

# A Novel Adaptive E-Learning Model Based on Developed Learner's Styles

Hazem M. El-Bakry, Ahmed A. Saleh and Taghreed T. Asfour

**Abstract**—Adaptive e-learning today gives the student a central role in his own learning process. It allows learners to try things out, participate in courses like never before, and get more out of learning than before. In this paper, an adaptive e-learning model for logic design, simplification of Boolean functions and related fields is presented. Such model presents suitable courses for each student in a dynamic and adaptive manner using existing database and workflow technologies. The main objective of this research work is to provide an adaptive e-learning model based learners' personality using explicit and implicit feedback. To recognize the learner's, we develop dimensions to decide each individual learning style in order to accommodate different abilities of the users and to develop vital skills. Thus, the proposed model becomes more powerful, user friendly and easy to use and interpret. Finally, it suggests a learning strategy and appropriate electronic media that match the learner's preference.

**Keywords**—Adaptive learning, Learning styles, Teaching strategies.

## I. INTRODUCTION

WITH the blooming of technologies the popularity of electronic learning programs enforces us to think about what advanced technologies can enhance learning depth, involve learners with the material, and increase material retention. Different humans have different learning ways. Some can assimilate knowledge in a better way when received auditory, visually or through another sense [1]. Traditional teaching styles tend to use one of these presentations more than others [2]. It is extremely difficult for a teacher to apply all multiple teaching strategies in a classroom. Nowadays, adaptive learning provide new ways to break of the traditional educational models one size fits all approach and make it possible to customize down to the individual [3]. An adaptive system adapts itself or another system in order to deal with different situations and fit to various circumstances [4]. Adaptive learning systems endeavor to transform the learner from passive receptor of information to collaborator in the educational process [5]. Those learning systems' primary application is in education, but another popular application is business training.

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Without knowing anything about the user, a system would perform in an exactly the same way for all users [6]. To individualize, personalize or customize actions a user profile is needed. The user information is stored and managed in form of user profile. Thus a user profile represents the system's beliefs about the user. The behavior of an adaptive system differs according to data in this profile. Based on this data we identify a person's individual learning style by using the learning styles dimensions. Then the system is rendering suitable course content in a dynamic form for each student, and adapting instructions toward that learner's strengths and preferences. Each course is divided into units. After a particular unit in a course is completed, a quiz is provided. The displayed course material to the user will be personalized with respect to his character. This is to enable him learn the subject in the most effective way and in the shortest possible time.

Our model covers the concept of digital design course. In fact most of our modern life technologies deal with the concept of digital design [7]. Digital logic has important use in all of today's digital computers and devices. It has such a prominent role in every day life in recent digital age [8]. Digital systems are used in communication, traffic control, medical treatment, space guidance, weather monitoring, the Internet and other huge enterprises [9]. Also the digital electronic circuits are the engines of digital cameras, computers, cell phones, MPEG players, GPS displays, handheld devices and other products using information in digital formats. Our proposed model can be used as an adaptive e-learning model not for logic design course only but also for all educational courses as image processing, computational models, principles of programming languages, compiler design, and other related courses.

Important topics are covered in our proposed environment. Such topics are integrated into a single environment using visual basic. So it appears to be portable, and machine independent, which makes it a useful tool for interactive and collaborative learning environment. The environment integrates several different materials to support the learners' preferred style. It includes a starting form used to gather information about user, a movie-like welcome component, an animated hyper-text introduction for the basic concepts, self assessment system, a logical simulator, and a set of visual examples for learners' motivation. The proposed model is designed by integrating visual basic, flash, Microsoft access, and other effective tools. Before writing this paper, several classroom experiments were carried out for the framework as

a model of adaptive learning based on user learning styles, teaching strategies and implementation of electronic media. The preliminary results were clear in improving the learners understanding, performance, and increase their motivation. It is proved that the proposed model facilitates and personalizes the learning process, which provides easy and attractive use for learners.

