DEVELOPMENT AND VALIDATION OF THE TRAINING MODULES OF ELECTRIC MOTOR FAULT DIAGNOSIS AND REPAIRS FOR ELECTRICAL/ELECTRONIC STUDENTS IN COLLEGES OF EDUCATION IN NIGERIA

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Abstract

A part of the highly needed skill in the industry that prevents overseeing emigration for greener pastures is winding and rewinding skills. This study discusses the new training modules of electric motor fault diagnosis and repairs for electrical/electronic technology students in colleges of education in Nigeria. The study adopted a research and development design. The instrument used for data collection was a structured questionnaire. Three experts validated the questionnaire. The study did not use any sample techniques because the population of 150 students and 13 lecturers were employed. The reliability of the questionnaire was .843 using Cronbach's alpha. The research questions were analysed using a statistical mean and standard deviation. Analysis of Covariance (ANCOVA) was used to test the null hypothesis at a 0.05 significance level. The findings of the study revealed that low speed and overheating are some of the fault diagnoses, while the ability to identify open or short-circuited coils in electric motors, assembly and reassembly of electric motors and installation of windings are some of the training modules on effective fault diagnosis and repairs. It was recommended that more emphasis should be on practical skills acquisition than theory and its integration into the curriculum of colleges of education in Nigeria.

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Keywords: Training modules, Skill acquisition, Faults Diagnoses and Electric motor repairs

Introduction

Electric motors are becoming popular due to their low cost, strength, and economical maintenance. However, it can be susceptible to failure, which can be harmful and costly. The early detection of winding failure is crucial to prevent damage and ensure machinery availability. Predictive maintenance, instead of repair works, can increase serviceable life and avoid equipment shutdowns (Malik, 2015). Electrical /Electronic technology (EET) students in colleges of education use learnt skills to operate, install and repair machines that include all electrical equipment and electric motors (Orji & Ogbuanya, 2018; Bakare & Orji, 2019; Orji & Ogbuanya, 2020). It exposes the students to the use of industrial machinery.

Electrical and electronic technology (EET) is unique because it is skill-oriented and requires workshops to provide learning situations in which the students experiment, study, create, construct design, and repair (Nema, 2008). When the EET students receive the training approach, there could be a reduction in the risk of machine failure, resulting in higher reliability and lower costs. EET students also learnt motor fault diagnosis and repairs to become self-reliant and sustainable. Abdullahi (2010) emphasised the importance of EET trainees in identifying and repairing electric motor problems. During the inspection, the trainees are expected to examine the motor's exterior, nameplate, bearings, winding, resistance, windings, start or run capacitors, and motor fan. This knowledge is crucial for the national economy and society as a whole, as it helps to identify and repair motor faults at a lower cost. Understanding motor fault diagnosis and repairs is essential for trainees to become self-reliant and sustainable.

The goal of the EET module, according to NCCE (2012) is to give students the information and abilities they need to maintain AC and DC motors in an industrial setting and develop good work habits. This entails knowing how to manage and repair electrical machines as well as operating principles and safety considerations. Electric motors and generators, which use electromagnetic technology to convert mechanical energy into electrical energy, are examples of electrical machinery that are important for winding activities and the trainees need to select the right tools and equipment. Ekwe (2009) emphasised the importance of rewinding an electric motor when it experiences excessive heat, overcurrent, vibration, or overuse. Rewinding is the term used to connote the repair of electric motors when the winding fails. Winding is the arrangement of conductors that generates the magnetic field in an electric motor, which drives the rotors (Tarnekar, Theraja, 2016). The learning of electric motor winding/rewinding takes time and requires constant practice at the colleges of education (Ba-Thuya, Khopkar, Wei, Toliyat, 2014).

Therefore, there is a need for a new module which is personalized, learner-centered, collaborative, ubiquitous, and lifelong to enable students to learn effectively and successfully (Sharples et al., 2017). When a new learning of this module is used in collaboration with the currently utilized curriculum for the teaching/training of EET students in winding/rewinding, this may help to increase students' motivation and thereby improve their learning success and skills in winding/rewinding (Pechenkina, Laurence, Oates, Eldridge & Hunter, 2017). Thus, the students learn new skills and become self-sustainable. These skills are crucial for self-employment or self-reliance in electric motor works (Fantuzzo & Tighe, 2000). Therefore, there is a need to develop training modules in electric motor fault diagnosis and repairs for students in electrical/electronic technology (EET) in colleges of education in Nigeria.

