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# An Intelligent Web-based System to Enhance Digital Circuits Concepts and Skills for Deaf Students

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***Abstract*— in this paper, an intelligent web-based system is presented. The proposed system uses artificial intelligence, internet technology, and virtual lab to enhance digital circuits' concepts and skills for deaf students at electronic and computing department at the vocational preparatory stage. The system provides deaf students with a learning environment which can be accessed and used easily anywhere at any time. It helps deaf students in training of digital circuits' skills and enhances the understanding of their scientific concept. It enables the teacher to manage and communicate with their students through the administration panel and interaction tools. It consists of four components: pedagogical module, expert module, interaction module, and student module.***

*Index Terms*—**Intelligent web-based, Digital circuits, Deaf students.**

## I. INTRODUCTION

The characteristics of web based learning systems include global accessibility, online resources availability, collaborative and interactive learning, motivation to learn, convenience, non-discriminatory, cost-effective, online evaluations, and etc. [1, 2] An important advantage of web-based courses is that instructional work areas are available for use at any time. Collaboration among distributed learners is possible and often more convenient than face-to-face teaching in classrooms [3]. Also, it is easily accessible and it offers greater flexibility where students can control their own pace of study. It can incorporate multi-media such as audio and video [4]. However, the problem is that most of web-based courses and other educational applications have been made available on the web are nothing more than a network of static hypertext pages. A challenging research goal is the development of advanced web based educational applications that can offer some amount of adaptively and intelligence. An intelligent and personalized assistance that a teacher or a peer student can provide in a normal classroom situation is not easy to get. Also, to be adaptive is important for web based courseware because it has to be used by a much wider variety of students than any "standalone" educational application. A Web courseware that is designed with a particular class of users in mind may not suit other users. Adaptive presentation can improve the usability of course material presentation. Adaptive navigation support and adaptive sequencing can be used for overall course control and for helping the student in selecting most relevant tests and assignments [5]. Web-based intelligent learning environments have the potential of bringing the individual tutoring experience to a broader audience [1]. Deaf students need a variety of visually accessible teaching strategies that don't rely solely on the written word. Nearly all written resources for education including e-learning courses are written for hearing people, without any adaptation for the deaf. Therefore it is essential that deaf students are taught using different mediums to see which are beneficial to their learning and possible work prospects [6]. This paper introduces an intelligent web-based system that aims to enhance concepts and skills of digital circuits for deaf students. The proposed system has four components: interaction module, pedagogical module, student module, and expert module. The students and their teacher can interact with the system through online interactive environment. Students can access content areas which provide links for educational materials. Also they can access utilities areas that provide sets of services. Teacher can provide advice and answer students' questions, and the students can collaborate with each other to solve problems. Teacher also, can access the administration area that provides administration to the system. The rest of this paper is organized as follows. Section 2 presents literature review, section 3 illustrates system architecture, Section 4 describes system overview, and section 5 introduces application of the system and results.

## II. LITERATURE REVIEW

The goal of various Intelligent Tutoring Systems (ITSs) is the use the knowledge about the domain, the student, and about teaching strategies to support flexible individualized learning and tutoring [5]. ITSs must be able to achieve three main tasks: accurately diagnose a student's knowledge level using principles, rather than preprogrammed responses; decide what to do next and adapt instruction accordingly; provide feedback [7]. ITSs both guide students through a curriculum of instructional activities, and monitor step-by-step progress on an activity [8]. ITSs have highly effective at increasing students' performance and motivation [9]. ITs use a variety of approaches like adapting to learners needs, adjusting the grain size of learning units (from simple to complex), promoting transfer of skills to different contexts,

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allowing students to abstract skills, modeling good problem solving approaches, providing appropriate feedback (based on students' input/responses), and adapting to changing conditions [10]. The ITS architecture contains at least four components: the domain model or expert knowledge module, the student model module, the teaching model or tutoring/pedagogical module, and a learning environment or user interface/communications module [1, 9, 11- 13]. ITS projects can vary tremendously according to the relative level of intelligence of the components. ITS's student model, represents the student's current state of knowledge at any point of time.

