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Application of TPM Early equipment, Safety, Health and Environment Techniques for Quality Improvement of Electrical Workshops

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Abstract: *This study determined the utilization of total productive maintenance techniques of early equipment and safety, health and environment for quality improvement in electrical workshop by technical colleges in Rivers State. Two research questions guided the study. The study employed the descriptive survey research design. The population of the study was 527 respondents (42 instructors and 485 experts from industries) while a sample size of 469 respondents (42 instructors and 427 experts from industries) were selected using simple random sampling technique. The researcher designed instrument titled "Total Productive Maintenance Techniques for Quality Improvement of Electrical Workshop Questionnaire" (TPMTQIEWQ) was used for data collection for the study. Face validation of the instrument was done by five experts. The test-retest reliability method was used for the study. The instrument reliability yielded an index of 0.88. The research questions were answered using mean and standard deviation. The findings of the study identified processes for utilization of TPM early equipment as well as Safety, Health and Environment Techniques in technical colleges. Based on the findings of the study, it was recommended that TPM principles in early equipment as well as Safety, Health and Environment Techniques should be implemented in technical colleges.*

Keywords: *Utilization, Equipment Maintenance, Safety, Health and Environment Techniques, Total Productive Maintenance*

Introduction

Electrical workshops are central to training and provide training equipment, machines and storage for training students on electrical skills acquisition. Training equipment are the hardware, software and multimedia materials used in the technical training process. The hardware is made of heavy equipment such as milling machines, welding sets, electrical switchboards and a whole lot of training materials. Training equipment and machines according to Dora (2017) are essential, because they provide the means to educate learners in school workshops. School workshops offer opportunities for practical training of technical education students in skill acquisition in respective technical trade areas. However, adequate an available institutional training equipment and machines are fundamental requirements for the successful implementation of the practical aspects of the curriculum (Bybee & Loucks-Horsely, 2000). This aspect of the curriculum can only be implemented where workshop facilities, tools, equipment and machines are adequate, relevant and most especially, maintained. While initial provision of training equipment might make it available for present training, maintenance of the equipment makes it available for the foreseeable future.

In Nigeria, Audu (2013) averred that one of the issues of great controversy among technical education educators is the issue of the poor maintenance state of workshop tools and equipment in technical institutions. Umar and Ma'aji (2010) stated that most of the technical colleges in Nigeria have been forced to perform below expected standards due to non-availability and poor management of facilities and equipment in the workshops for effective skills acquisition. For effective instruction, the work environments for technical education programmes must not only be provided for, but systematically maintained. This has necessitated the adoption of quality improvements in maintenance of facilities, equipment and machines. one method of maintenance adopted by industries is the total productive maintenance technique.

Total Productive Maintenance (TPM) is a Japanese concept of equipment management which includes autonomous maintenance, planned maintenance, quality maintenance, focused improvement maintenance and safety health and environment techniques that allows a facility to improve decisively the equipment performance in the manufacturing area with the help of all employees. The frontline TPM techniques are autonomous maintenance, planned maintenance, quality maintenance and focused improvement maintenance. While these techniques have been widely implemented, less importance have been given to early equipment maintenance as well as safety health and environment techniques.

The fifth TPM pillar is the early equipment management. This uses the experience gathered from previous maintenance improvement activities to ensure that new machinery reaches its optimal performance much early than usual. Working with a myriad of stake-holders including suppliers, the company is able to hit the ground running with highly reliable and productive equipment. Such an approach has a positive impact on profitability of the company as maintenance costs are dramatically reduced. The productivity as well as output quality of the machines is also guaranteed from the very first day when the equipment is commissioned (David, 2017).

Taking TPM to the administrative functions is the next logical step in the total productive maintenance programme so as to have the whole organization speaking from the same page.

Productivity Press Development Team (1996) stated that as these are supportive functions, making them understand and apply the principles of lean in their own operations makes it easy for them to provide efficient service to the main value-creating processes.