Statement of the problem

A part of the goal of electrical/electronic technology (EET) in colleges of education is to prepare NCE graduates to possess adequate practical skills in all electrical /electronic machines/tools including electric motor winding/rewinding employability or self-reliance. Skill generation of electrical winding/rewinding offers the graduates more opportunities to get well paid, strengthening their employment opportunities. This training in the college could enable the students to secure employment after graduation.

Presently, most EET graduates do not have adequate knowledge, techniques and skills for winding/rewinding electric motors in Nigeria because of inadequate training as evidenced by the unemployment rate in the country. Today's world of technology depends largely on highly skilled personnel for productivity, where colleges of education have a major role in their production. Unfortunately, the social and economic changes of today have changed the job demands making electrical/electronic technology (EET) graduates in colleges of education either unemployable or ill-fitted for the demands of the jobs they get. Technical education instructions are largely theoretical and cannot equip college of education graduates with skills to live and fit into the world of work.

Also, effective employment of EET graduates from colleges of education has continued to be a mirage due to the complexity of knowledge of winding/ rewinding in Nigeria. With the development of training modules for electric motor fault diagnosis and repairs, students may have the opportunity to learn the skill of winding and rewinding better. Hence, it becomes imperative to investigate the development and validation of fault diagnosis necessary for electric motor maintenance and repair skills required by electrical/electronic technology in the College of Education for self-employment.

Purpose of the Study

The major purpose of this study is to develop and validate the training modules of electric motor fault diagnosis and repairs for electrical/electronic students in colleges of education in Nigeria. Specifically, the study sought to;

1. determine the training modules for electric motor fault diagnoses and repairs required by electrical/electronic technology students in colleges of education
2. determine the competence needs of electric motor fault diagnosis and repairs required by electrical/electronic technology students in colleges of education

Research questions

1. What are the training modules for electric motor fault diagnoses and repairs required by electrical/electronic technology students in colleges of education?
2. What are the competencies needed for electric motor fault diagnosis and repairs required by electrical installation and maintenance work students in technical colleges?
3. What is the effect of training modules on electric motor fault diagnosis and repairs of electrical/electronic technology students in colleges of education?

Hypothesis:

The hypothesis was tested at 0.05 level of significance:

H_{o1}: There is no significant difference in the mean scores of students taught with fault diagnosis training modules and the conventional approach of electric motor winding on task performance.

Literature Review

An electric motor

An electric motor is an electro-mechanical device that converts electrical energy into mechanical energy. Its principle of operation is electromagnetic induction. The type of AC supply determines the types of induction motors. Electric motors work on the interaction between the motor's magnetic field and electric current in a winding (Tarnekar, Theraja & Theraja, 2016). This interaction generates a force in the form of torque, which is applied to the motor's shaft. In magnetic motors, magnetic fields form in the rotor and the stator. The product between the two fields gives rise to force and torque on the motor shaft. One or both of these fields should change with the rotation of the motor. This is done by switching the poles on and off at the right time or varying the strength of the pole (Beater, 1977).

An induction motor (IM) is a type of asynchronous AC motor where power is supplied to the rotating device using electromagnetic induction. An induction motor is a rotating transformer because the stator (stationary part) is essentially the primary side of the transformer and the rotor (rotating part) is the secondary side. The details of the damaged windings are recorded and removed.

Needs Assessment: Common Faults in Electric Motors and Their Causes (Ya'u, Babaji & Hassan, 2020)

1. **Over-Current (Electrical Overload)**: Under various operating conditions, electrical devices may occasionally draw more current than their maximum capacity. This surge can occur unexpectedly and significantly affect the motor's performance. To mitigate the risk of over-current, it is essential to install devices that help prevent such occurrences (Bridgestone, 2013). Typically, these devices are integrated into the circuits and are designed to automatically shut down excess current flow.
2. **Low Resistance**: Most motor failures are attributed to low insulation resistance which is considered one of the most challenging issues to address. During the early stages of motor installation, the insulation resistance typically exceeds one thousand mega-ohms. Over time, however, the performance of the insulation tends to

deteriorate significantly as the resistance gradually decreases. Fortunately, a solution has been identified to help prevent failures related to low resistance.