It gathers information about the students' knowledge and behavior including prior relevant learning, progress with the curriculum, preferred learning styles, and other types of learner-related information that could have possible implications on their performance and learning styles. The student model is also used as the basis for corrective feedback [1]. ITS's domain model (also known as the cognitive model/expert knowledge model) consists of the concepts, facts, rules, and problem-solving strategies of the domain in context. It serves as a source of expert knowledge, a standard for evaluation of the student's performance and diagnosis of errors [12]. ITS's tutoring module (also called teaching strategy, instructional module or pedagogic module) provides a model of the teaching process. It designs and regulates instructional interactions with students. It correlates current performance level with its own pedagogic goal and finally decides which pedagogic activities will be presented [1].

For example, information about when to review, when to present a new topic, and which topic to present is controlled by the pedagogical module [9]. Communications module (also called interaction module) represents the user's interface models. Interactions with the learner, including the dialogue and the screen layouts, are controlled by this component, and it shows how the material should be presented to the student in the most effective way [9]. A number of web-based intelligent learning systems have been developed. Ashraf A. Kassim, Sabbir Ahmed Kazi and Surendra Ranganath (2004) present a web-based intelligent learning environment for digital systems. The system allows students to solve problems related to the digital systems course, at any time and from any Internet-linked computer. It comprises five components: a communications module, a pedagogical module, a student model, an expert model and the domain knowledge [1]. C.J. Butz, S. Hua, R.B. Maguire (2006) introduced a Web-based intelligent tutoring system for computer programming by utilizing Bayesian networks. It helps a student navigate through the online course materials, recommend learning goals, and generate appropriate reading sequences [14]. Hossein Movafegh Ghadirli and Maryam Rastgarpour (2013) present a web-based intelligent tutor. This system can adapt with learning styles, aptitude, characteristics and behaviors of a learner. It uses expert simulator and its knowledge base [15]. Kenneth R. Koedinger, Emma Brunskill, Ryan S.J.d. Baker, Elizabeth A. McLaughlin, and John Stamper (2013) discuss the status and prospects of this new and powerful opportunity for data-driven development and optimization of educational technologies, focusing on Intelligent Tutoring Systems. They provide examples of use of a variety of techniques to develop or optimize the select, evaluate, suggest, and update functions of intelligent tutors, including probabilistic grammar learning, rule induction, Markov decision process, classification, and integrations of symbolic search and statistical inference [16]. Ahmed R. Salman (2013) describes a web- based intelligent tutoring system (ITS) framework.

A formal model of ITS compose of a user environment and pedagogical environment is presented, and this represents domain knowledge based on ontologies to improve the sharing and reusing of teaching materials. The system constructs the user environment based on users' knowledge levels, psychology characteristics, learning style, etc [12]. There are a number of studies applied for deaf students. An intensive research on e-learning content adaptation for deaf students has been studied by Bueno, Fernandez del Castillo, Garcia and Borrego (2007). The problems faced by deaf students when reading text are compiled and tested with several recommendations to adapt text in an e-learning computing course which eventually showed a promising result on the level of understanding among those students [17]. Rosella Gennari, Ornella Mich(2008) presented the intelligent interface of LODE, an e-learning web tool for Italian deaf children who have problems in the comprehension of narratives in a verbal language; it aims at stimulating global reasoning on written e-stories. LODE aims at eliciting children to globally reason on e-stories through a series of apt exercises. It is a semantic web application relying on constraint programming. The research focuses on critical issues faced in the design and assessment of the interface of their e-tool [18].

Debevc, Stjepanovic and Holzinger (2014) have developed an adapted e-learning environment for people with disabilities. The usability and pedagogical effectiveness of the e-learning course are evaluated using a Software Usability Measurement Inventory and Adapted Pedagogical Index method [19].

## III. SYSTEM ARCHITECTURE

The architecture of the proposed system, as shown in Fig. 1 has four components: pedagogical module, expert module, interaction module, and student module.

