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A Virtual Learning Environment to Improve Electronic Circuit Concepts and Skills for Deaf Students

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***Abstract*—This paper presents a virtual learning environment to improve the concepts and skills of electronic circuits for deaf students in electronic computing department at the vocational preparatory stage. The Virtual Learning Environment for Electronic Circuits VLEEC represents a valuable support for teachers and deaf students. It is adapted to the special needs of deaf students via a number of components and tools designed to be attractive, interactive, and interesting to deaf students. It also supports the teacher with a set of administration and communication tools that enable him to manage the learning environment, monitor his students and interact with them. The results clearly indicate the effectiveness of the VLEEC to improve electronic circuits' concepts and skills for deaf students.**

Keywords—Virtual learning environment; adaptive learning environment; electronic circuit concepts; electronic circuit skills; deaf students.

I. INTRODUCTION

Nowadays, there exists a common problem that is detected among science and engineering students: their lack of professional knowledge and skills. Those students lack the ability to apply the theory and research methods practically. This problem is becoming more prominent among some poor condition schools [1].

Engineering learning is very difficult at present because the different technological areas involving several interrelated concepts and tend to become very complex [2, 3]. In view of that, many engineering education experts say that it is necessary to develop new learning methods, using information tools to improve teaching and learning [4-6].

This problem is more manifested in the case of dealing with deaf students, especially at preparatory stage. Deafness according to WHO (World Health Organization*) is defined as the lack or complete loss of the ability of hearing [7]. A deaf is defined as one who cannot hear, and consequently cannot comprehend speech and language through the ear. Communication then for a person who cannot hear is visual, not auditory [8].

"Electronic and digital experimental studies are very important components in engineering education. It not only acts as a bridge between theory and practice, but it also solidifies the theoretical concepts presented in the classroom" [9]. Electronic circuit experiment is a vital part of education and a valuable method of learning because it gives the learner the feeling of involvement. It can practice the students' operation ability and also provides a good opportunity for them to put into practice what they've learned in class [10].

"In the field of Computer and Software Engineering, different types of practical activities have to be performed in order to obtain basic competences which are impossible to achieve by other means. Practical laboratory activities are an essential part of any computer curriculum since they strengthen the concepts presented during the lectures. For that reason, new virtual spaces are required so practical activities can be carried out" [11]. Such spaces are called Virtual Learning Environment VLE.

Deaf students in the department of electronic computing, in vocational preparatory stage at deaf schools, study electronic circuit course. In this course, students are taught electronic circuit including: numerical systems, logic types, logic gates ...etc. This course is difficult for them, where their teachers confirmed that they face some problems and difficulties with its contents. These difficulties are due to the inability of the students to imagine the electronic circuits and the contents of the subjects that are not tangible.

* World Health Organization (WHO) [Online]: http://www.who.int/mediacentre/factsheets/fs300/en/

Therefore, this paper aims to improve the concepts and skills of electronic circuits for deaf students at electronic computing department through a proposed system called Virtual Learning Environment for Electronic Circuits "VLEEC". In VLEEC, the special needs of deaf students are taken into consideration. Bilingual information (text and sign language), interactive tools, interaction and communication components are included.

Section 2 presents related work, section 3 illustrates overview, and structure of the VLEEC, section 4 introduces experimental work with application of VLEEC and finally results are concluded.

II. Related Work

"Virtual reality technology is an exciting tool that involves a safe and supportive environment to transfer knowledge between virtual and real worlds. Through such technology, individuals with special needs can look carefully at their own strengths, abilities, and learning preferences in comparison to the required learning task and expected learning outcome" [12].

"Virtual learning environment is any combination of distance and face-to-face interaction, where some kind of time and space virtuality is present" [13]. "It is defined as the delivery of learning through electronic mediation which bridges the gap caused when the instructor and student are separated in either time or place. The range of electronic mediation includes voice, video, data, and print through such formats as radio, television, Web-based programming, and streaming audio and video, as well as a variety of recording technologies" [14].

