DOMESTIC ELECTRICAL ELECTRICAL INSTALLATION

Design and Development of a Domestic Electrical Installation Trainer for Students of Abia State College of Education (Technical) Arochukwu

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Abstract

Students' domestic electrical installation (house wiring) practice in real world environment may be dangerous to students and the properties considering the voltage involved. Hence, this paper designed and developed a simulated domestic installation trainer that will train students on domestic wiring while taking safety into consideration. The domestic electrical installation trainer software has three modules, namely, theory, practice and multiple choice test. The theory module consists of four sections; hand tools and equipment, materials, safety regulations and steps for domestic conduit wiring respectively. The practice module trains students on how to conduct surface conduit wiring of a bedroom including feedback on wrong step or operation. In specific, with the trainer in place, a student can mark the positions of the wall socket, lighting switch and lamp holder on the wall and ceiling and then install them. A student can also draw lines on the wall to represent PVC conduits, clean wrong lines, select colour of lines and size, draw cables from distribution board to accessories. On the other hand, the trainer trains students on electrical installation from electric pole to the distribution board while giving feedback on both correct and wrong connections. The multiple choice test module tests students' understanding of the theory module they covered. Student can view his/her multiple choice test result immediately after finishing the test. Likewise, the lecturer can view students' results after the test. The developed system has general, admin and lecturer login interfaces. Hence, the database stores users' login details and students results. The software was implemented using Java programming language in NetBeans (8.2) IDE (Integrated Development Environment). MySQL database was incorporated into the developed system for storage of various data, such as users' login details and results. The database and its tables were created using MYSQL workbench (8.0). The developed system was tested by students and staff. The result of the test indicated that the developed system is effective and efficient. The evaluators recommended the use of the developed system for teaching domestic electrical installation in the College.

Keywords: domestic electrical installation; electrical installation; house wiring; residential electrical installation; trainer software

1 Introduction

Electrical/electronic technology programme in Nigerian trade centres, Colleges of Education, Polytechnics and Universities contains many trades such as auto-electrical repairs, electronic equipments repairs, electronic systems production and domestic electrical installation among others. Electrical Installation according to the Abu Dhabi Regulation and Supervision Bureau (2014) comprises any fixed or temporary cable, switchgear or other electrical equipment or apparatus within a premises or other place where there is an electricity supply (including outdoor locations). Electrical installation falls into four main categories, viz; industrial, commercial, institution, and

domestic. Domestic electrical installation is of low voltage type consisting of distribution boards, meters, general circuits, power circuits, fire alarm circuits, communication circuits, earthing and protective devices among others(Rigby, 2005). The process of realizing domestic electrical installation begins with design and calculations. This followed by piping, running cables in conduit pipes, connecting cables to various wiring accessories such as socket outlets, lamp holders and switches among others and finally connecting the circuits to power supply coming into a building. The process ended with inspection, testing and commissioning. All the above steps are carried out in accordance to standard safety rules and regulations (Scaddan, 2011).

The practice of the process of teaching and learning of domestic electrical installation in school setting is carried out in two main phases; school workshop and industrial attachment settings (Federal Republic of Nigeria, 2013). Some schools in addition, take students to houses where electrical installations is taking place with the view of acquiring more practical skills before embarking on industrial attachment. These three approaches provide students with adequate competences in domestic electrical installation. But, sometimes these three approaches are not all implemented during students' training programme due to the non-availability of either training equipment or teaching staff. This situation often leads to the graduation of students with low level of skills to handle domestic electrical installation. To address this training inadequacy, the researcher set out to develop domestic electrical installation software that can supplement teaching and learning of domestic electrical installation in trade training centers, Polytechnics, Colleges of Education and Universities.

2 Problem statement and justification

Domestic electrical installation practice is one of the trades in electrical/electronic technology programme of Nigerian Colleges of Education, trade centers, Polytechnics and Universities. The practice offers students of electrical/electronic technology opportunity to learn among other things how to perform both surface and conduit wiring of industrial, commercial and domestic edifices (building). The present practice of teaching and learning domestic electrical installation involves using face-to-face interaction with teacher in the Class and workshop as well as in industrial attachment settings. But in Abia State College of education(Technical) Arochukwu, this practice is supplemented by attaching students to ongoing domestic building projects so as to acquire more practical skills in domestic electrical installation. But sometimes ongoing domestic building(s) may not exist during the time students need to acquire skills for domestic electrical installation. This will lead to graduation of students with inadequate skills for electrical domestic installation. To mitigate this training inadequacy, the researcher set out to develop domestic electrical installation trainer software. Such software will enable students to acquire skills in domestic electrical installation at anytime and anywhere thereby supplementing the efforts of lecturers in electrical/electronic technology department in the area of domestic electrical installation.

3 Objectives of the study

The main objective of the study is to design and develop domestic electrical installation trainer software for Students of electrical/electronic technology. Specifically, the study will;

1. Determine the software requirements of the domestic electrical installation trainer software
2. Design the domestic electrical installation trainer software

3. Develop the domestic electrical installation trainer software
4. Test the developed domestic electrical installation trainer software
5. Determine student's satisfaction with the developed domestic electrical installation trainer software.

4 Literature review

This section presented the concepts of electric circuit, steps in conduit electrical installation, safety and electrical plans. The section also presented hand tools and materials used in conduit wiring. The section ended with some software trainers developed to supplement teaching and learning domestic electrical installation.

4.1 Electrical circuit

An electrical circuit is a set of phase, neutral and earth conductors installed as a group to supply power to a location and which originate from one Protective Device. There are different types of circuits which include, but not limited to ring circuit, radial circuit, final circuit and distribution circuit respectively. Ring Circuit: a circuit which is wired from a single protective device, being run through an area to be supplied (via appropriate socket-outlets, switched flex outlets, etc) and returning back to the same protective device, thus forming an electrically continuous loop. Radial Circuit: a circuit which is wired in a 'radial' or 'branch' configuration, emanating from a protective device, to the area to be supplied; Final Circuit: a circuit which directly supplies appliances (normally via socket-outlets, switched flex outlets, isolators, ceiling roses, etc.); and Distribution Circuit: a Circuit connecting between Distribution Boards .Distribution circuit is also be referred to as a 'sub-Circuit' (Abu Dhabi Regulation and Supervision Bureau, 2014).