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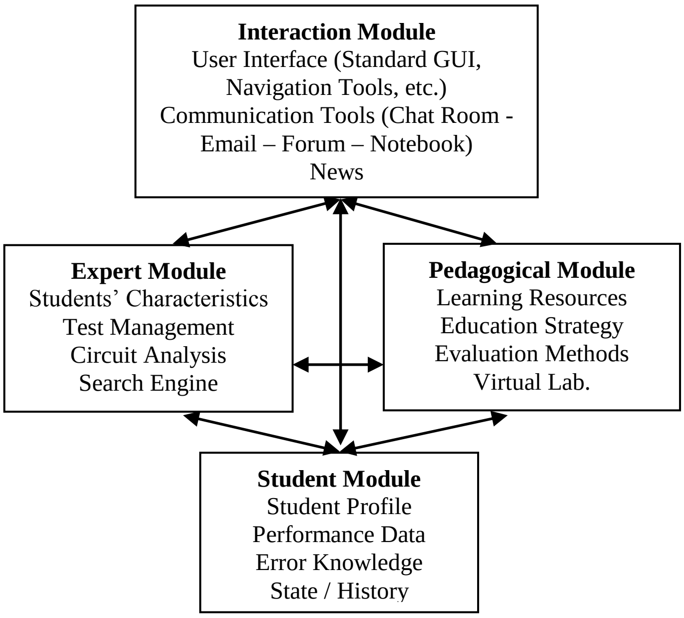


**Fig. 1. System architecture**

### *A. Pedagogical Module*

The pedagogical module organizes the learning resources. It uses Expert module for tacking decisions about the curriculum sequencing, and dynamically presents educational materials (goals, lesson tutorials, activities, exercises, tests, and virtual lab) based on educational strategy and information provided by the student model. It controls the sequence of the presented topics, where the system applies “mastery learning” strategy, so learners study tutorials according to their personal level and they can't move from current topic to next before achieving certain level (>= 65%). The teaching units consist of HTML pages that contain content materials (text, images, and video) and interactive virtual laboratory related to the digital circuits. Each lesson has behavioral objectives, introduction, lesson contents, summery, exercises, and lesson test. Students can customize their learning environment by selecting their preferred settings (color- font- size…..etc.). They can print lesson contents and display the content in a new (Popup) window; also they have navigation tools through lesson pages, exercises and tests (see Fig. 2). All pages contents are translated to sign language and presented as video to support learning process for deaf students.


**Fig. 2. Lesson contents**

The pedagogical module also uses the Expert module to evaluate students and update the student module. Two evaluation measurements types are generated: formative achievement tests (pre-test, lessons tests, and post-test) for concepts, and circuits analyzer for practical skills of digital circuits. It provides students with positive and negative feedback which, consists of pieces of knowledge to help them to eliminate their misconceptions. The proposed system provides the learners with a set of experiments and instructions on how to build and simulate the digital circuits provided in each experiment. The system helps learners to understand the concepts of digital circuit and increases educational efficiency, where the digital circuits' virtual lab is included with significantly less operating cost. Learners have a freedom to carry out experimental work and gain hands-on experience by using the virtual lab to build the digital circuit, then the circuit analyzer component checks if the circuit runs correctly or has errors.

### *A. Expert Module*

The expert module is responsible of decisions about: evaluating and updating student module, curriculum sequencing, circuits' analysis, and feedback provision. The decisions are done by means of a set of production rules. Rule is statement that expressed in the IF and THEN form. While, rule base is the knowledge system whose knowledge base contains a set of production rules. Meanwhile, rule-based expert system is an expert system whose knowledge base contains a set of production rules [20]. Learners can study topics and move from one to another according to their personal level. If any learner tries to access a topic before execute the requirements (pre-test and post-tests with mastery learning level), the expert module redirects him to his unfinished topics. Pedagogical module generates tests dynamically and the students' solutions are evaluated by expert module at the runtime. The expert module has a test management component, which checks the learners' solutions for every question and generates corrective feedback. It supplies learners with supportive material for wrong answers or not answered questions to adapt learning process. Also it adapts the instructional content to the student's needs, it evaluates students' response for tests and provides feedback to the learner including: test topic, right answers counter, wrong answers counter, percentage, grade, and taken time. Sample of the used production rules included to evaluate a cognitive test T with items i is shown in Fig. 3 and the UML sequence diagram for test evaluation is shown in Fig. 4.

```
If student_answer_of_question [i]  then
      Set question feedback[i] to "Right answer"
      Increment right_answer_counter[T]
      Add question_degree [i] to total_degree[T]
Else
      Increment wrong_answer_counter[T]
      Get  question_supportive_material [i]
      Set  question_feedback[i]  to  "Wrong   answer"  &
        question_supportive_material [i]
End if
```