The benefits of virtual learning environment include: break down barriers for students with hearing impairments and deafness by providing real world applications to practice essential basic skills; easy way of online delivery materials for both students and teachers; enable the students to access these resources at any time, at any place; offer potential of supporting large groups of students; support active and independent learning with online communication, online assessment and collaborative learning [12, 15, 16].

The tools and features that comprise a Virtual learning environment VLE typically include: 1) Communication and interaction tools between teachers and their students. 2) Delivery of learning resources and materials. 3) Shared learning resources. 4) Support for students through help and FAQs. 5) Authentication. 6) Navigation structure. 7) Personalization. 8) Self-assessment including summative assessment [15].

There are many studies that use virtual learning environments for deaf and hard-of-hearing children, David Passig and Sigal Eden introduce two studies to compare the rotating Virtual Reality (VR) three-dimensional (3D) objects with the practice of rotating 2D objects, and investigate their impacts to enhance the spatial rotation thinking of deaf and hard-of-hearing children. Also they investigate the effect of using virtual reality environments as a tool for improving structural inductive processes and the flexible thinking with deaf and hearing-impaired children. The results clearly indicate that practice with VR 3D spatial rotations significantly improved students' performance of spatial rotation inductive thinking and flexible thinking of students [17, 18].

Nicoletta Adamo-Villani, Edward Carpenter, and Laura Arns (2006) developed an immersive 3D learning environment to increase mathematical skills of deaf children. The application teaches mathematical concepts and ASL (American Sign Language) math terminology through user interaction with fantasy 3D virtual signers and environments [19]. Chien-Yu Lin, Pi-Hsia Hung, Li-Chih Wang, and Chien-Chi Lin (2010) establish a study that takes the advantage of virtual environment designing motion trajectory in order to figure out the element in Quenching 3D spatial sense [20].

Katja Straetz and others (2004) present a learning management system (LMS) which offers German Sign Language videos in correspondence to every text in the learning environment. The system is designed notably for deaf adults who want to maintain and improve their mathematical and reading/writing skills [21]. Also, Drigas A.S. and Kouremenos D. (2005) present a learning management system (LMS) which offers Greek Sign Language videos. In the LMS, the special needs of deaf learners are satisfied, and signers are able to learn in their own language [22].

Javier Bueno F., Soledad García, Reca Borrego, and Raul Fernández del J. (2007) report a proposal to solve the problems that deaf students have to face when reading a text (printed, downloaded from a web page or e-learning course) [23]. Catherine S. Fichten and others (2009) explored e-learning problems and solutions reported by 223 students with disabilities, 58 campus disability service providers, 28 professors, and 33 e-learning professionals from Canadian colleges and universities [24].

Matjaž Debevc, Primož Kosec, and Andreas Holzinger (2010) present basic e-learning accessibility guidelines for deaf and hard of hearing and basic directions for suitable design of e-learning sites accessibility [25]. Also, Matjaz Debevca, Zoran Stjepanovicb, and Andreas 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 [26].

III. VLEEC Overview and Structure

Fig. 1, shows a use case diagram for VLEEC. It describes the interactions between external users and the learning environment to accomplish a particular goal. Two user levels are distinguished in the VLEEC. According to the user level there are different roles: students and teacher/administrator, each of them interacts with the other through the communication tools. They have a different privilege, tools, and permissions. Fig. 2, shows the structure of VLEEC.

After the user opens the VLEEC learning environment the login form appears and checks the user privilege (student or teacher/administrator) to navigate through the suitable user interface.

The deaf student can access the content area for studying the educational materials. His roles include: review general goals, perform pre-test, study lesson content (behavioral objectives, introduction, lesson contents, summery, exercises, and lesson test), and perform post-test. Also, the student can review help about how to use the VLEEC learning environment, follow news and advertisements posted by his teacher, record comments, communicate with his colleagues and teachers through communication tools (chat, email, and forum), review his progress level and exams result, modify his personal data, use search engine for searching about any additional information in the learning environment or on the internet. To improve students' practical skills, he can interact with virtual lab to connect electronic circuits, verify and evaluate the results of these circuits, and detect the bugs if there is an error.