3. Overheating: Overheating is caused by various factors. Each electric motor has a specified design temperature. When a motor is initiated with an inappropriate current value, it tends to operate at a temperature significantly higher than its design specification. It is crucial to ensure that motors are paired with their optimal current values. Additionally, overheating can occur if an electric motor is required to function in a high ambient temperature environment (Bridgestone, 2013). This leads to a considerable reduction in the rate at which heat can be dissipated. Therefore, the area where electric motors are situated must be equipped with an effective cooling system, and a ventilation system should also be provided in case the cooling system fails

4. Moisture: Moisture has a significant impact on the performance of electric motors, contributing to the corrosion of the motor shafts, bearings, and rotors (Bridgestone, 2013). This can also result in insulation failure. It is essential to keep the motor inventory dry at all times.

Corrective maintenance of an electric motor

1) It involves servicing the windings to prevent accumulated dirt from affecting insulation. Vacuuming the dirt from the windings and internal air passages is crucial, but high-pressure air should not be used as it can damage the insulation.

2) The motor's insulation is being ripped off by abrasive dust, necessitating the winding to be re-varnished or replaced.

3. Insulation plays a crucial role in maintaining the strength of a motor, as moisture can reduce its dielectric strength, potentially leading to shorts.

4. The motor should be thoroughly cleaned to remove any oil and grease, and avoid using solvents that may damage the insulation.

5. The motor should be re-varnished or rewounded if the insulation appears brittle, overheated, or cracked, depending on the severity of the condition.

6. Loose coils and leads can cause insulation to wear, crack, or fray due to magnetic field or vibration changes. Minor issues can be resolved with re-varnishing and retying leads.

7. Check lead-to-coil connections for overheating or corrosion, often exposed on large motors but taped on small ones, and repair as needed.

Winding essential needs:

When rewinding the electric motor, the following should be noted before the previous coil is removed from the stator: Count the number of slots, the number of spans that are made up of a coil should be in series, overall coils should be in each stage, counting of coils between the start legs and the end of the coil (Span), counting of wire round 3600 on the former to form each coil in series (No of turns), a gauge of wire should be in either metric or flat gauge (Size wire Gauge -SWG), strands of wire, winding formulae: In and Out, wave, basket, or lap type of winding, winding and terminal connection.

Methodology:

The development design for this study is based on the research and development model. Research and development according to Gall, Gall and Borg, (2007) is an industry-based development model in which the findings of research are used to design new products and procedures, which then are systematically field tested, evaluated, and refined until they meet specified criteria of effectiveness, quality, or similar standards. The research and development design has 10 phases, including identifying instructional goals, conducting instructional analysis and others. This study aims to develop training modules for students in electrical/electronic technology in colleges of education, specifically for fault diagnosis and repairs of electric motors. The study uses three phases: Needs Assessment, Development of training modules, and Testing of Electric Motor Windings and Fault Diagnosis. These phases ensure that the training modules meet the essential needs of the windings and ensure the effectiveness and quality of the products.

The study was conducted in all six geographical zones in Nigeria. The choice of all zones was informed by the existence of Federal Colleges of Education with enough human and material resources suitable for the successful development and evaluation of the training modules. The study comprises 163 respondents, including 150 NCE III students and 13 teachers of electrical/electronic students in 13 Federal Colleges of Education (FCE) in Nigeria (FCE (Special) Oyo, Oyo State- 03, FCE (Technical) Umunze, Anambra State-09, FCE (Technical), Omoku, Rivers State-10, FCE (Technical) Gombe, Gombe State-14, FCE (Technical), Asaba, Delta State.-08, FCE (Technical), Akoka, Lagos State-24, FCE, Zaria, Kaduna State-14, FCE, Okene, Kogi State-10, FCE, Kano, Kano State-12, Adeyemi College of Education, Ondo, Ondo State-14, FCE, Osiele, Abeokuta, Ogun State-10, FCE, Kano, Kano State-12 and FCE, Okene, Kogi State-10).

The population is manageable and adequate, as it is suitable for final-year students preparing for the final examination. The data collection was conducted using a structured questionnaire to assess competency needs on effective fault diagnosis and repairs of electric motors for self-reliance. Three experts from the Department of Industrial Technical Education, University of Nigeria, Nsukka, validated the questionnaire. The reliability coefficient was 0.843, and two teachers were involved in the training, testing, and data collection phases. They were trained on administering pre-test, post-test, and score subjects according to the researchers' marking guide. One teacher was trained in teaching electric motor winding and rewinding, while the other was trained in facilitating the teaching of the developed electric motor module package. The training modules involved testing of electric motor windings and fault diagnosis through the three stages of installing, disassembling, and reassembling the motor. All three stages must be provided with the winding essential needs.