**Fig. 3. Example of production rule for cognitive test evaluation**

A practical exam for the digital circuits' skills is evaluated

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by another component of the expert module; it is the circuit analyzer. It examines and analyzes the learners' circuits, identify errors, and provide explanations and suggestions to guide them to the right answers. Learners use virtual lab to create the required circuit, the circuit analyzer verifies the circuit components and connections. It checks the containment for all required components, and examines whether the components are properly connected. Then it generates the suitable feedback including conclusion about the nature of errors and their causes. Fig. 5 presents an example of the circuit analyzer component production rule to check the circuit C with items i. Fig. 6 Shows UML sequence diagram for circuit analysis.

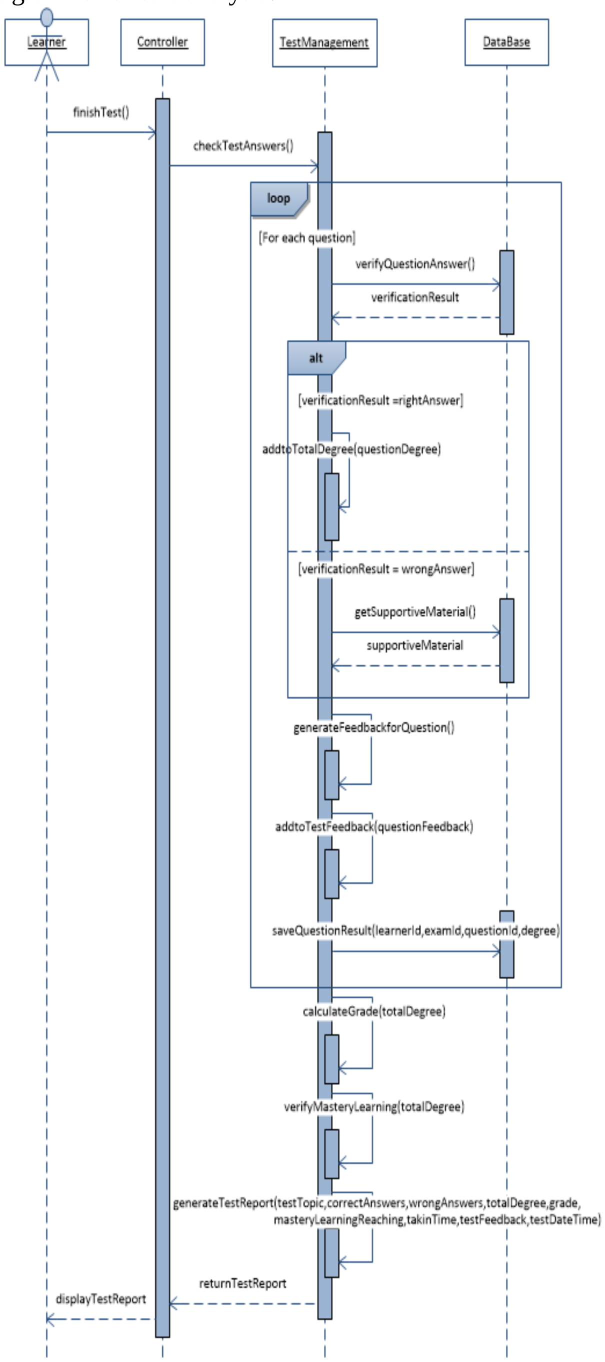


**Fig. 4. UML sequence diagram for test evaluation**

```
If circuit_compontents [i]  = lamb then
        Increment lamb_count[C]
Else If circuit_compontents [i]  = switch Then
        Increment switch_count[C]
Else If circuit_compontents [i]  = battery Then
        Increment battery_count[C]
Else If circuit_compontents [i]  = wire Then
        Increment wire_count[C]
End If
```