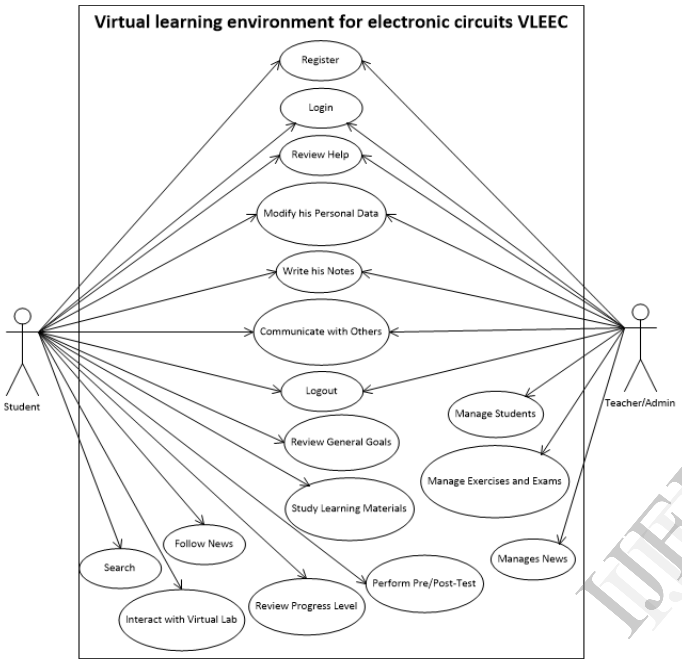

Fig. 1. VLEEC use-case diagram.

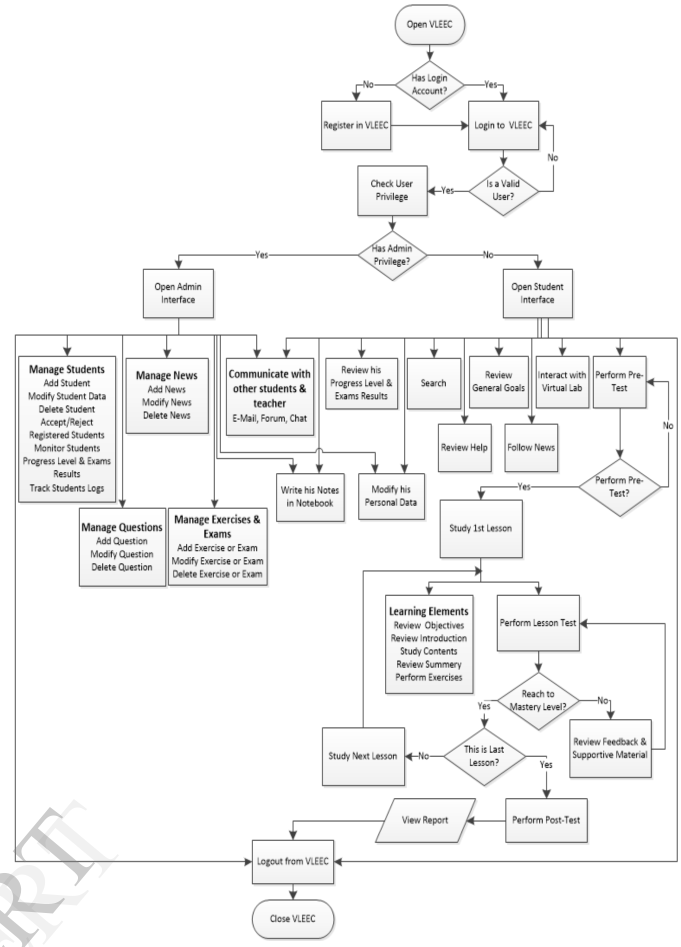

Fig. 2. The structure of VLEEC.