## II. RELATED WORK

There are different tools used to categorize each person according to their learning styles: Kolb questionnaire, honey and Mumford questionnaire [10]–[11], GRSLSS questionnaire [11], Myers-Briggs type indicator [12], and finally Felder-Silverman.

In [12], the authors suggested new teaching strategies on e-learning context matching with learner's personality using the Myers-Briggs Type Indicator tools. There are several studies focus on the effectiveness of multimedia and learning styles in the educational systems [13]–[14]. But few give an idea of which combinations of learning styles and electronic media are more effective than others.

Another study in [15] described the development of learning styles integration taxonomy, teaching strategies and the proper implementation of electronic media to personalize the learning process. The design of this personalized teaching environment based on an adaptive taxonomy using Felder and Silverman's learning styles. The adaptation in Tangow [16] lies in presenting a different sequence of alternative contents of the concepts. Concepts can be represented by example and exposition. The system uses only the Sensing-intuitive dimension from the Felder-Silverman learning style model. The PHP programming course [17] provided different representations for each learner, and used different types of resources such as theory, colors, text, slideshows, audio, etc. One disadvantage of PHP programming course was that electronic media is limited to graphics, audio, video, and hypertext and that doesn't integrate teaching strategies. The course presented in [18] achieved adaptation by providing different representations for each learner. Also different types of resources were used. In this sense, our proposed model is significantly different from the previous efforts done in this field.

Due to the importance of digital design and the growth within internet based technologies, the authors in [19] realized a Java programmed testing system. Such system which is a component in an Internet based Digital Logic Design Virtual Laboratory realized to the stage of tasks delivery. A set of virtual instruments are at the disposal of the laboratory. Each instrument is designed to be used by the students to present the decisions of tasks of distinct type. The test consists of a number of tasks. Every teacher defines a desired number of tasks which are stored in a database. Another application presented in [20] based on Adobe Flash and SCORM within a MOODLE learning environment. It provides individualized assignments for students learning digital systems. The assignments are evaluated automatically and the result is reported to the MOODLE platform. Since the tasks are solved

by the students remotely and unattended, students get their personalized assignment by selecting one from the pool of available assignments based on the student's unique learner id. While the authors in [7] presented an overview of an e-learning system and discussed some web-based tools for teaching the basics of digital logic in such a system. Also the authors in [21] presented a web-based system for teaching logic design concepts and practices for computer science and engineering students. Such system was implemented by using LabVIEW. The experiments which included digital logic gates, combinational logic circuits, seven segment display, sequential logic and counters were easily constructed and performed, both in traditional and online setups. Vladimir Mateev [22] provided a Web-based virtual instrument for testing students' knowledge to construct truth tables of analytically-defined Boolean functions. It was a component of the testing subsystem of the Internet based Digital Logic Design Virtual Laboratory (DLDVDL) that can be used from authorized users only. The instrument was realized as a Java applet.

## III. THE PROPOSED MODEL

The presented model provides a basic treatment of digital circuits and the fundamental concepts in their design. It is suitable for use as an introductory course in an electrical engineering, computer engineering, or computer science curriculum. Learners usually found logical design materials boring and complex. That's because the learners find materials difficult to visualize or even interact with. Especially when material includes coverage of low level electronics, electronic circuits, Boolean function, combinational logic and Karnaugh map then learners can lose interest or perceive higher levels of complexity.

The choices of effective e-learning tools are seemingly endless, according to availability of multiple tools. We integrate visual basic (version 6) with flash and other tools as an example of simple adaptive learning tools that improves the learner's performance in classes.

The first component of our implemented framework is the starting registration form. It contains simple questions to be filled by current user in addition to his name as shown in Fig.1. When the user presses result, Fig. 2 appears.

We present explicit feedback at the starting of our framework in order to prevent interrupting the normal process of learning. While simple questions increase the interest for complete filling the questionnaire.