4.2 Hand tools and equipment for domestic electrical installation

There are many types of hand tools and equipment involved in the execution of domestic electrical installation. These include but not limited to:

- **Conduit bender:** used for creating bends and turns in rigid conduits(bending spring for PVC conduits)
- **Fish tape or Draw wire:** facilitates pulling cables through a conduit
- **Conduit cutter(eg. hack saw):** used for precise cutting of conduits to desired lengths
- **Marker (eg. white chalk or charcoal):** aid in marking conduit parts
- **Sledge Hammer:** for cracking walls
- Chisel-used for cracking walls to secure conduits and boxes
- **Spirit Level:** ensure alignment of installation
- **Measuring tape:** ensuring accurate measurements
- **Pliers:** used for cutting wires or cables
- **Cable strippers:** used for stripping cables
- Screwdriver-connecting cables to accessories
- Screw driver tester-for testing presence or absence of phase current
- **Testing lamp:** for testing presence or absence of phase current
- **Mobile scaffolds/step ladder:** for accessing and mounting electrical components among others

- **Continuity tester:** for testing the continuity of electrical circuits

4.3 Materials for domestic electrical installation

Different types of materials are involved in domestic electrical installation. Thes include but not limited to:

- **Conduit:** is steel, PVC or flexible pipes that carries cables and give them protection against physical damage(20-25mm thick PVC pipe (routing)
- Gum
- Coupler-used for joining conduits
- Male bush
- Mortar-used for holding conduits and boxes
- Boxes(Looping box, 3x3-box, 3x6-box,4-way box, Y-box,2-way box and stop-end box,etc)
- Switches(assorted)
- Sockets(assorted
- Fan regulators
- Distribution board
- Change over Switch
- Electric meter
- Cables of different sizes(eg. 1.00mm2,150mm2,2.50mm2,4.00mm2,10mm2,16.00mm2,etc)
- Insulation tape
- Cut out fuse
- Protective devices(assorted)
- Electric pole

4.4 Steps in conduit electrical installation

The following are some of the major steps involved in conduit electrical installation.

1. Planning and Preparation
2. Marking out accessories positions(using electrical floor plan, electrical wiring diagram or conduit layout)
3. Piping(chiselling, measuring, cutting, bending ,joining and laying boxes / conduits into walls, ceilings and slabs)
4. Pulling of cables through conduit using fish tape or draw wire
5. Terminating wires- involves cutting, stripping, and fastening lugs or crimps on the ends of wires or cables to prepare them for a secure connection. The termination can be within junction boxes, electrical panels, main electrical switchgear or any other electrical equipment.
6. Fittings(connecting accessories such as wall sockets, switches, lamp holder ,etc to circuits(cables)
7. Inspecting the installation
8. Testing the installation

4.5 Safety requirements

The following are some general safety requirements in relation to domestic electrical installation:

- All parts of an Electrical Installation shall be designed and constructed so as to prevent Danger.
- All parts of an Electrical Installation shall be sufficiently sized and rated to safely carry out the function for which they are required.
- All parts of an Electrical Installation shall be insulated appropriately according to the function they serve and in consideration of the expected operating environment, so as to prevent Danger.
- All Exposed-Conductive-Parts of an Electrical Installation and of Appliances must be connected to Earth via appropriate Earth Conductors, so as to protect against electric shock. Except in specified circumstances, all Electrical Installations shall be provided with Earth Leakage Protection at the source of supply, at all Final Circuits and at other appropriate points. In addition, Earth Equipotential Bonding shall be provided.
- All Electrical Installations must be protected against damage caused by excess current due to a fault or overload by suitable Protective Devices.
- All Electrical Installations must be provided with a means of isolating the electricity supply at suitable sections, subsections and Circuits, and at points where Appliances are used.
- All parts of an Electrical Installation must be suitably located so as to provide safe access for operation, maintenance and repair and must be protected against accidental or deliberate interference or damage. Electrical Installations must be designed and constructed with particular consideration given to the risk of fire due to electrical faults and the propagation of fire through parts of the Electrical Installation.
- All Electrical Installations must be inspected and tested at the time of first commissioning and at regular intervals thereafter to ensure ongoing safety, Inspection and testing of Electrical Installations must be carried out with due skill and care to avoid Danger to persons, property and installed equipment (Abu Dhabi Regulation and Supervision Bureau, 2014).

4.6 Architectural and electrical plans

Architectural and electrical plans play vital roles in conduit electrical installation practice. An Architectural floor plan is a type of drawing that provides a two-dimensional, birds-eye view of a room or building (Scaddan, 2011; Entz, 2023). It contains only architectural symbols as shown in Figure 1.

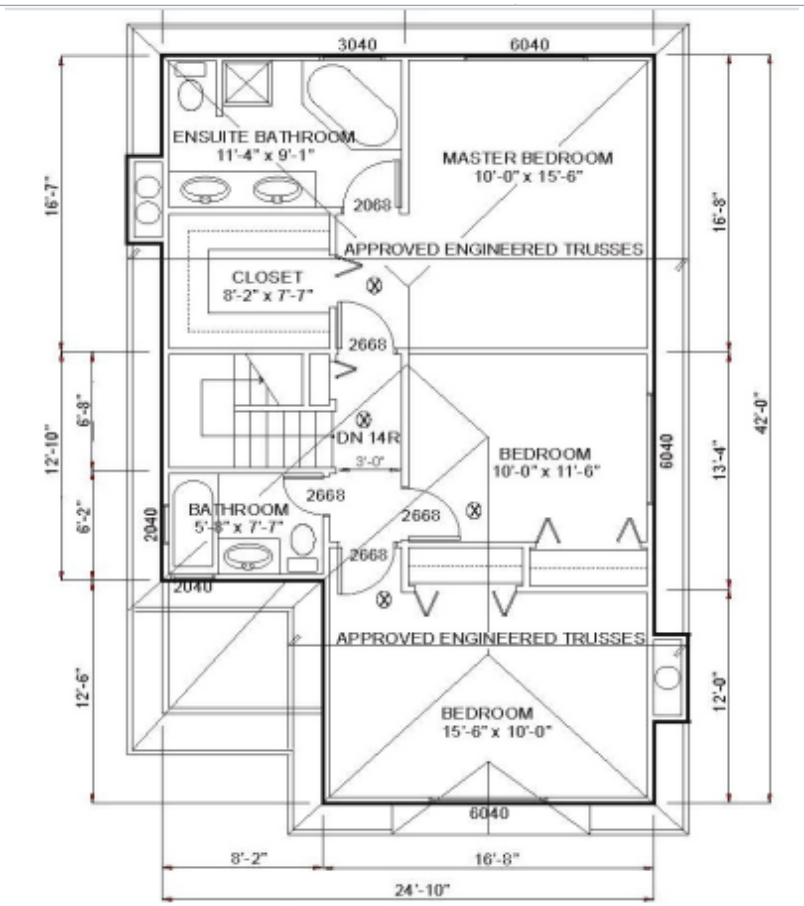


Figure 1. Architectural floor plan of a residential building (source: Vancouver, 2012).

Electrical floor plans on the other hand are architectural floor plans with electrical layout superimposed on it as shown in Figure 2.