Teacher/administrator can navigate through the administration interface. His roles include: modify his personal data, monitor learners' performance, keep tracking of their progress, record comments and remarks in a note book, and interact with his students using communication tools (chat, email, and forum). He has the ability to accept or reject students' registration, modify students' data, or delete a student. Also, he has the ability to manage exercises and exams through the evaluation panel, modify existing questions or add a new question with its cognitive level to the questions databank, or modify exams and exercises. The teacher can also view reports about the results of concepts achievement tests and practical skills tests for each learner. The teacher manages news and advertisements by adding, editing, updating or deleting news through news panel.

VLEEC learning environment is adapted to deaf students via a number of components designed to be attractive, interactive, and interesting to them. It integrates tools needed to interact with learners through communication tools, virtual lab, etc. The environment offers facilities and services to support them through easy and friendly Graphical User Interface GUI. Interface layouts are divided into parts according to functionality, so the learner can easily find the functions he needs. GUI is structured in three parts: top, right, and middle, as shown in Fig. 3. The top part "Interaction Area" includes the interaction controls containing links for functions that are needed such as: learning progress, modifying personal data, logging out, communication, virtual lab, help and search. The right part "Navigation for Learning" consists of the navigation tools through the learning resources and pedagogical modules. The middle part "Content Area" is the learning and working area in which learning contents are displayed.

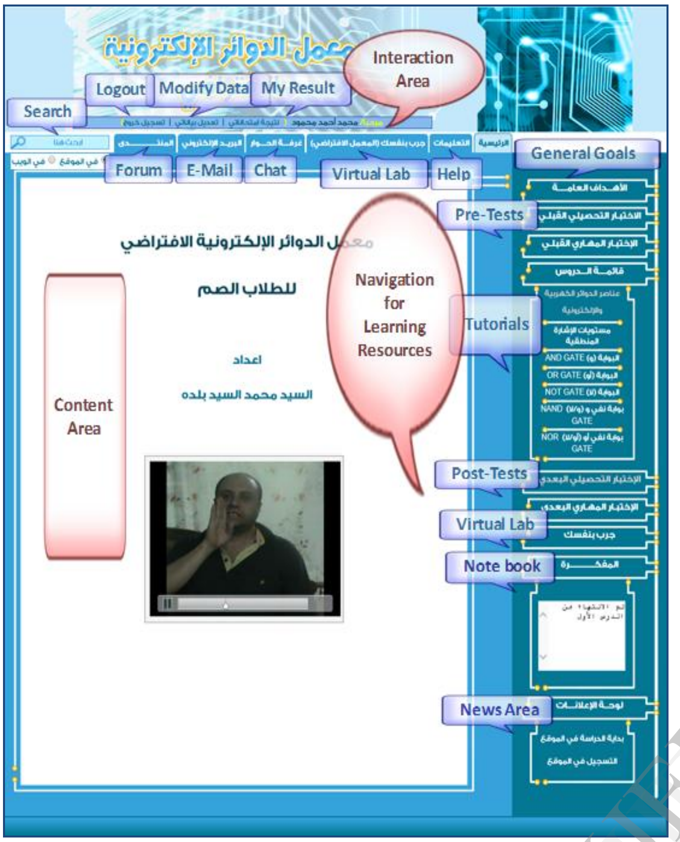

Fig. 3. Learner's interface structure.

The learning material displayed in the content area has template based content structuring. The use of templates for pages, exercises, and tests makes the creation of the learning content much easier and guarantees a homogeneous and clearly arranged design.

The template is structured into panes according to functionality. It is structured in four panes – header, right, middle, and footer as illustrated in Fig. 4. The header pane is the title bar displaying the title of the page. The right pane provides links to the educational contents of the current lesson including: behavioral objectives, introduction, lesson contents, summery, exercises, and lesson tests to evaluate the learner. Learners can adapt their learning environment and improve the readability of the displayed text through selection of their favorite settings (text color- font size…..etc.). They can print lesson contents and display the contents in a new (Popup) window for increasing the displaying area for the contents. The middle pane displays the lesson content text and sign language video represented in this text. There is a navigation menu at the top left corner to navigate through the lesson contents. The footer pane provides basic navigation controls, as back and forward.