The questionnaire answers are sent to the system. The system gathers information about the learner and environment in a direct manner. Then all user-related data stored in the users' profiles, including personal information, preferences, and interaction with system. These properties are stored after assigning them values that may be final or change over time. Each learner has his own user profile which enables the system to deliver customized instruction, on the basis of the student's learning style. Learning style is defined as the characteristics, strengths and preferences in the way people receive and process information [23]. It refers to the fact that

every person has different level of motivation, attitudes, and responses.

Fig. 1 Starting registration form

Fig. 2 The resulted learning style

Several tools are used to determine learners' learning styles. We use our modified dimensions based on Felder and Silverman's model. This model rates the student's learning style in a scale of six dimensions. Our model classifies learners into six axes: active vs. reflective, sensing vs. intuitive, visual vs. verbal, sequential vs. global, Traditional vs. Advanced and Work in group vs. Standalone. Table I shows those learning styles dimensions. The active learners gain information through a learning by doing style, discussing or explaining it to others, while reflective learners gain information by thinking about it quietly first. Sensing learners tend to learn facts through their senses, while intuitive learners prefer discovering possibilities and relationships. Visual learners prefer images, diagrams, and graphics, while verbal learners remember what they've heard, read or said. Sequential learners gain understanding from logical

continuous steps, while global learners take big intuitive leaps with the information. Traditional learners could assimilate information better using the traditional learning way without using illustrative educational tools, while advanced are keen to try things out. They tend to be impatient with long discussions and are practical and down to earth. Work in group learners tend to like group work and become more effective and motivated, while Standalone learners prefer working alone or in a small group contains only few persons so they could understand better.

TABLE I  
OUR MODIFIED LEARNING STYLES DIMENSIONS MODELS

LEARNING STYLE DIMENSION	TYPE	DESCRIPTION
Processing (LSD1)	Active (A)	Learning by doing style.
	Reflective (Re)	Learning by thinking about information.
Perception (LSD2)	Sensitive (S)	Rather deal with facts, raw data and experiments, they're patient with details.
	Intuitive (I)	Rather deal with principles and theories, are easily bored when presented with details.
Entry Channel (LSD3)	Visual (Vi)	Easy to remember what they see: images, diagrams, time tables, etc.
	Verbal (Ve)	Remember what they've heard, read or said.
Understanding (LSD4)	Sequential (Seq)	Follow a lineal reasoning process when solving problems and
	Global (G)	Take big intuitive leaps with the information.
Realistic (LSD5)	Traditional (T)	Not prefer educational tools
	Advanced (Ad)	Easy to learn by using educational tools
Behavior (LSD6)	Work in group (W)	Prefer working in groups
	Standalone (St)	Prefer working alone

We have six learning style dimensions  $LSD = \{LSD1, LSD2, LSD3, LSD4, LSD5, LSD6\}$ , Each dimension is a combination of six values, see TABLE I,  $LSD = \{(A/Re), (S/I), (Vi/Ve), (Seq/G), (T/Ad), (W/St)\}$ . Then, there are 64 ( $2^6$ ) learning styles combinations.

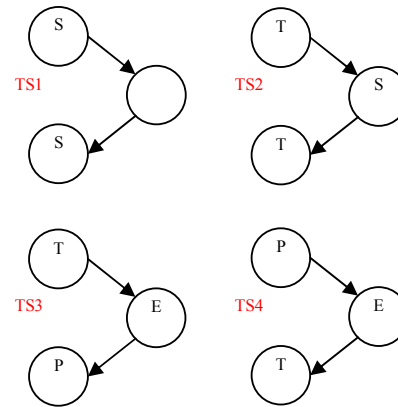
This does not mean that a person possesses only six styles, but that the six styles show a greater presence than their counterparts. For example everybody is active sometimes and reflective sometimes. The preference for one category or the other may be strong, moderate, or weak.