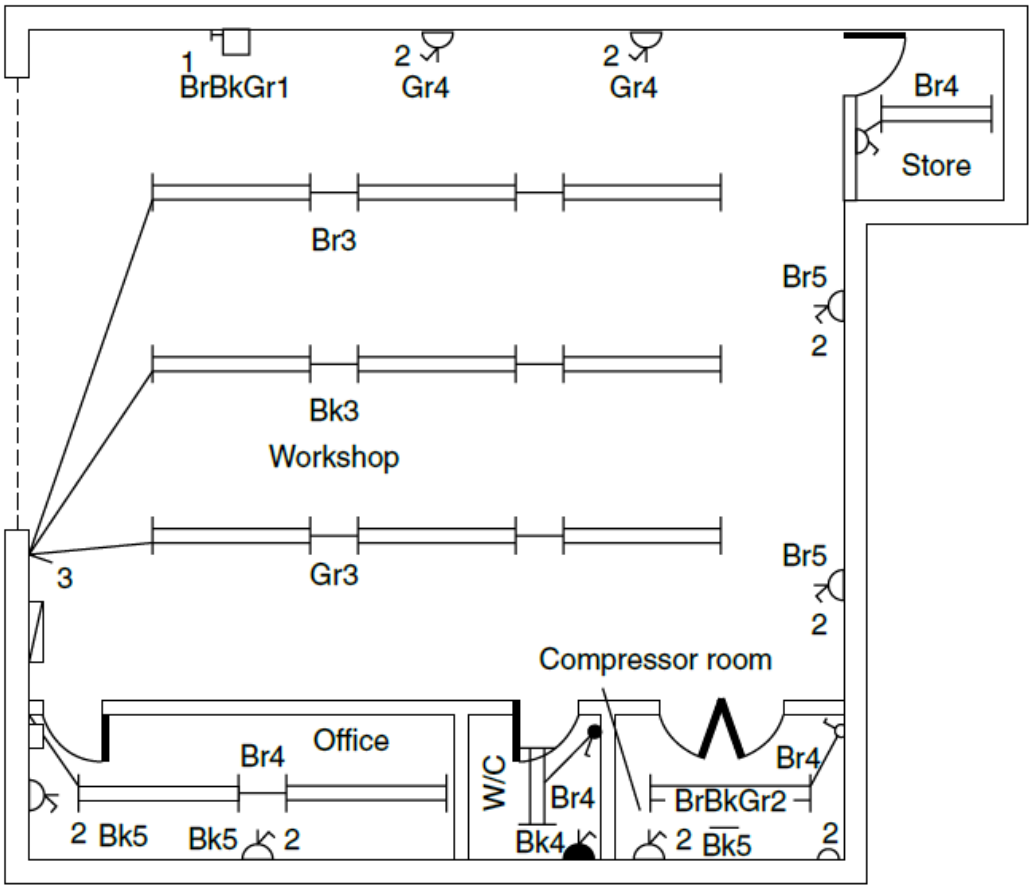


Figure 2. Electrical floor plan of a garage/workshop.

Electrical floor plans are two dimensional drawing as they do not show the actual position of accessories. This problem is resolved by using isometric electrical drawing as shown in Figure 3. An isometric electrical plan shows the electrical layout as in three-dimension .Both electrical floor plan and electric isometric plan guides electrical installer during installation process.

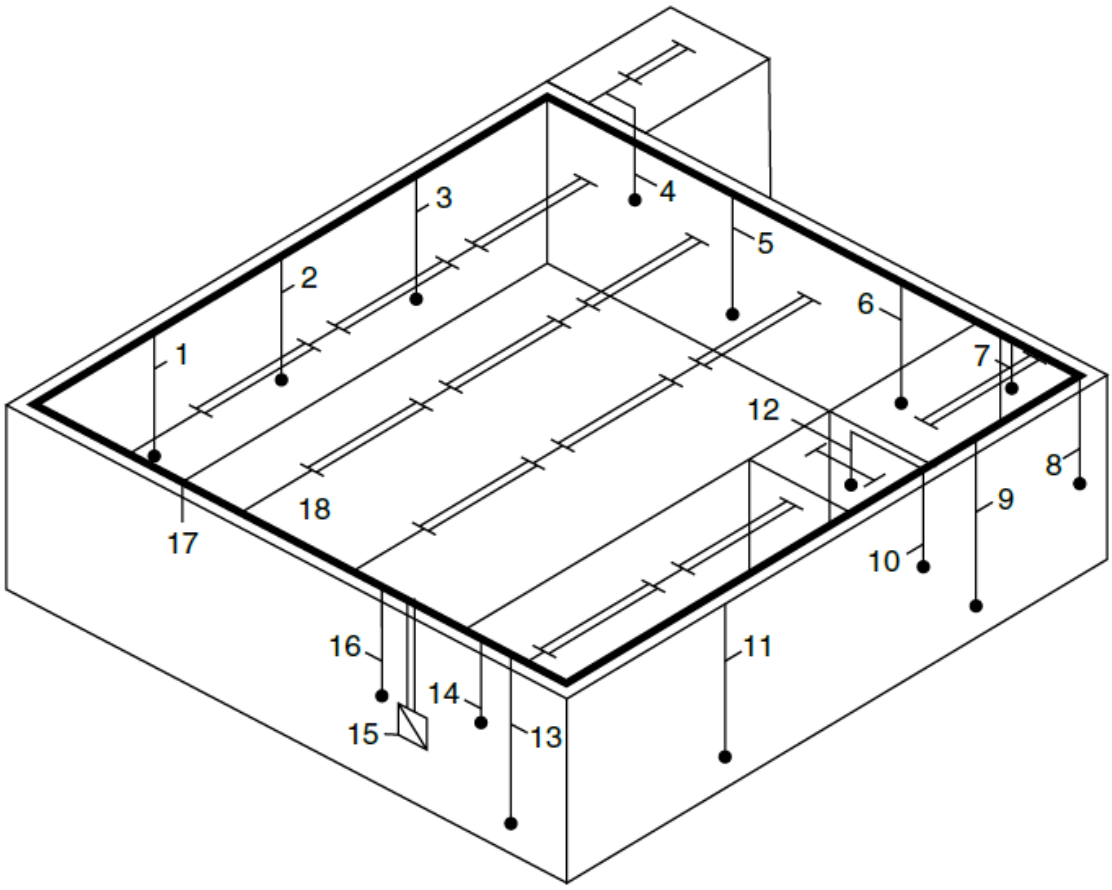


Figure 3. Isometric electrical drawing for a garage/workshop (source: Scaddan, 2011).

4.7 Software for domestic electrical installation training

This sub-section presents a number of domestic electrical installation trainers developed to enable students to acquire skills of domestic electrical installations. Such trainers are usually computer based learning environments.

4.7.1 Residential electrical wiring trainer

Lab-Volt Systems (2010) developed a residential electrical wiring trainer that will enable students to perform the following activities

- Wiring a Subpanel
- Wire a 30-Amp 120/240V Receptacle
- Wire a Switch-Controlled Light Fixture
- Wire a Switch-Controlled Receptacle
- Wire Two Receptacles in Sequence
- Wire a Switch-Controlled Split Receptacle
- Wire Three-Way Switches and Light Fix
- Wire a Doorbell.
- Install a Phone Jack
- Install a Coaxial Cable Connector

4.7.2 Residential electrical installation software

PC|SCHEMATIC A/S(2012) developed a software that guides students through the work processes of creating the documentation of an electrical installations in a small building. In specific, the software will enable students to:

- Make a simple floor plan with walls, doors and windows
- Place electrical and alarm installations on this house plan
- Use unit drawings
- Use the coordinate system, elevation and the layer function
- Make your own pickmenu
- Learn about list settings
- How to change database

5 Methodology

This study adopted Model Driven Development (MDD) methodology. This methodology was suitable for the present study. The Model Driven Development (MDD) methodology consists of seven phases like investigation phase, analysis of problem, requirement phase, decision analysis, Designs, Construction phase and implementation phase (Onyia, 2018).