**Fig. 5. Example of production rule for circuit analyzer**

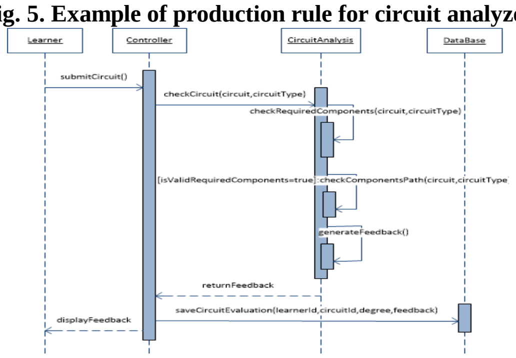


**Fig. 6. UML sequence diagram for circuit analysis**

The pedagogical module provides learners with external resources through web search, also it supplies them with search engine, which allows them to find any information contained in the system. The expert module displays the result of searched text automatically including details such as: result number, page title, URL, result weight score, date and size of the file. The search results are determined according to the algorithm shown in Fig. 7. Fig. 8 Shows UML sequence diagram for search engine.

```
 Input Search text T
Get items_in_search_database
Get predefine_attributes_count[ ]
For each item i in items_in_search_database[SDB]
        For each attribute a in item[i]
              SearchTextIntoAttributeCount[ ] =
                 Get search_into_attribute_result_count[T, a]
        Loop
        Calculate item_weight[predefine_attributes_count[ ],
              SearchTextIntoAttributeCount[ ]]
        If item_weight[i] > 0 then
        Add item[i] to search_result[T]
        End if
Loop
Determine priority_search_result[T]
Return priority_search_result[T]
```

**Fig. 7. Production rule for search**

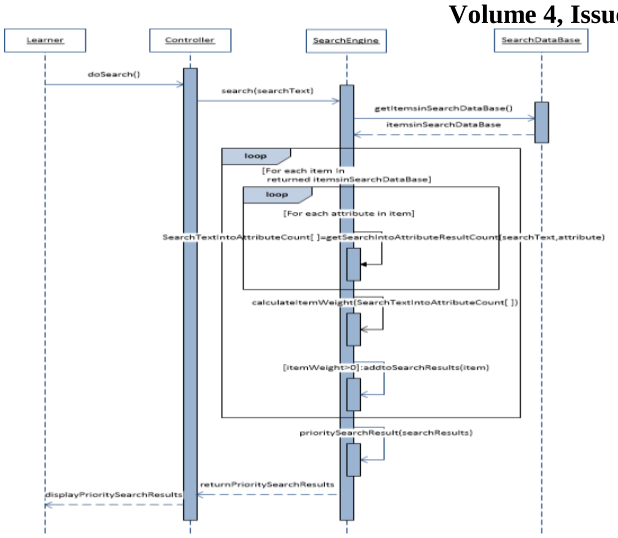


**Fig. 8. UML sequence diagram for search engine**

### *B. Interaction Module*

The interaction module provides learners with user interface. It integrates all types of tools (communication tools, virtual lab, etc.) needed to interact with learners through GUI. It was designed and developed according to the quality standards for the construction of E-Learning environments and virtual laboratories for deaf students. It provides a set of interaction and communications tools includes synchronous tools (Chat-Room) or asynchronous tools (E-Mail and Forums) which allows learners to communicate with each other's and with their teacher.

### *C. Student Module*

Student module dynamically presents the learner's current state of knowledge and skills at any time. It makes learning environment adaptable to individual learner. Student model gathers and records information about the student knowledge and behavior including personal data, student characteristics, prior relevant knowledge, progress level, error knowledge, etc. Learner has the ability to login the system by the legal learner's account (user name and password), if he already has one, or has the ability to create account if not. After the learner login to the system, all information about his activities including access date, visited pages, student works, tests' evaluations, and other specific information are recorded. So learner can view his performance and progress through GUI, where details about his tests include questions count, correct questions count, wrong questions count, not answered questions count, degree, percentage, grade, taken time and test date and time are presented. Farther more, the wrong and not answered questions are displayed with link to supportive material.