Our applied modification on learner's styles dimensions help learner to develop vital skills. Additional dimensions used to reduce the probabilities of error in determining the learner's learning styles. The process of selecting learner's style became more precise and specific. Thus, it could be used by college instructors and students in engineering and the sciences, although it could be applied in a broad range of

disciplines. The teaching strategies designed to encourage learners to observe, analyze, express an opinion, look for a solution and facilitate a deeper understanding of the information. The process of selecting suitable teaching strategy based on the resulted learning style. Our frame work suggests four strategy paths as in Fig. 3. LSC can be associated with a teaching strategy (TSi):  $TS = \{TS1, TS2, TS3, TS4\}$ . Teaching strategies hold a one-to-many relationship with the learning styles. There can be one or many teaching strategies that accommodate one learning style. Teaching strategies are given to learners to facilitate a deeper understanding of the information. The emphasis relies on the design, programming, elaboration and accomplishment of the learning content.

The strategies make use of all resources, elements and components which have been integrated into a single environment. The first teaching strategy TS1 tends to use the Simulator-Theory-Simulator approach. The system starts by presenting the Simulator as an Application. The learners attempt to analyze and solve the problem without the benefit of the upcoming course's theory. Therefore, the teacher presents the chapter's theory or ideas, and the system presents additional applications to make the learning process so easy. The second teaching strategy TS2 uses the approach Theory-Simulator-Theory. System starts by presenting the chapter's theory before simulator related. The learners attempt to analyze and solve the problem using the course's knowledge. They can reuse the theory to facilitate the learning process. In the third one, the system starts by presenting the chapter's theory or idea before examples related. Afterwards additional practical exercise and problem solving will be presented. The last strategy TS4 uses the opposite teaching of TS3.

The logic gates simulator constitutes the second component of the framework. It contains an animated welcome page (movie like) illustrated with text, pictures, animation, and speech as in Fig. 4. Our simulator defines combinational circuits, common logic gates found in digital circuits, and demonstrates course concepts. We provide links to pages where the learner can view symbols, truth tables, animation of particular logic gates. The combinational logic simulator includes encoders, decoders, multiplexer, and demultiplexer. The combinational logic gates react to the values of the signals at their inputs and produce the value of the output signal, transforming binary information from the given input data to a required output data. Fig. 5 shows the octal to binary encoder and Fig.6 shows the multiplexer. Logic gates include AND, OR, NOT, NAND, NOR, EXOR, and EXNOR gates, in addition to Half Adder, Full Adder, and S-R Flip-Flop. In Fig. 7 shows the half adder, Fig. 8 shows the EXNOR gate and Fig. 9 shows S-R Flip-Flop.



S: Simulator T: Theory E: Examples P: Practical exercise

Fig. 3 Learning strategies

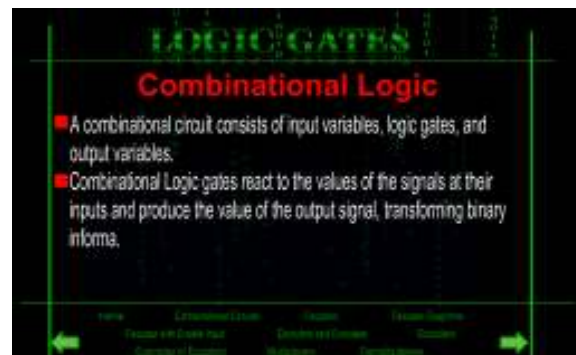


Fig. 4 Animated welcome page.

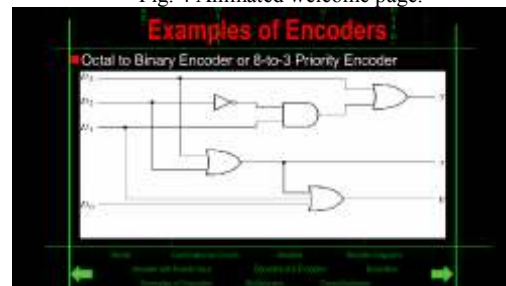


Fig. 5 Octal to binary encoder.