In addition, spreading the initiative into other functions removes the silo mentality and encourages horizontal cooperation within the workforce. The organization will also benefit by having a larger pool of workers who understand the principles of TPM and can easily be called upon to play a positive role in its implementation. TPM as a concept has been found to be beneficial to industries in maintaining their equipment and improving productivity. This technique if applied to technical training institutions in Rivers State, Nigeria might be an essential tool for helping to elongate the lifespan of machines while helping the machines to work at optimal levels. However, such an effort will require

empirical evidence before such a recommendation will be made to the relevant technical education training authorities in Rivers State, Nigeria for inclusion of TPM as a concept to technical equipment maintenance and utilization.

One of the defining characteristics of learning environments in Technical Education programmes are available and accessible machines and equipment for training and skills acquisition. Machineries and equipment are central in skills acquisition. However, the perennial challenge of inadequate training equipment in technical education programmes calls for a systematic method of optimum utilization of available materials and equipment (Bupe & Charles 2015). One of the fundamental ways of ensuring the optimum utility of available resources is through proper maintenance of existing facilities and equipment. A revolutionary concept of Total Productive Maintenance (TPM) has been adopted in many industries across the world to address the said problem. TPM emphasizes proactive and preventative maintenance to maximize the operational efficiency of equipment. It blurs the distinction between the roles of production and maintenance by placing a strong emphasis on empowering operators to help maintain their equipment. The implementation of a TPM programme creates a shared responsibility for equipment that encourages greater involvement by plant floor workers, which are students in the case of a school workshop. In the right environment, this can be very effective in improving productivity (increasing up time, reducing cycle times, and eliminating defects). As a bold new concept of maintenance for industrial settings, non- implementation of TPM might lead to incessant breakdowns of equipment, poor utilization of equipment, increased wastage of training materials as well as poor working conditions for trainee-students. School administrators will be missing out on a great opportunity of building maintenance culture across the system to support effective utilization of training equipment.

Statement of the Problem

The focus of most TPM researches in education has been on the the first three pillars of autonomous, planned and quality improvement. Less researched has been on focused improvement, early equipment as well as the safety dimensions of TPM. The best of TPM is in the full implementation of its different dimensions. a partial, slow adoption of TPM will need benefits, but will also lead to challenges in unimplemented areas. Interestingly, some studies have been carried out to determine the application of total productive maintenance (TPM) techniques for quality improvement in different tertiary institutions in Nigeria. However, based on the researcher's knowledge, none of these studies determine the process of utilization of total productive maintenance (TPM) techniques for quality improvement of electrical workshop in technical colleges in Rivers State. This served as a gap in knowledge/research gap that this study sought to bridge. It is against the identified problem and gap that this study sought to determine the process of utilization of total productive maintenance (TPM) techniques for quality improvement of electrical workshop in technical colleges in Rivers State.

Purpose of the Study

The main purpose of this study is to determine the process of utilization of total productive maintenance (TPM) techniques for quality improvement of electrical workshop in technical colleges in Rivers State. Specifically, the study sought to:

i. Determine the process of utilizing early equipment maintenance techniques among instructors and experts for quality improvement of electrical workshops in technical colleges in Rivers State.
ii. Determine the process of utilizing safety health and environmental techniques among instructors and experts for quality improvement of the electrical workshops in technical colleges in Rivers State.

Research Questions

The following research questions were posed to guide this study.

i. What is the process of utilizing early equipment maintenance techniques among instructors and experts for quality improvement of electrical workshops in technical colleges in Rivers State?
ii. What is the process of utilizing safety health and environmental techniques among instructors and experts for quality improvement of the electrical workshops in technical colleges in Rivers State?

Literature Review

Total Productive Maintenance (TPM)

Total Productive Maintenance (TPM) is designed to maximize equipment effectiveness (improving overall efficiency) by establishing a comprehensive productive-maintenance system covering the entire life of the equipment, spanning all equipment related fields (planning, use, maintenance, etc.) and with the participation of all employees from top management, down to shop-floor workers, to promote productive maintenance through motivation management or voluntary small group activities (Tsuchiya,1992). Laine (2010) averred that TPM is an holistic view of the impacts of maintenance in production. TPM means that whole organization is making commitment for sustain, develop and maintain manufacturing capacity. One of the leading principles in TPM is that every employee participates. TPM is basing on teamwork and for managers especially coaching these teams to top performance. When creating favourable environment for motivation growth we can achieve highly motivated employees playing in our team. According to Venkatesh (2009) TPM is a continuous improvement program, the author continues to say that TPM is to increase production and raise the morale of the employees as well as increasing their job satisfaction.