## IV. SYSTEM OVERVIEW

The system overview is shown in Fig. 9. It illustrates how learners and instructors interact with the system through online interactive environment. They can communicate synchronously through chat-rooms or asynchronously through e-mail and forums. So, instructor can provide advice and answer learners' questions, and the learners can collaborate with each other to solve problems.

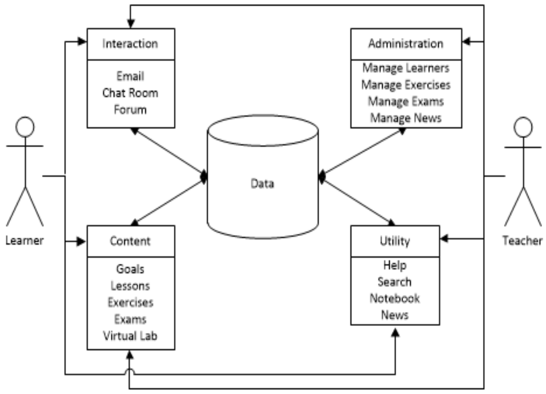


**Fig. 9. System overview**

Learners can access content areas which provide links for educational materials including general goals, lessons objectives, lessons content, exercises and exams. Also they can access utilities areas that provide sets of services (help, search, notebook ......etc.). Instructors can login to the administration area that provides administration to the system.

Data block consists of database and data files. The database contains the entities used to handle the data related to the system modules. Fig. 10 Shows the Entity Relationship Diagram ERD underlying the relationship between entities of the system data base.

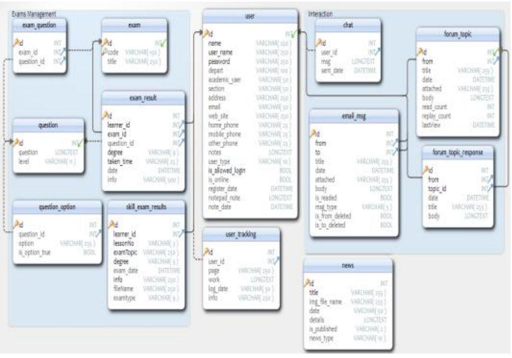

**Fig. 10. Entity relationship diagram**

The next part describes the learners and instructors view of the system.

### *D. Learners View*

Fig. 11 Shows the UML activity diagram for learner's activities. Learners are able to access the system from any place at any time. After learners login to the system, they can get help that provides information about the system usage. They can navigate through system components. Also they can access the content area for studying the educational materials. In case they have problems or questions, they can contact the teacher via synchronous or asynchronous communications facilities, where he advises them and answers their questions online. Additionally, he can give hints and links to other extensive learning material and learners explore it by themselves.

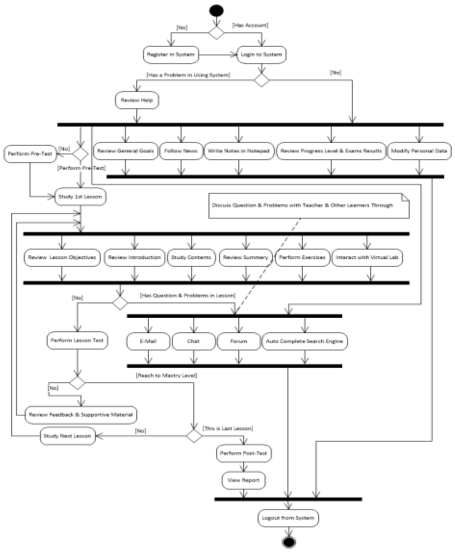

**Fig. 11. UML activity diagram for learner's activities**

Moreover learners can collaborate with each other to solve problems and they can use search engine to extract any information in the system or in web. They can view news and advertisements posted by the instructors in news area. They can use the notebook for keeping notes, comments, and remarks to remember each time they access the system.