Fig. 6 Multiplexers

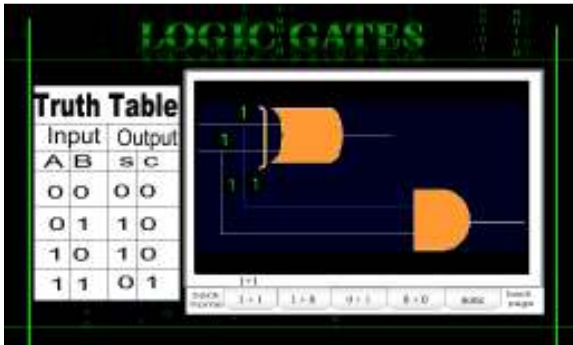


Fig. 7 Half Adder simulator

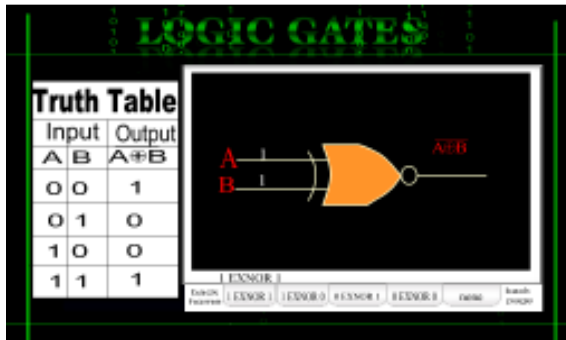


Fig. 8 EXNOR gate simulator

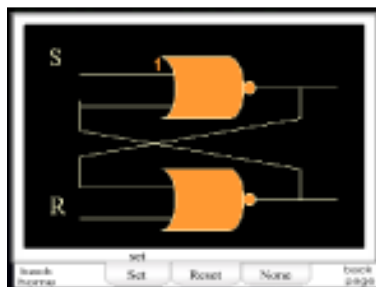


Fig. 9 S-R Flip-Flop simulator

In our simulation learners choose the input and see animated path through gate getting output in a repeated form. Learners not only watching how gates work but they can get immediate help at any step in the learning process through navigation in the introduction components. Combinational circuits' simulators are presented in Fig. 10, Fig. 11, and Fig. 12. A practical exercise is one of the environment resources. It presents visual examples that demonstrate many of the fundamental concepts of digital design; it includes simplification of Boolean functions, Complement of a Function, Minterms, Maxterms, and Karnaugh map. Fig. 13 shows a practical example. The question solved in a step-by-step manner, which can help the learner to interact with examples in an amusing way.