Fig. 4. Page template for lesson contents.

Using the sign language videos for each text allows deaf students to concentrate on the contents and increase their motivation. It supports independent learning and increases the possibility to learn in a self-directed way. Learners do not need a teacher or interpreter for learning, and they have the feeling that they are considerable.

VLEEC provides deaf students with a set of electronic circuits and instructions on how to build and simulate these circuits. It provides them with an interactive virtual lab for the electronic circuits. The Virtual lab helps students to understand the concepts of electronic circuits and increases educational efficiency with significantly less operating cost. It enables students to carry out experiments repeatedly in a safe environment during lessons. Students have the freedom to conduct experimental work and gain hands-on experience. They use the virtual lab to build the electronic circuit in any way, and then they check this circuit to investigate its components and connections.

Evaluation tools include exercises and tests to monitor deaf student's performance and progress. Tests include initial assessment through pre-test, formative assessment through lesson tests and final assessment through post-test. The scientific concepts of electronic circuits are measured by electronic achievement tests, and practical skills of electronic circuits are measured by electronic practical tests. Exercises and tests incorporate the facility to feedback on responses and direct students to links and other resources. Regular and meaningful feedback improves students' motivation, helps for diagnostic purposes and saves time.

Students can study topics and move from one to another according to their personal levels; first they perform a pre-test only one time before accessing any topics, then they must pass the current topic tests with a certain level (>=65%) before they move to the next topic. After learners finish all entire lessons of the course, they take post-test in order to evaluate the learning outcomes. If any learner tries to access topics before executing the requirements, VLEEC redirects him to his unfinished topics.

The achievement tests are evaluated electronically through the electronic test debugger, which checks the students' solutions for every question and generates corrective feedback. It supplies the students with supportive material for wrong answers or unanswered questions to adapt the learning process. Also it evaluates the students' responses for tests and provides feedback to the learner including: test topic, number of right answers, number of wrong answers, grade, and taken time.

The practical tests for the electronic circuit skills are evaluated electronically by the intelligent circuit analyzer. It examines and analyzes the students' circuits, identifies errors, and provides explanations and suggestions to guide them to the right answers. Students use a virtual lab to create the required circuit, the circuit analyzer verifies the circuit components and connections. It checks the containment for all the 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 if there is an error.

Adaptable learning environment is provided, where VLEEC records all information about the student behavior and activities including personal data, student characteristics, prior relevant data, test evaluation results, progress level, error knowledge, etc. learners can view their performance and progress level where details about their tests are presented. Farther more, wrong and unanswered questions are displayed with link to supportive material. Fig. 5, display a report for a student's results in an achievement and practical test.

When the student selects any test, the details of this test will appear. These details include the number of questions, the number of correct answers, the number of wrong answers, the number of unanswered questions, the degree, the percentage, the grade, taken time, and the test date and time. Furthermore it displays the wrong and unanswered questions with link to supportive material.

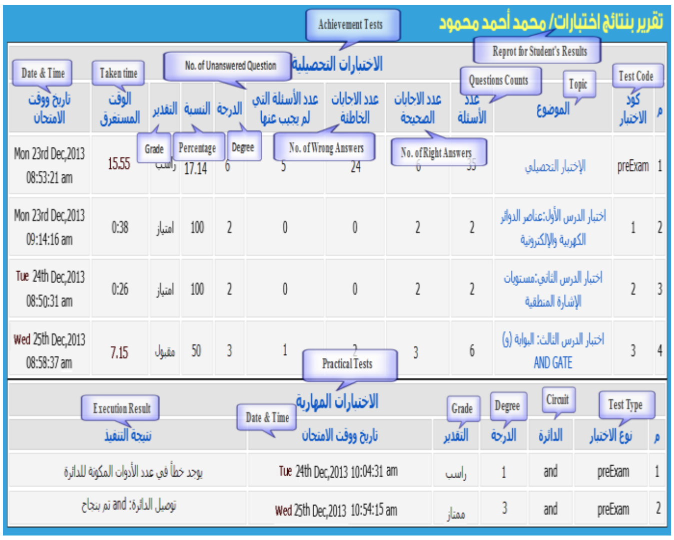

Fig. 5. Learner performance report.