### *E. Teacher View*

The system provides a set of functions for teacher to manage the learning process. Fig. 12 Shows the UML Activities diagram for the teacher.

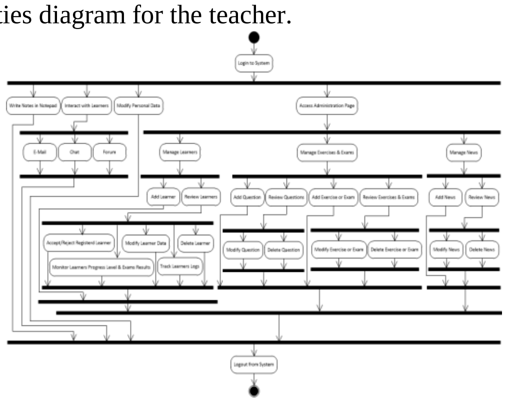

**Fig. 12. Teacher activity diagram**

The teacher can monitor learner's performance and keep tracking of his progress. The system provides teacher with general information about all learners including personal data, current status of each topic, last access date, and other specific information about each covered topic including difficulty level, questions and obtained score. He has the ability to prevent any learner from accessing the system, and to modify the learners' data. Also, teacher has the ability to manage exercises and exams through the evaluation panel. He can modify the questions and add a new question with its cognitive level to the questions bank. He can create exercises and exams by selecting questions from questions bank and add them to the exams bank, he can also modify exams and exercises. Teachers also view reports about cognitive tests and practical skills tests for each learner. Teacher manages news and advertisements by adding, editing, updating or deleting news through news panel. The system provides him with a text area, so that he can write and update notes, comments, and remarks.

## V. APPLICATION AND RESULTS

This section explains the system applications to evaluate its effectiveness. The system is applied into sample contains of electronic and computing department students at the vocational preparatory stage at school for deaf students in Mansoura – Egypt. The SPSS 16.00 (Statistical Package for Social Sciences) statistical program was used to evaluate all the data collected from pre-and post-tests for the experimental group. Fig. 13 shows the average of student degree in pre/post application for achievement test arranged according to the levels of cognitive domain (knowledge, Comprehension, Application). Also, Fig. 14 Shows the average of student degree in pre/post application for Practical Skills test.

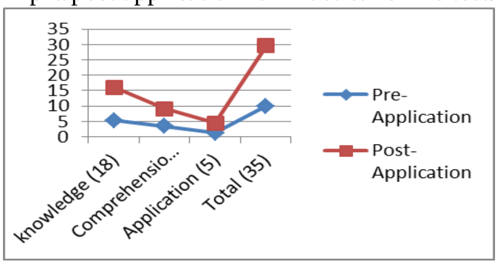


**Fig. 13. Average of student degree in pre and post-application for achievement test**

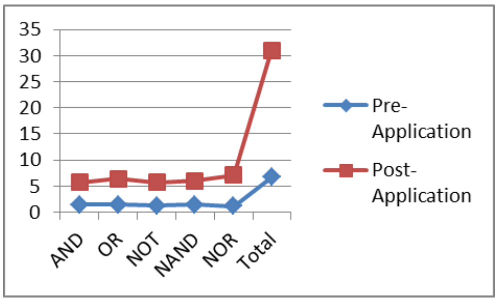


**Fig. 14. Average of student degree in pre and post-application for practical skills test**

From the previous two figures, We can concluded that there are statistically significant differences between means scores of the experimental group in the pre/post of the concepts achievement test and practical skills test in favor of the post test. The differences return to the effectiveness of the proposed system which improves students' concepts and skills.

## V. CONCLUSION

This paper presents the architecture of an intelligent web based learning system for digital circuits. The system helps to enhance deaf students learning concepts and training digital circuits' skills. It enables the teacher to manage and communicate with their students through the administration panel and interaction tools. To evaluate its effectiveness, the system is applied and the statistical analysis of results

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concludes the evidence of the effectiveness of the proposed intelligent web-based learning system.

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