This study analyzed quantitative data on the installation, disassembly, and reassembling of an electric motor. The data was numerical and measured on an interval scale, with items with a mean value of 3.50 or above considered accepted or needed. Items with a standard deviation of 1.96 or above were considered rejected or not needed. The null hypothesis was tested using the Analysis of Covariance (ANCOVA) at a 0.05 significance level. The data was analyzed using SPSS 22. The training modules involved testing of electric motor windings and fault diagnosis through the three stages of installing, disassembling, and reassembling the motor. The data was interpreted as follows: items with a mean value of 3.50 or above were accepted or needed, while items with a mean value of less than 3.50 were rejected or not needed. The null hypothesis was upheld when the p-value associated with the F-calculated value for the experimental and control group was greater than the p-value (0.05).

Results:

Research Question 1: What are the training modules for electric motor fault diagnoses and repairs required by electrical installation and maintenance works students in technical colleges?

Table 1: Mean and Standard Deviation of training modules for electric motor fault diagnoses and repairs required by electrical installation and maintenance works students in technical colleges.

S/N	Faults Models in Electric Motor	$\overline{X}$	SD	Decision
1	Low speed	4.18	0.81	Agree
2	Burnt coil	4.42	0.62	Agree
3	Starting fault	4.48	0.62	Agree
4	Faulty bearing	3.24	0.36	Disagree
5	Insulation fault	4.45	0.62	Agree
6	Capacitor fault	4.27	0.67	Agree
7	Stiff rotor	3.18	0.28	Disagree

Note: X= Mean SD= Standard deviation

Table 1 shows that students and teachers strongly agreed on items 1, 2, 3, 5, and 6, while disagreed on items 4 and 7. The mean aggregate scores ranged from 3.18 to 4.48, with a grand mean value of 3.57, above the cutoff point of 3.50. The standard deviations ranged from 0.50 to 0.89, less than 1.96, indicating minimal differences between respondents on the study's items.

Research Question 2: What are the competencies needed for electric motor fault diagnosis and repairs required by electrical installation and maintenance work students in technical colleges?

Table 2: Mean and Standard Deviation of competency needs of electric motor fault diagnosis and repairs required by electrical installation and maintenance work students in technical colleges

S/N	Item Statement	$\overline{X}$	**SD**	**Decision**
1	Ability to identify motor fault	4.64	0.65	Agree
2	Ability to disassemble motor	4.55	0.51	Agree
3	Ability to assemble motor	4.42	0.56	Agree
4	Ability to use the right tool for the right job	3.28	0.42	Disagree
5	Competency in winding and rewinding coil	4.36	0.50	Agree
6	Ability to fit in insulation paper properly	4.48	0.62	Agree
7	Ability to identify starting coil	4.48	0.51	Agree
8	Ability to identify running coil	4.39	0.61	Agree
9	Competency in the use of multimeters	4.64	0.65	Agree
10	Ability to fix bearing fault/change faulty bearing	4.55	0.51	Agree
11	Competency in use of standard wire gauge	4.42	0.56	Agree
12	Knowledge on winding slots arrangement	4.48	0.62	Agree
13	Ability to identify top and bottom wires	3.36	0.48	Disagree
14	Ability to interpret circuit diagram	3.97	0.83	Agree

Table 2 shows that items 1,2,3,5,6,7,8,9,10,11,12 and 14 were agreed while item 4 and 13 were strongly disagreed. The Table shows that practical skills in electric motor maintenance are essential for training students for self-reliance. The cluster means of 4.28 indicate that practical skills are necessary for fault diagnosis and repair. The values of standard deviations range from 0.42 to 0.83, indicating strong agreement in the objectives of the instructions.