5.1 Software requirement specifications

The following are the software requirement specification for the project.

5.1.1 Hardware requirements

- RAM: 1 GB or above
- Hard disk: 4 GB or above
- Processor: 2.4GHZ or above

5.1.2 Software requirements

The following specification are needed

- Window 10
- MySql
- J.D.K
- J.R.E.
- Netbeans (e.g. Version 8.2)
- Connector J 5.6

5.1.3 System users

- Admin
- Lecturer
- Students

5.1.4 Functional requirement specifications

Admin:

1. Login and logout.
2. View, add, delete, update and print lecturer, students and admin usernames and passwords

Lecturer:

1. Login and logout.
2. View and print students' results

Students:

1. Login and logout.
2. Learn theory and practice troubleshooting
3. Take examination
4. View and print results

5.1.5 Non-functional requirement specifications

1. Provide data security
2. Be efficient during operations
3. Be portable
4. Be reliable
5. Maintainable

5.2 Design

5.2.1 System physical architecture

The project adopted client-server architecture with two layers; the application and the database layer. The application layer is the, Graphical User Interface (GUI) while the database layer serves as the database system (MySQL). The system architecture is shown in Figure 4.

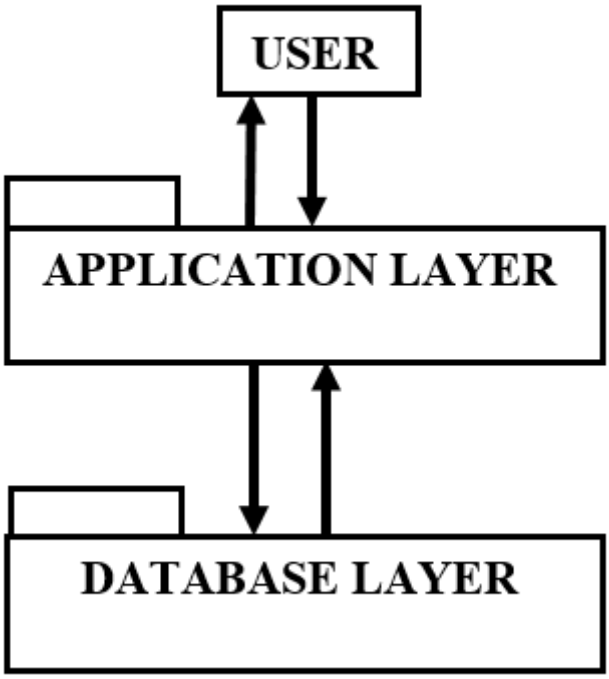


Figure 4. Two-layer architecture.

The database named electrical installation_db contains 3 tables. Figure 5 shows the 3 tables along side with fields in them. The database and its tables were created using work bench.

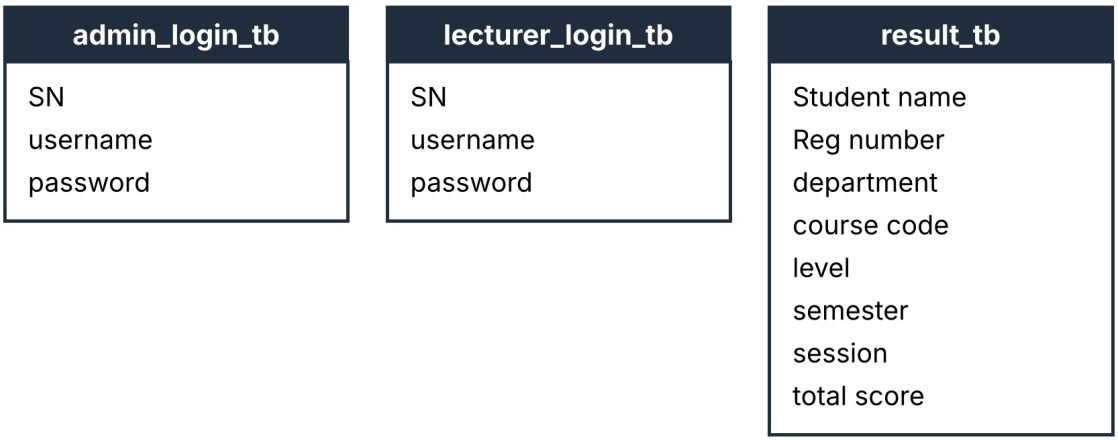


Figure 5. Database tables.

5.2.2 Use case

The Use case diagram that shows the major functions of the users using UML (Unified Modelling Language) is shown in Figure 6.

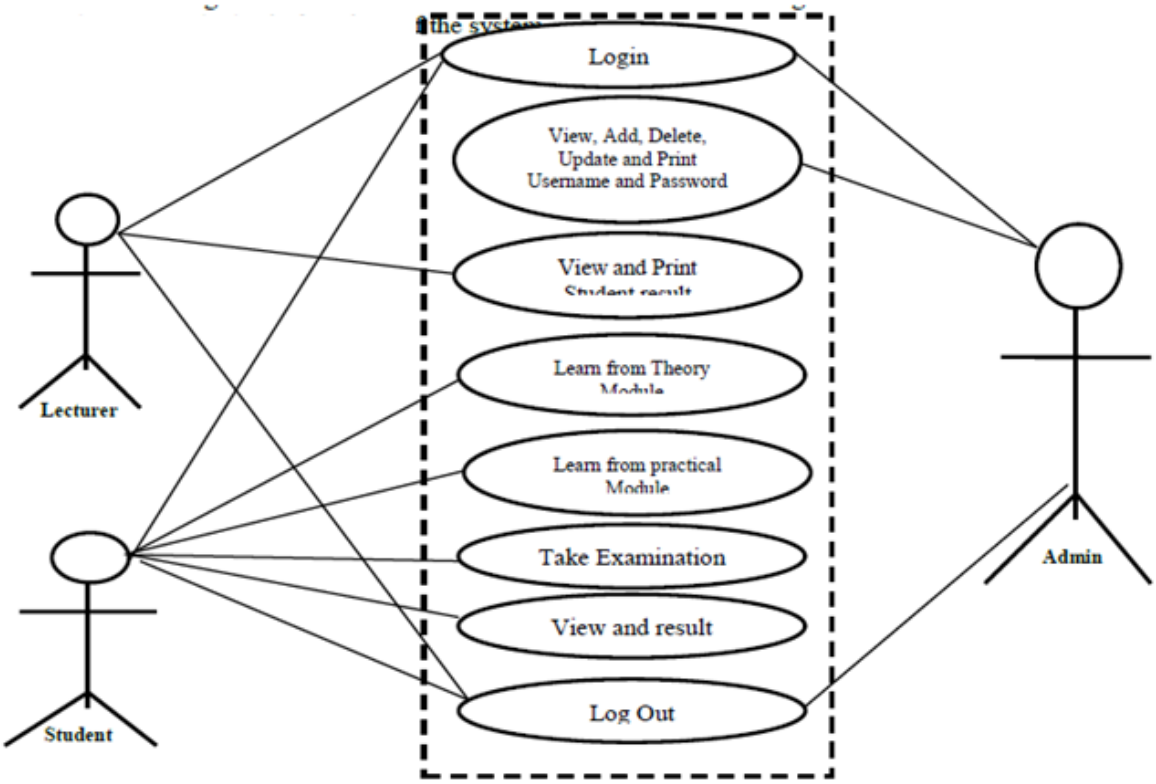


Figure 6. Use case diagram.