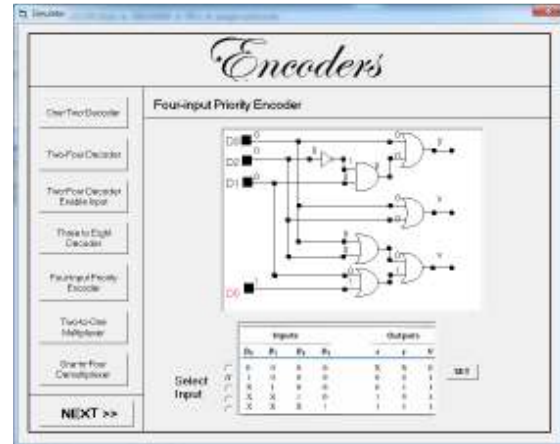


Fig.10 Encoders simulator

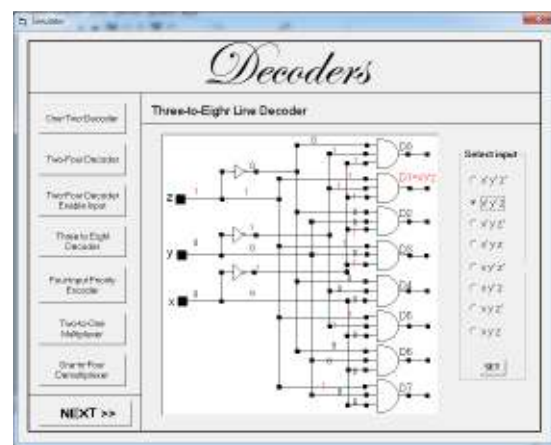


Fig. 11 Decoders simulator

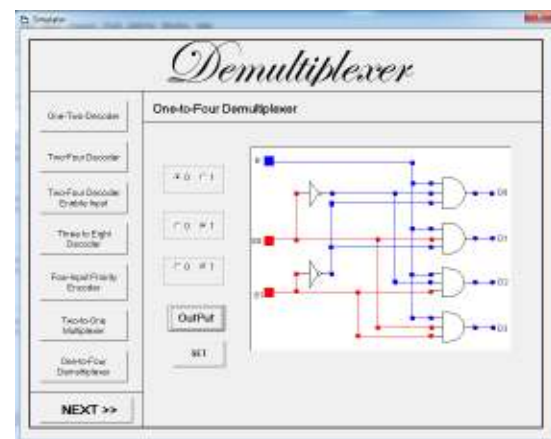


Fig. 12 Demultiplexer simulator

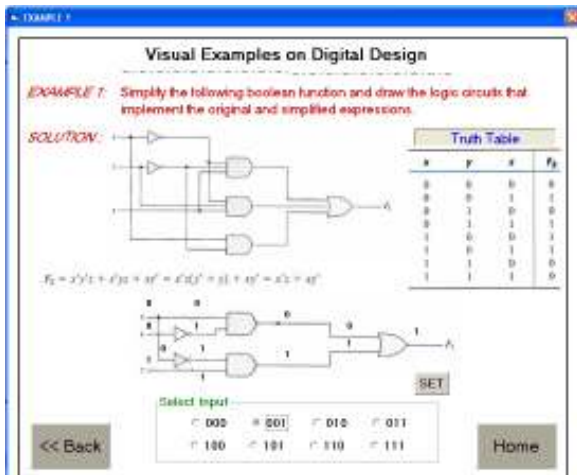


Fig. 13 Example on simplification of a Boolean function

Some learners master a material course by studying it once. Other learners may not understand a material from the first time, so the situation must be different. Therefore our framework provides an examination mechanism. Such mechanism leads to other situations according to the exam results.

The framework provides examination within 10 questions as a multiple choice questions that selected randomly from database contains pool of questions and their answers. The questions organized by concepts. For each concept a set of standard questions was prepared capable to assess learning level of the learner. A learner may fail to passes the same examination more than one time, or may be multiple learners examined at same time and place. So, the system generates different examination pages each time. It checks the answers by comparing the learner's answer to the correct answer in the database. It displays "Wrong" as a message supported by audio in case of invalid answer, and if the answer is true "Correct" message supported by audio will be displayed. The displayed messages according to answers are shown in Fig. 14 and Fig. 15. After the termination of the exam, the system counts passed and failed questions. It displays the final result in a score sheet and gives a comment on results. According to the result of the examination, the system decides the next course that will be learned.

The system decides the next unit according to the following three cases:

1. If a learner's pass percentage of the examination of a unit is 100%, then the next unit will be provided.

2. If a learner's pass percentage of the examination of a unit is 70% or 90% because of frequently wrong answers, then the special course materials will be provided. It includes course material that should be studied when learner makes popular mistakes in the examination

3. If a learner's pass percentage of the examination of a unit is 60% or less, the system presents another teaching style and so on until the score becomes acceptable. The learner profiles will be adjusted, and the next unit will be the unit that the student has tried but never passed.

