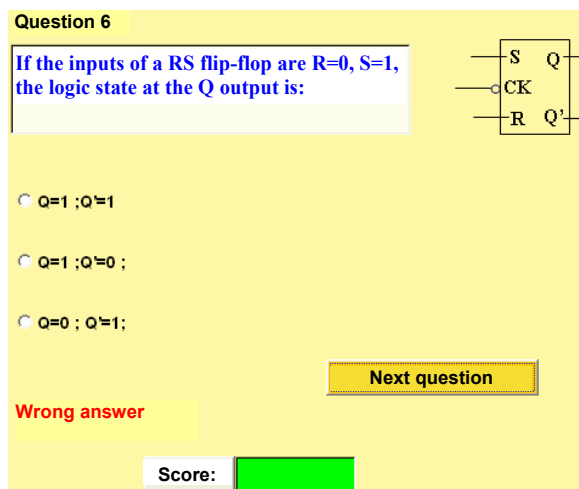

Fig. 6. Test containing multiple choosing items

questions appears in a new random order.

Table 2

The DEIC proposes problems for the learners to be solved as homework in the traditional way, on paper. The proposed problems consist in closed and open answer tests [6]. Some items used for the closed answer test are similar with the items of the interactive tests and other ones are associative items. The open answer test contains primarily problems to be fully solved.

The knowledge accumulated by the learner by covering the available learning materials give to he or she the ability to solve practical applications.

III. EVALUATION OF THE DEIC

There is quite a short time since DEIC has been applied in the teaching activity to the "Edmond Nicolau" Electrotehnic Group School of Cluj-Napoca. Despite of this short period we were very interested in the opinion of the students about using DEIC in the instruction process. The survey results are encouraging. Table 2 presents the survey results. In addition, Fig. 7 shows a chart highlighting the agreement and disagreement for each item in the survey.

Most students (75%) found DEIC easy to use, while only 12% did not. The instant feedback was appreciated, with 50% agreeing or strongly agreeing with the statement "I like the instant performance feedback using DEIC". Furthermore, 56% agreed or strongly agreed with the statement "DEIC helped improve my skill level", while 69% agreed or strongly agreed with the statement "DEIC helps me to prepare for the assessments". The students appreciate (66%) the problems provided in DEIC as helping them to better understood the course material. The rate of using DEIC is not so high (34%), the reason being the short period since it is available for the teaching process. The survey results are also encouraging regarding the computer-based teaching style: 56% of the students consider that "It would be a good idea to have Web-based materials in other courses", while 26% disagree this teaching style. We are sure the appreciation of the students will strongly increase for the computer-based teaching style as they became more and more accustomed with it.
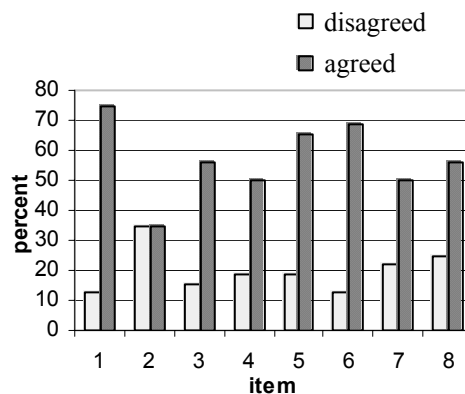

Fig.7. Graphical representation of the survey results

Student evaluation results for DEIC (Key: SD- Strongly Disagree, D-Disagree, N-Neutral, A-Agree, SA-Strongly Agree

No.	Item	SD (%)	D (%)	N (%)	A (%)	SA (%)
1	DEIC is easy to use	9	3	13	66	9
2	I often use DEIC	9	25	31	31	3
3	DEIC helped improve my skill level	3	13	28	31	25
4	I am more confident about my learning after using DEIC	9	9	31	38	13
5	The problems provided in DEIC helped me understand the course material better	6	13	16	50	16
6	DEIC helps me to prepare for the assessments	3	9	19	47	22
7	I like the instant performance feedback using DEIC	9	13	28	31	19
8	It would be a good idea to have Web-based materials in other courses	13	13	19	28	28

IV. CONCLUSIONS

A Web-based Interactive Course to teach digital electronics was presented in this paper. DEIC represents a computer-based, modern, and interactive didactical method. Through the means of theoretical aspects presentations, interactive simulations of digital circuits, and self-assessment tests this method assures the development and accumulation of the required competencies for the students.

DEIC benefits by a series of positive aspects. There is a high accessibility for all the course-related materials without any constraint regarding the time, place and staff. The cost for material dissemination is low in the conditions of existing infrastructure (computer network and internet access). The contents can be very easy and quickly updated at negligible costs. The method gives the students some pleasure for study, due to the opportunity to use the computer in all the learning stages. The self assessment tests are very well appreciated by the students for the opportunity to practice and learn from their mistakes without penalty or loss of face. Thus, students can practice each question until satisfied that they have mastered the particular skill, situation, or concept.

Another strong point is the possibility to simulate the behavior of the circuit individually, once and again, if it is the case. There is no need to be in the laboratory or to use expensive experimental setups and instrumentations. Let us remember here that the experiments are very important in the learning process, taking into consideration that we tend to remember up to 90% of what we are doing in an active manner.

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