Ho_1: There is no significant difference in the mean scores of students taught with fault diagnosis training modules and the conventional approach of electric motor winding on task performance

Table 3

Summary of Analysis of Covariance (ANCOVA) for the Test of Significance of two Treatments on Students' Task Performance in fault diagnosis of training modules

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	95.525[a]	2	457.763	10.085	.001	.478
Intercept	1360.958	1	1360.958	29.983	.000	.577
Pretest	57.996	1	57.996	1.278	.271	.055
Group	691.196	1	691.196	15.227*	.070	.409
Error	998.615	22	45.392			
Total	17389.500	25				
Corrected Total	1914.140	24				

***Significant at sig of F< .05**

In Table 3, the F-calculated value for the mean scores of the experimental and control groups with fault diagnosis training modules performance test was found to be 15.227 with a significance of .070. Since the value .070 is greater than .05, the null hypothesis is therefore accepted. This implies that there is no significant difference between the mean score of students taught with fault diagnosis training modules and those taught by conventional methods. It means that those taught with new training modules perform better. It, therefore, shows that the new module should be used to train students to wind/rewind electric motors.

Discussion:

The study revealed that faults models in electric motors like low speed, burnt coil, faulty bearing, insulation fault, wrong wire connection, case/housing noise, improper coil fitting, capacitor fault, power quality and the like are required for training electric motor fault diagnoses and repairs students. This is in agreement with the findings of Correa et. al. (2000), who identified various faults and repairs of electric motor systems that are necessary to be a requirement for integration into the curriculum for teaching and learning in electrical/electronic technology students in colleges of education in Nigeria.

The study further revealed in research question 2 that those practical skills such as the ability to identify motor faults, ability to disassemble the motor, ability to assemble the motor, competency in rewinding coil, competency in motor wire connection, ability to fix bearing fault/change faulty bearing and the likes are required for training electric motor fault diagnoses and repair works students. This is in agreement with the findings of Richard (2015), who identified practical skills in the repairs of electric motor systems that are necessary to be a requirement for integration into the curriculum for teaching and learning in electrical/electronic technology students in colleges of education.

. Also, hypothesis 1 was found that all the stages of the training modules of fault diagnosis and repairs of electric motors should be integrated into the curriculum for the teaching of electrical/electronic technology students in colleges of education. This finding is in line with Onweh and Akpan, (2014) who observed that the training modules on fault diagnosis and repairs of electric motors should be integrated into the curriculum for the teaching of electrical/electronic technology students in colleges of education. However, it was observed that there is a paucity of literature in this area and thus the finding stands to fill the gap.

Findings:

1 Fault model identification is necessary for electric motors` faults diagnosis and repair training.

2. Practical skills are required for self-reliance in the repairs of electrical motors.

1. The following contents were identified for task performance in fault diagnosis training modules based on the repairs of the electric motor: They are disassembling an electric motor winding, installing the new windings and reassembling the

electric motor. The process involved is explained thus:

A) **Disassembling of an electric motor winding**

The process of disassembling an electric motor winding is as follows**:** identify tools for dismantling electric motor, maintain a clean work area, remove the motor's outer housing, force the rotor out of the stator by hand, cut the old windings free using a pair of wire cutters, pull the cut coils free of the stator by hand, replace the insulation paper lining in the stator of electric winding and document the motor's appearance before electric motor modifications.

B) Installing the New Windings

The process of installing the new winding in an electric motor winding is stated thus: identify the number of spans in series, identify the winding connection, determine the winding formula, rewind the stator using the same gauge of wire, varnish the coil tightly in the stator and insulate any exposed part of enamel copper connector., connect running and starting winding to the terminal box and securely completed windings using the tabs around the stator winding.

C) Reassemble the motor

The process of reassembling an electric motor is as follows: reinsert the rotor into the stator**,** fit both pieces back into the motor housing**,** replace the end plates on either side of the unit and tighten the screws, bump test the end winding to ensure no detrimental resonance frequency present of the completed winding**,** test the motor out**,** ensure safety and cleanliness**,** conduct operations safely and maintain clean work area.

Recommendations

Based on the findings of the study, the following recommendations were made;

1. Lecturers and technologists in the colleges of education should integrate the training modules on fault diagnosis and repairs of electric motors into the curriculum for the teaching of electrical /electronic technology.
2. The National Board for Technical Education (NBTE) and the National Commission for Colleges of Education (NCCE) should integrate the developed training modules in fault diagnosis and repairs of electric motors into the curriculum for the teaching of electrical/electronic technology (EET) in the Polytechnic and colleges of education.
3. There should be an emphasis on more training in electric motor maintenance, highlighting its attendant benefits to life.

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