6 Implementation

6.1 Program code

The project was implemented using Java programming language. The codes were written in Java NetBeans (8.2) IDE (integrated Development Environment).

6.2 Sample outputs

Sample outputs of the system are shown in Figures 7–14.

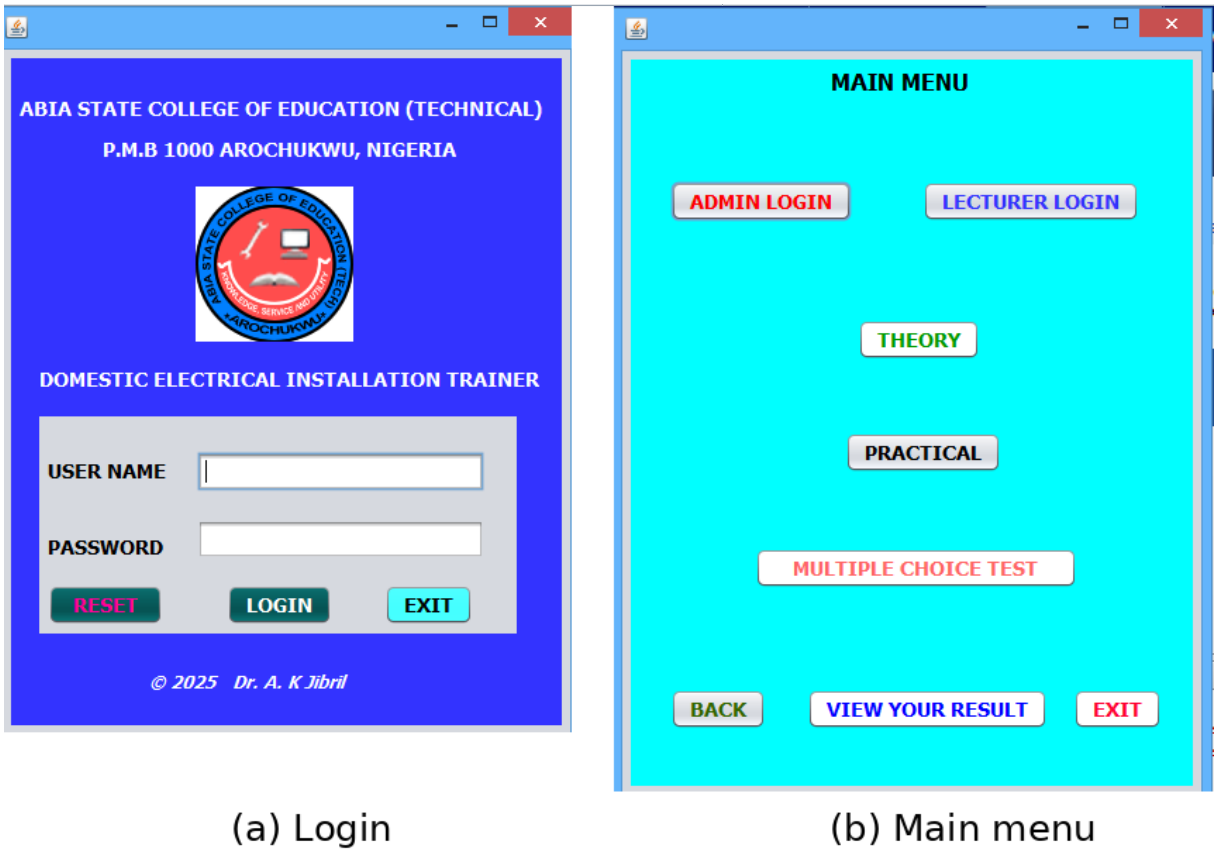


Figure 7. (a) General login and (b) main menu interfaces.

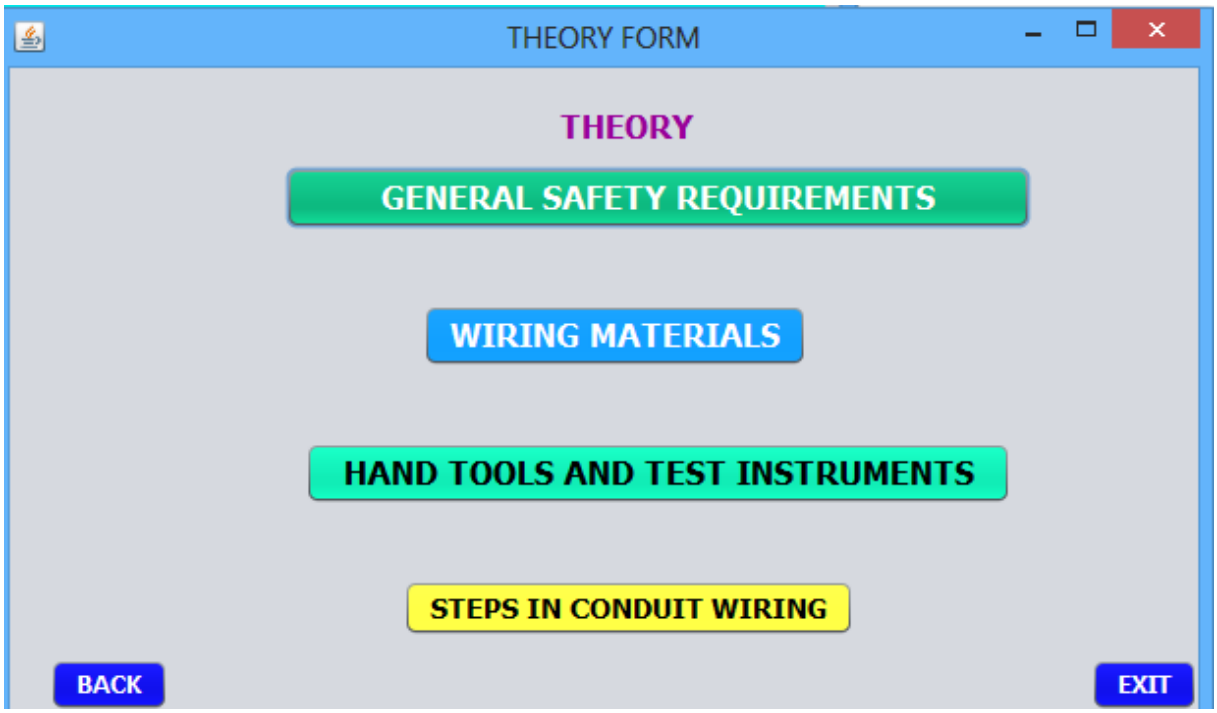


Figure 8. Theory module main interface.