VLEEC contains search engine, where deaf students can search for additional information. The result of searched text automatically include details such as: result number, page title, quoted text, URL, result weight score, date and size of the file. Fig. 6, illustrates search result component. Furthermore, students can search for external resources on the internet.

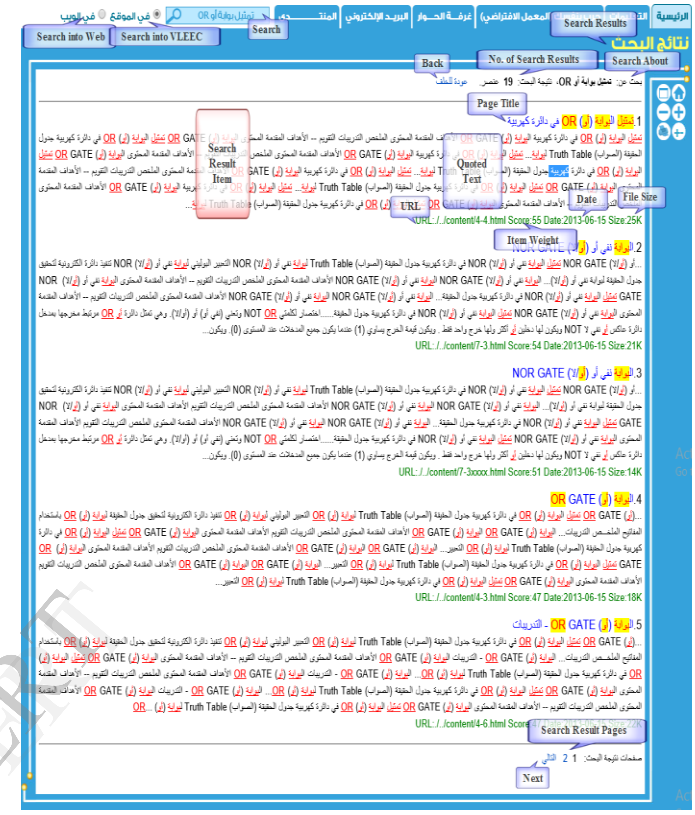

Fig. 6. Search Result.

The VLEEC provides students with notebook facility for annotating course notes. The students can use it for keeping their comments, and remarks. Also they can view news and advertisements posted by the instructors in news area.

Integrated communication components are consisting of chat-room, e-mail and forums which support various types of communication (synchronous and asynchronous) enabling deaf students to communicate directly with each other and with their teacher while working on the course. Students may use them to work on their tasks together, share files and post their own pages. Communication components help students to better manage their assignments and complete their course. It encourages the students' participation and collaboration. Each communication component runs in a separate window, so the student can communicate with others while studying the learning material.

The e-mail tool allows students and instructors to correspond with each other without requiring the use of Internet e-mail accounts. It enables them to compose new mail messages, view and read inbox, outbox and draft.

A discussion forum for electronic circuit topics allows the students and the teacher to leave messages, read, search and respond to messages left by others. It allows the students to explore and express their ideas related to the electronic circuit and encourages them to reflect more on their contributions. It can be used as a place for students to post questions about the electronic circuit. Answers to one student's question are posted to the discussion forum for all. So, It can cut down on the total number of questions from individual students.

Chat room permits synchronous communication, which allows users to communicate in real time using easily accessible web interface without need to any software installation. The teacher can use live chat during the electronic circuit course as a way for deaf students to receive a quick response to a question. Deaf students have availability to adapt chat room by choosing room background and font type, size and style …etc., they can send emotion.

IV. EXPERIMENTAL WORK

In order to assess the effectiveness of the VLEEC to improve electronic circuit concepts and skills for deaf student, an experiment was applied. This section explains the VLEEC applications to evaluate its effectiveness.