System can select suitable learning style with attention to the behavior and interest of the user as in Fig. 16. Although it pays attention to the results of exams and tests, this does not form the basis of decision making about the selected learning style.

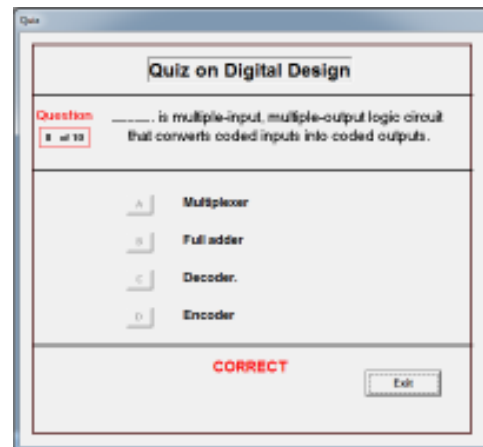


Fig. 14 Displayed message if answer is correct



Fig. 15 Displayed message if answer is wrong

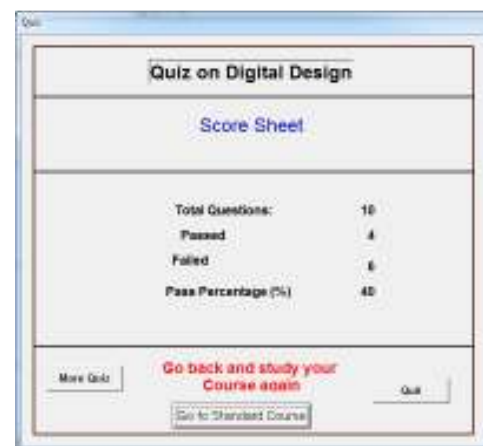


Fig. 16 Score sheet and pass percentage

IV. EXPERIMENTAL RESULTS

We carried out experiments in order to evaluate the effectiveness of our proposed tools on the learning process. Thirty students were randomly selected from different classrooms. They were divided into two groups, each one contains 15 students. The students of first group have already completed the logical design course and done their exams in a traditional learning process. Then each one of the first group was given the questionnaire in TABLE II.

The questionnaire measure five criteria named as increased motivation, flexibility, fairness, enjoyable, and pinpoint weakness. Five options were given for responses: (N) No answer, (1) Poor, (2) Below average, (3) Good, (4) Excellent. The responses are shown in TABLE III.

TABLE II  
QUESTIONNAIRE GIVEN FOR STUDENTS  
Select suitable value for each question

Questions	N	1	2	3	4
Do you find the learning process increases your motivation in learning logic design?					
Do you find the learning process flexible?					
Do you find the marks given to you fair?					
Do you find the learning process enjoyable?					
Could you identify your weaknesses in this course?					

N= "No answer", 1= "Poor", 2= "Below average", 3= "Good", 4= "Excellent"

TABLE III  
RESULTS OF THE FIRST GROUP  
Select suitable value for each question

Questions	N	1	2	3	4
Do you find the learning process increases your motivation in learning logic design?	0	4	4	5	2
Do you find the learning process flexible?	1	4	5	3	2
Do you find the marks given to you fair?	0	2	7	3	3
Do you find the learning process enjoyable?	2	6	2	4	1
Could you identify your weaknesses in this course?	0	4	5	5	1

N= "No answer", 1= "Poor", 2= "Below average", 3= "Good", 4= "Excellent"

We demonstrate our model and visual examples for the second group of students. They have been allowed to use self assessment testing system, and each of them has been given the same questionnaire. Their responses are listed in TABLE IV.