TPM starts with 5S. Problems cannot be clearly seen when the work place is unorganized. 5S can be called as foundation stone of TPM implementation. It is a Japanese way of housekeeping. Cleaning and organizing the workplace helps the team to uncover problems. Making problems visible is the first step of improvement. If this 5S

is not taken up seriously, then it leads to 5D i.e. Delays, Defects, Dissatisfied customers, Declining profits and Demoralized employees (ReVelle, 2004). The 5S are

Japanese Term	English Translation	Equivalent 'S' term
• *Seiri*	• Organisation	• Sort
• *Seiton*	• Tidiness	• Systematise
• *Seiso*	• Cleaning	• Sweep
• *Seiketsu*	• Standardisation	• Standardise
• *Shitsuke*	• Discipline	• Self - Discipline

Figure 1: 5S of TPM Source: Japan Institute of Plant Maintenance, 1999

SEIRI - Sort out: This means sorting and organizing the items as critical, important, frequently used items, useless, or items that are not need as of now. Unwanted items can be salvaged. Critical items should be kept for use nearby and items that are not be used in near future, should be stored in some place. For this step, the worth of the item should be decided based on utility and not cost. As a result of this step, the search time is reduced (ReVelle, 2004).

SEITON - Organise: The concept here is that "Each items has a place, and only one place". The items should be placed back after usage at the same place. To identify items easily, name plates and colored tags has to be used. Vertical racks can be used for this purpose, and heavy items occupy the bottom position in the racks (Japan Institute of Plant Maintenance, 1999).

SEISO - Shine the Workplace: This involves cleaning the work place free of burrs, grease, oil, waste, scrap etc. No loosely hanging wires or oil leakage from machines (Petersen, 1993).

SEIKETSU - Standardization: Employees has to discuss together and decide on standards for keeping the work place / Machines / pathways neat and clean. This standards are implemented for whole organization and are tested / Inspected randomly (Petersen, 1993).

SHITSUKE – Self-discipline: Considering 5S as a way of life and bring about self-discipline among the employees of the organization. This includes wearing badges, following work procedures, punctuality, dedication to the organization (Japan Institute of Plant Maintenance, 1999).

TPM Pillars

Once a high degree of stability is established using the 5S program, an organization can start implementing the total productive maintenance in earnest. Total productive maintenance has eight pillars that are aimed at proactively establishing reliability of machines. Essentially, people are at the centre of this system and must be continuously trained to identify and eliminate waste. It is a system that is based on a clear set of principles and structures and should not be interpreted to be a set of tools or techniques to be applied haphazardly.

TPM Early Equipment Maintenance

The fifth TPM pillar of Early Management uses the experience gathered from previous maintenance improvement activities to ensure that new machinery reaches its optimal performance much early than usual. Venkatesh (2009) averred that working with a myriad of stake-holders including suppliers, the company is able to hit the ground running with highly reliable and productive equipment. Such an approach has a positive impact on profitability of the company as maintenance costs are dramatically reduced. The productivity as well as output quality of the machines is also guaranteed from the very first day when the equipment is commissioned.

Using the input from the people who use these machines on a daily basis, suppliers of the equipment can improve the maintainability and operability in the next iteration of their products.

Early equipment management also called as maintenance prevention is actually preface before using or purchasing equipment to consider their reliability, maintainability, safety and operability as well as estimated maintenance costs. TPM approach not only consider reliability and maintainability when purchasing new equipment but aims to overall system improvement by prevention of all other losses. Equipment with effective maintenance prevention should not in any case produce nonconforming products or break down (Sharma 2012).