A. Variables: The study variables are*:*

• *Dependent Variables:* Electronic circuit concepts and skills for deaf students.
• *Independent Variable:* Virtual learning environment VLEEC.

B. Sample: The sample consists of electronics and computing department students at the vocational preparatory stage at deaf students school in Mansoura city – Egypt.

C. Hypothesis: Two hypotheses are considered:

• There are statistically significant differences between means scores of the experimental group in the pre and post application of the concepts achievement test with its levels (knowledge, Comprehension, and Application) and total score in favor of the post application.
• There are statistically significant differences between means scores of the experimental group in the pre and post application of the practical skills test with its dimensions and total score in favor of the post application.

D. Assessment tools: The study employed two main measurement tools: achievement test and practical skills test.

• *An electronic achievement test:* was developed and its content validity and reliability were checked. The achievement test aimed at investigating students' level of understanding of electronic circuit concepts. It consists of 35 multiple choices items. The knowledge levels of these items were arranged according to the levels of behavioral objectives of the electronic circuit course. Subsequently, these items were grouped into the three levels of cognitive domain (knowledge, Comprehension, Application) of Bloom's taxonomy.
• *An electronic practical skills test:* was used to measure the learners' practical skills of electronic circuits. It contains five experiments about the construction of main electronic circuits (AND, OR, NOR, NAND, NOR) which learners perform through the virtual lab and the VLEEC analyzes the student's work, identifies errors, and provides explanations and suggestions to guide them to the right answers.

*E. Methodology***:** The present study employed pre-post for one experimental group. This experimental design enables the manipulations of the variables to be observed in order to investigate the effectevines of VLEEC. The measurement tools are applied to the experimental group as a pre-test before learning process and as a post-test after learning through the VLEEC.

*F. Statistical analysis***:** To study the effectiveness of VLEEC, the SPSS 16.00 (Statistical Package for Social Sciences) statistical program was used to evaluate all the data collected from the pre-and post-tests.

Fig. 7, 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. 8, shows the average of student degree in pre/post application for Practical Skills test. The results indicate that Students' grades rise in the post-test than in the pre-test.

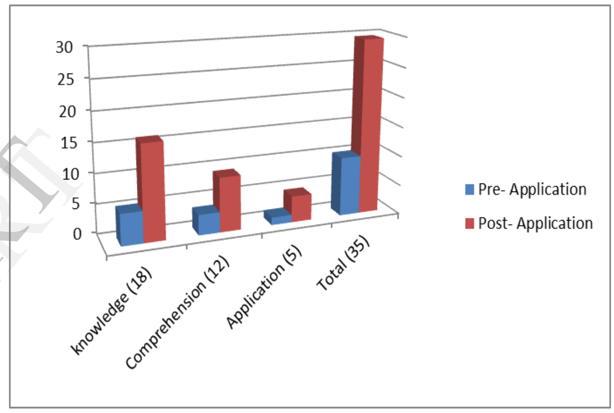

Fig. 6. Average of student degree in pre and post-application for achievement test

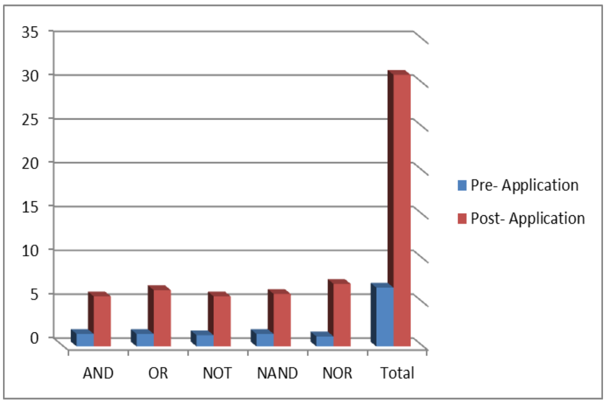

Fig. 7. Average of student degree in pre and post-application for practical skills test

To validate the hypothesis, Wilcoxon test is used for related groups and value of (Z) is calculated to know the significance of the difference between the averages of the two applications (pre, and post), value of (η2) is calculated to check the size and the amount of influence.