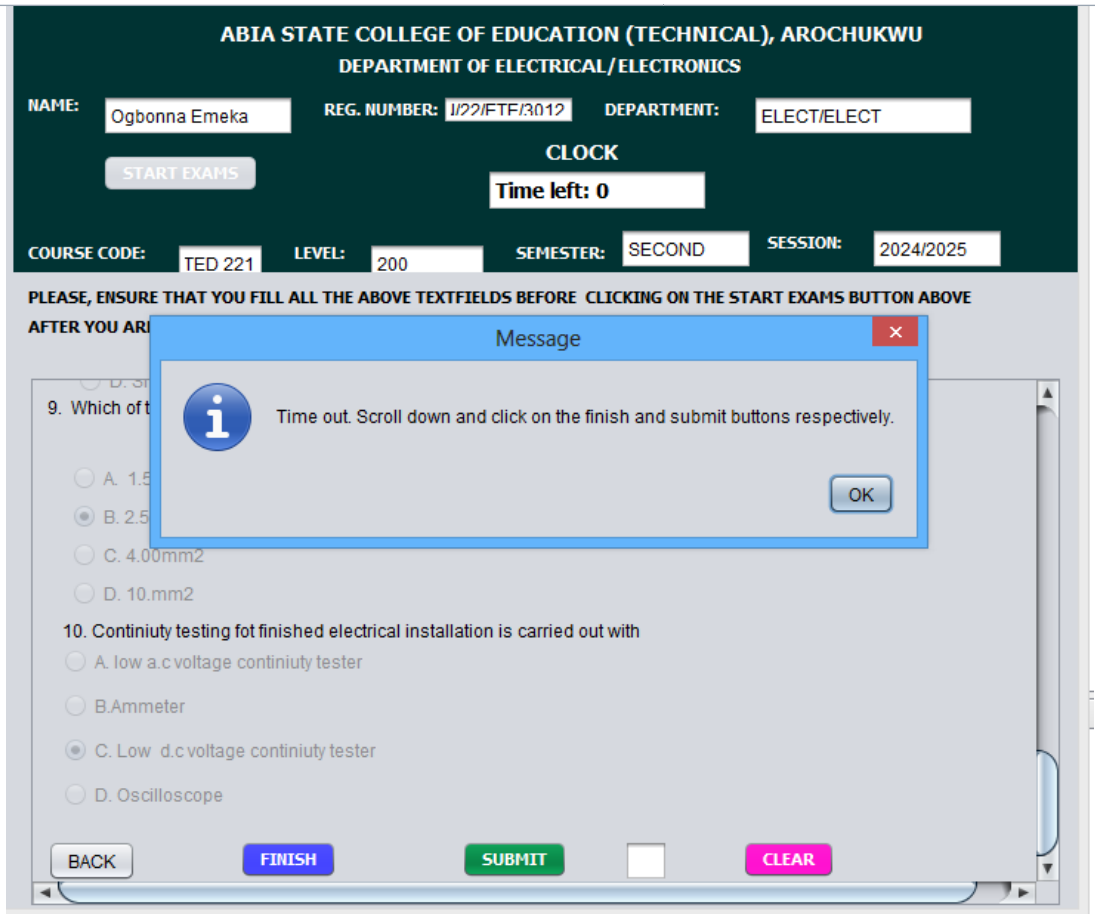


Figure 9. Multiple choice test environment.

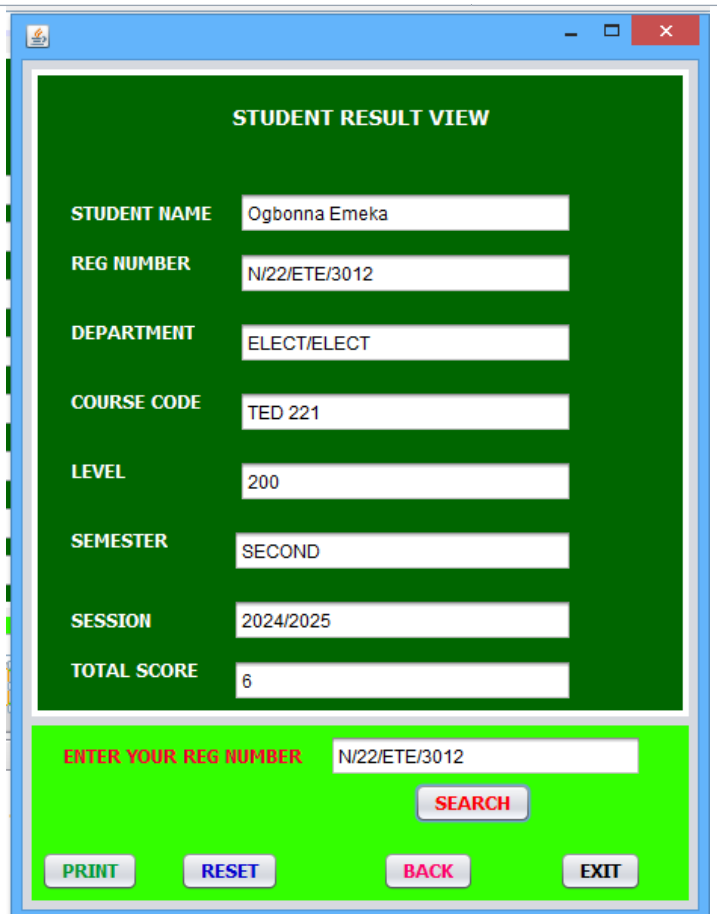


Figure 10. Students' result interface.