The questionnaire indicates that 80% of respondents conclude that the system helps increase their motivation level in learning logic design. The result also shows that 86.6% of the respondents thought of flexibility of the system. And 93.3% of the respondents agreed the marks awarded by the system were fair. 86.6% of the students found the experience enjoyable, two student did not like the experience at all, and. Finally 80% of respondents think the system could help them pinpoint their weaknesses in logic design course, while one student doesn't answer. We compare results of the first group without using our model, and the other group used our model. For Choices N, 1, and 2, if the number of response decreased,

it indicates a positive response, which is what occurred. While for choices 3, and 4, the increasing numbers of responses indicates positive response, which also occurred as in Fig. 15.

TABLE IV  
RESULTS OF THE SECOND GROUP  
Select suitable value for each question

Questions	N	1	2	3	4
Do you find the learning process increases your motivation in learning logic design?	0	1	2	6	6
Do you find the learning process flexible?	0	1	1	5	8
Do you find the marks given to you fair?	0	0	1	6	8
Do you find the learning process enjoyable?	1	0	1	9	4
Could you identify your weaknesses in this course?	1	0	2	7	5

N= "No answer", 1= "Poor", 2= "Below average", 3= "Good", 4= "Excellent"

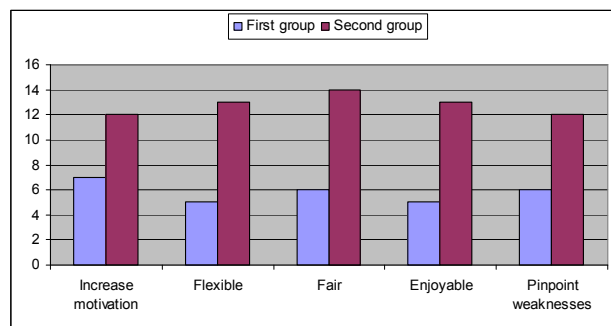


Fig. 15 Comparison between the results of the two groups

After the students of the second group answer the test in the Starting registration form, we make a survey to count the results of the modified learning styles test. They had to answer this test to obtain their learning styles in order to get a chance to explore the system. The results were shown in TABLE V. The system treats different students' styles with different ways. The most important differences appear in the visual and verbal dimensions. The system shows pictures or tables for a visual style's student. While for the verbal style student shows plain text. For the other dimensions as the active or reflective, it shows very similar materials since they were answered exercises. For the sensitive or intuitive dimensions, the materials were examples with a few explanations about them. We found that the active students were more than reflective. Comparing the sensitive and intuitive dimensions the majority of the students were sensitive. The greatest gap was found between the visual and verbal dimensions. Where 12 students were visual and the rest were verbal. The 12 Advanced students prefer the educational tools while 3 Traditional students not prefer. Also the majority of students preferred standalone and only 4 students like working in groups. Finally, for the sequential and global dimensions, the preponderance was sequential.

TABLE V  
RESULTS OF THE MODIFIED LEARNING STYLES TEST

Learning Style Dimension	STYLE	NUMBER OF STUDENTS
Processing	Active	9
	Reflective	6
Perception	Sensitive	9
	Intuitive	6
Entry Channel	Visual	12
	Verbal	3
Understanding	Sequential	10
	Global	5
Realistic	Traditional	3
	Advanced	12
Behavior	Work in group	4
	Standalone	11

### V.CONCLUSION

A new framework for effective use of profiling, explicit feedback and learning styles in an adaptive e-learning environment has been presented. Such framework consists of five main parts, Starting registration form, self learning materials, visualization in an interesting way, practical examples, and self testing. The framework is simple and easy to be implemented using simple tools to support adaptive e-learning systems for digital logic educational material, and it could be also used in other courses such as image processing, computational models, information theory, information engineering and digital communications. The framework finds a better way to engaging learners in the learning process. Also it is identifying user's strengths and weaknesses and then adapting user's study sessions to his personal needs. Through the results of our experiment, it has been shown that our proposed model improves the learning process, and affects the students in a positive way. In addition an opinion poll showed a positive feedback on the environment tools from the students. In future work, we plan to enhance our tools by adding more features, visual examples, and make more performance evaluation experiments.

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