Test hypothesis 1:

Table 1 summarizes the statistical analysis of the pre and post application results in the achievement test for the experimental group.

TABLE I. STATISTICAL ANALYSIS OF THE PRE. AND POST APPLICATION RESULTS FOR THE EXPERIMENTAL GROUP IN THE ACHIEVEMENT TEST

Test Level	Rank	Rank Mean	Rank Sum	Z	Sig.	Influence Size η2
Know-ledge	Negative	0.00	0.00	2.414	0.05	0.912
	Positive	4.00	28.00			
	Equal					
Compre-hension	Negative	0.00	0.00	2.384	0.05	0.901
	Positive	4.00	28.00			
	Equal					
Appli-cation	Negative	0.00	0.00	2.388	0.05	0.902
	Positive	4.00	28.00			
	Equal					
Total	Negative	0.00	0.00	2.371	0.05	0.896
	Positive	4.00	28.00			
	Equal					

From table 1, There are statistically significant differences between means scores of the experimental group in the pre and post application of the concepts achievement test with its levels and total score in favor of the post application, due to Z values are equal (2.414, 2.384, 2.388, 2.371) at the sig. level of (0.05), and the size of the influence of the independent variable on the dependent variable is equal (0.912, 0.901, 0.902, 0.896) with large influence amount.

Test hypothesis 2:

Table 2 summarizes the statistical analysis of the pre and post application results in the practical skills test for the experimental group.

TABLE II. STATISTICAL ANALYSIS OF THE PRE AND POST APPLICATION RESULTS FOR THE EXPERIMENTAL GROUP IN THE PRACTICAL SKILLS TEST.

Test Dimensions	Rank	Rank Mean	Rank Sum	Z	Sig.	Influence Size η2
AND Circuit	Negative	0.00	0.00	2.401	0.05	0.907
	Positive	4.00	28.00			
	Equal					
OR Circuit	Negative	0.00	0.00	2.392	0.05	0.904
	Positive	4.00	28.00			
	Equal					
NOT Circuit	Negative	0.00	0.00	2.428	0.05	0.917
	Positive	4.00	28.00			
	Equal					
NAND Circuit	Negative	0.00	0.00	2.414	0.05	0.912
	Positive	4.00	28.00			
	Equal					
NOR Circuit	Negative	0.00	0.00	2.392	0.05	0.904
	Positive	4.00	28.00			
	Equal					
Total	Negative	0.00	0.00	2.410	0.05	0.910
	Positive	4.00	28.00			
	Equal					

From table 3, There are statistically significant differences between means scores of the experimental group in the pre and post application of the practical skills test with its dimensions and total score in favor of the post application, due to Z values are equal (2.401, 2.392, 2.428, 2.414, 2.392, 2.410) at the sig. level of (0.05), and the size of the Influence of the independent variable on the dependent variable is equal (0.907, 0.904, 0.917, 0.912, 0.904, 0.910) with large influence amount.

So the differences between the grades of the two tests scores in the achievement test and practical skills test are in favor of the post application. The differences return to the effectiveness of the VLEEC learning environment which improves students' concepts and skills.

V. CONCLUSION

At this paper a virtual learning environment VLEEC for deaf student has been proposed. This environment is implemented for improving electronic circuit concepts and skills for deaf student. The VLEEC learning environment represents a valuable support both for teachers and students. It is adapted to the deaf students via a number of components and tools designed to be attractive, interactive, and interesting to the deaf students. It supports the teacher with a set of administration tools that enable him to manage learning environment and monitor his students. The VLEEC learning environment is applied to students at electronics and computing department, vocational preparatory stage, deaf students school in Mansoura city – Egypt to evaluate its effectiveness. The the statistical analysis of results and findings conclude the evidence of the VLEEC effectiveness.

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