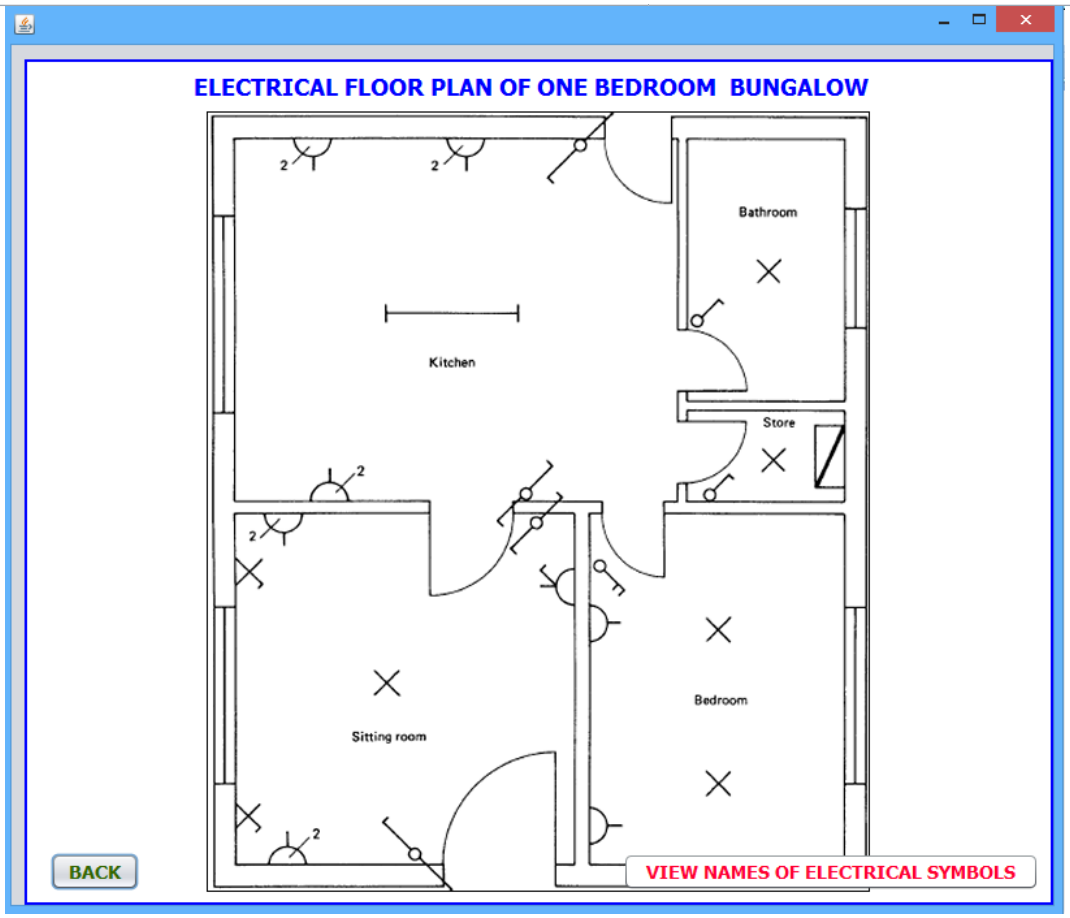


Figure 11. Electrical floor plan of the one-bedroom bungalow to be wired.

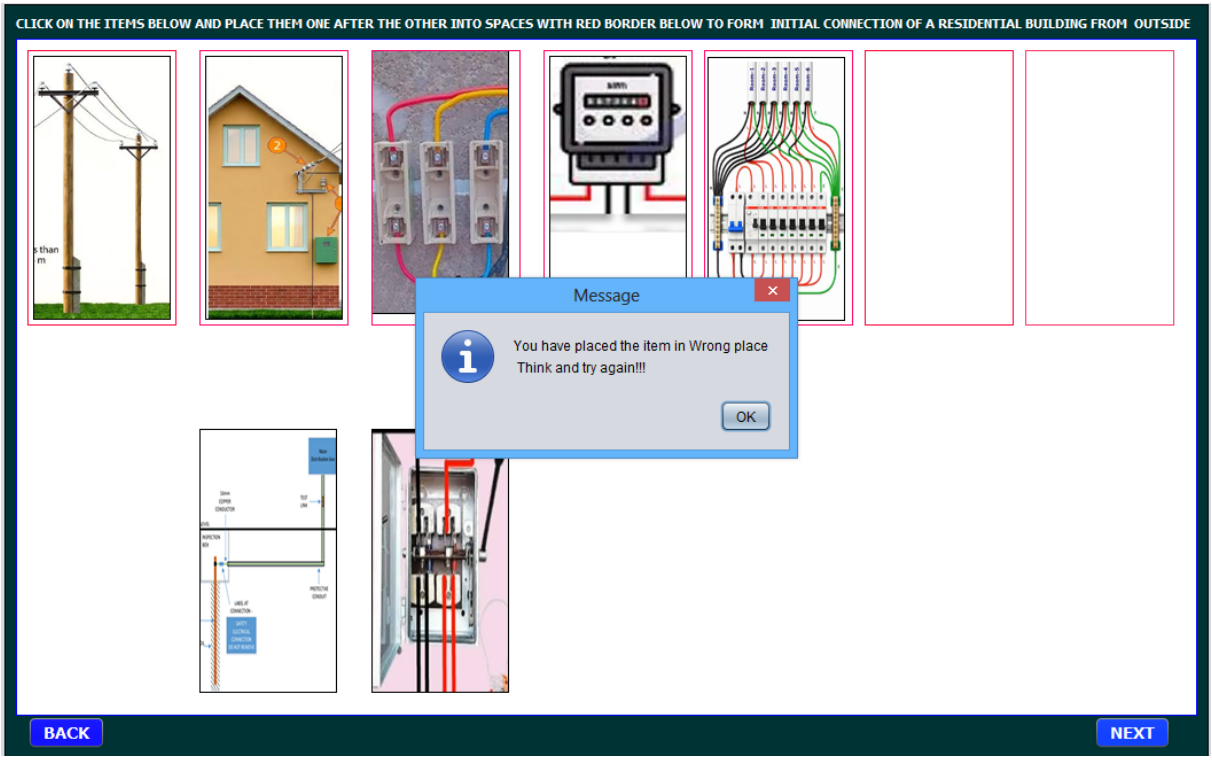


Figure 12. Practice environment I (wiring a one-bedroom bungalow from the electric pole to the distribution board).

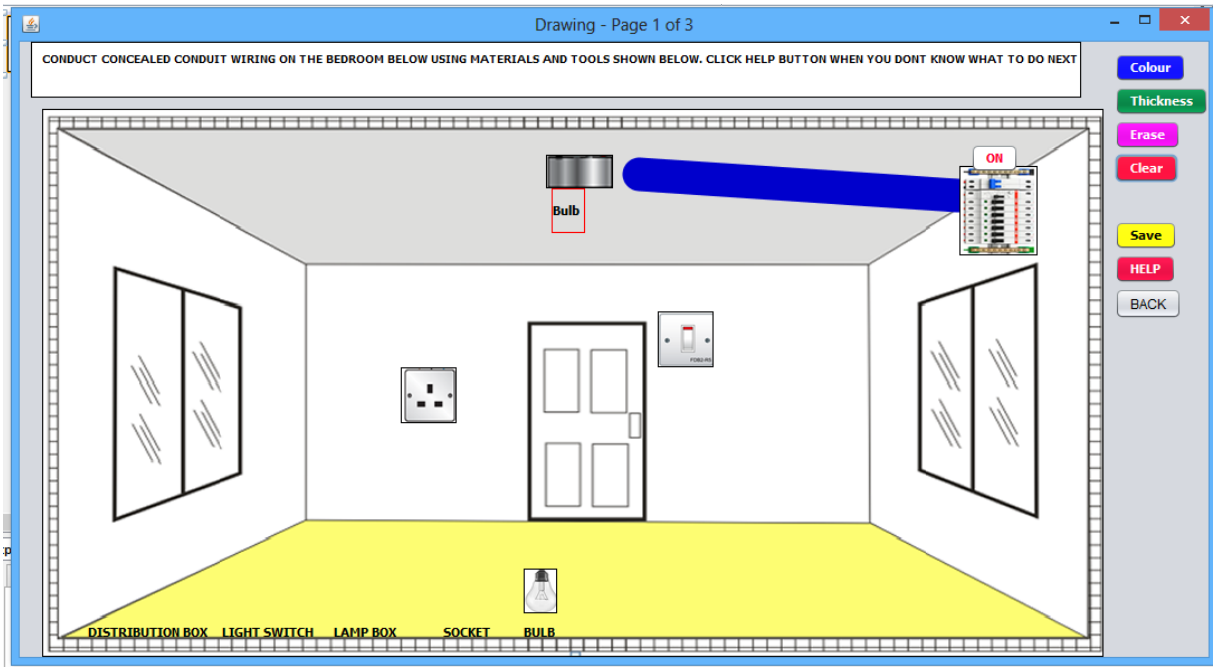


Figure 13. Practice environment II (laying PVC conduit from the distribution board to the lamp box).

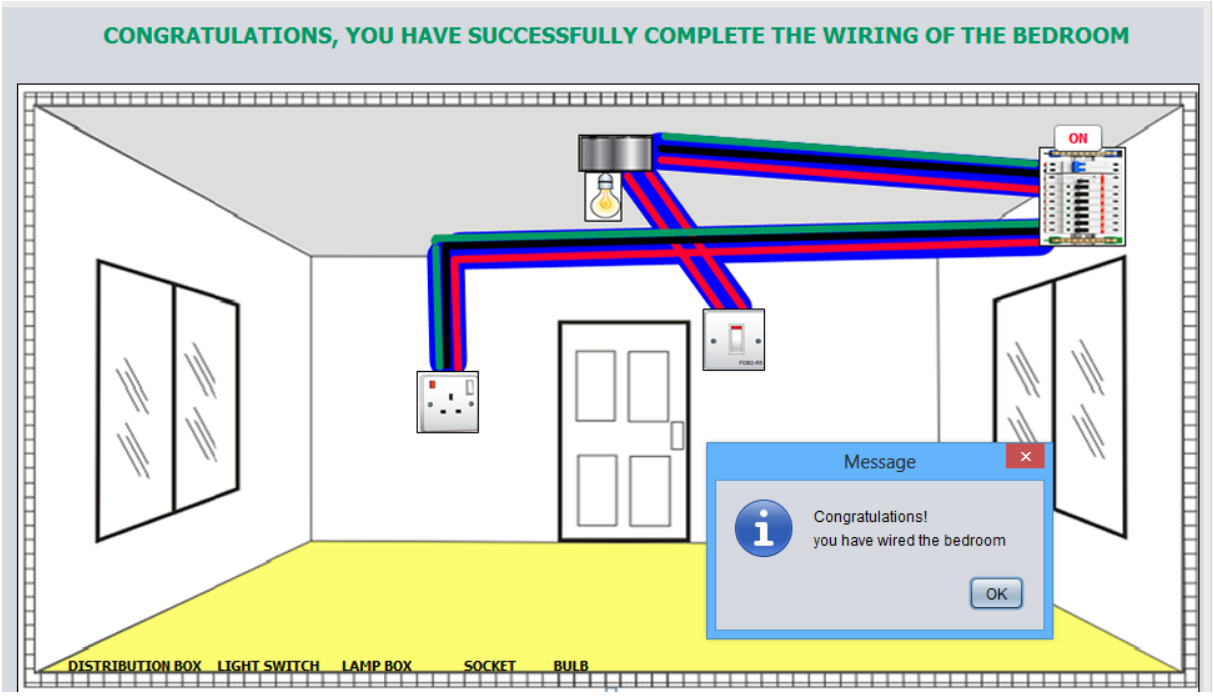


Figure 14. Completed bedroom wiring.

7 Performance evaluation

The potential users of the developed software tested the developed software. Thereafter, they filled questionnaire designed to measure students' satisfaction with the performance of the software. Table 1 shows the mean and standard deviation of their responses.

Table 1. Mean and standard deviation of the students' responses.

S/N	Item	Mean	SD	Remark
	Functional Software Requirements			
	Admin			
1	The software enables admin to add username and password	3.90	0.30	Agree
2	The software enables admin to login and logout	4.00	0.00	Agree
3	The software enables admin to update and delete user record	4.00	0.00	Agree
4	The software enables admin to view username and password	4.00	0.00	Agree
	Lecturer			
5	The software enable lecturer to login and logout	3.90	0.30	Agree
6	The software enable lecturer to add new lecturer username and password	3.60	0.49	Agree
7	The software enable lecturer to view examination result	3.80	0.40	Agree
8	The software enable lecturer to print examination results	3.80	0.40	Agree
	Student			
9	The software enable student to learn from theory module	3.60	0.49	Agree
10	The software enable student to learn from the practice module	3.70	0.46	Agree
11	The software enable student to take examination	3.90	0.30	Agree
12	The software enable student to view his/her examination result	4.00	0.00	Agree
13	The software enable student to print his/her examination result	3.70	0.40	Agree
	Non-Functional Software Requirements			
14	The software is well organized	3.50	0.50	Agree
15	The software buttons are responding to mouse click quickly	3.70	0.46	Agree
16	The feedback massages provided by the software are self- explanatory	3.50	0.50	Agree
17	The software has data security	3.70	0.46	Agree
18	I felt comfortable when using the software	3.60	0.49	Agree
19	It is easy to navigate to different parts of the software	3.70	0.46	Agree
	Recommendation			
20	The developed software can be used for teaching troubleshooting and repair of motor starting system in the College	3.70	0.46	Agree

N = 10 respondents; SD = standard deviation. Four-point scale; cut-off mean 2.50.

The data in Table 1 shows that all the mean values of the items are greater than the cut-off point of 2.50 on four-point Likert. This implies that the students are satisfied with the performance of the developed system. Furthermore, the values of the standard deviations (SD) were very small. This signifies that the opinion of students were very close for all the items. Finally, the mean value of item 20 was found to be 3.70. This value implies that the students unanimously recommended that the developed system can be used for teaching domestic electrical installation in the College.

8 Conclusion and recommendation

Students' performance in domestic electrical installation course may be improved by supplementing their training with the use of domestic electrical installation softwares. Hence, the author designed and developed domestic electrical installation trainer software. The software was implemented using Java programming language in NetBeans (8.2) IDE (Integrated Development Environment). MySQL database was incorporated into the developed system for storage of various data, such as users' login details and results. The database and its tables were created using MYSQL workbench (8.0). The developed system was tested by students and staff. The result of the test indicated that the developed system is effective and efficient. The evaluators recommended the use of the developed system for teaching domestic electrical installation in the College.

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