Bupe and Charles (2015) developed a total productive maintenance model for manufacturing companies. Data was collected using designed questionnaires, structured interviews, direct observations and company records. The results of the research came double folded by reviewing that, the maintenance department employed 67.6% breakdown maintenance, 24.3% preventive maintenance and 8.1% not applicable. The research also reviewed that 78% of the time the operators were not involved in maintenance activities with only 14% operator involvement. Based on these results, knowledge and information sharing, operator involvement and training should be considered. The researchers then designed a TPM model which would result in effective implementation of TPM for higher competitiveness in the dynamic business environment.

TPM Pillar of Health, Safety and Environment (HSE)

That workers must be able to perform their functions in a safe environment devoid of health risks cannot be gainsaid. The health, safety and environment pillar of total productive maintenance ensures that all workers are provided with an environment that is safe and that all conditions that are harmful to their well-being are eliminated. While the goal of any organization is to produce value for the customer in an efficient and productive manner, this should be done in a way that is does not put to risk the safety of workers. It is therefore important that any solutions which are put in place should consider the well-being of the worker above all else (Aditya, Rashmi, Aniket, & Jay, 2017).

Safety, health and environmental pillar is counted in as from sustainability point of view. Manufacturing industry is globally huge source of pollution, as a result TPM does have strong emphasis in this area. Of course, this pillar aims to prevent any human or equipment errors leading to injuries or accidents. Zero safety and zero environmental accidents will be achieved by identifying and eliminating any abnormalities (Sharma 2012). In practice, workers must be safe when working in manufacturing site. The value for the customer should not be done by the benefit of workers health or life. It has been noticed that correlation exists between productivity and safe working environment (Gitachu 2016).

Beako, *et al* (2018) investigated effective utilization of power tools by students of metal works in technical college workshops in Rivers State. The population of the study is 143, comprising of 26 Metal works Teachers and 105 Metal works Technicians of private owned metal workshops in Rivers State. A self-designed instrument structured on 5 point Likert scale was used and was validated by three experts. Mean and Standard Deviation was used to answer the research questions while z-test statistical tool was used to test the hypotheses. The finding identified 10 benefits of effective utilization of power tool which include reduction of hazards, save materials from wastage. The study also identified 20 safety precautions to be observed when using power tools in Technical College Workshops which include; putting on hand gloves to protect hands and use of safety shoes during operations.

Methodology

The study employed the descriptive survey research design and was carried out in Rivers State. The population of the study is 527 electrical maintenance instructors and experts. The population comprised of 42 teachers known as maintenance instructors from the 5 technical colleges in Rivers State (Rivers State Post Primary Schools Board, 2021) and 485 experts from industries. A sample size of 469 respondents were selected comprising 42 electrical maintenance instructors and 427 experts in Rivers State. Simple random sampling technique was adopted in selecting the sample of the study. The researcher developed instrument titled Total Productive Maintenance Techniques for Quality Improvement of Electrical Workshop Questionnaire (TPMTQIEWQ) which was used for data collection. Face validation was carried out for the instrument. 5 experts with two from industries and 3 experts in vocational technical education validated the instrument. The reliability of the instrument was established using the test-retest method on 30 respondents, of which ten were instructors and twenty from the industries. The

validated instrument was then administered on 30 respondents who were not part of the study population. After 2 weeks, the same instrument was re-administered to the same set of respondents and the scores obtained were correlated using Pearson Product Moment Correlation (PPMC) and the correlation index gave a value 0.88.The instrument (TPMIQITEQ) was administered to sampled instructors and students by the researcher with the help of five trained research assistants, using direct delivery and recovery method. The retrieved questionnaires were analyzed using Mean ($\bar{x}$) and Standard Deviation (σ) to answer the research questions.

PRESENTATION OFINDINGS

Research Question 1: What are the mean responses of instructors and experts on the processes of utilization of early equipment maintenance techniques for quality improvement of electrical workshops in technical colleges in Rivers State?

Table 1: Mean Responses on Utilizing Early Equipment Maintenance Techniques

		Instructors, N=40		Experts N=391	
S/N	Early Equipment Management techniques for quality improvement	Mean	SD	Mean	SD
1	Early management should notice also ergonomically placing, feedback mechanism and safety features	2.85	1.10	2.83	1.07
2	examine and analyze the present situation	3.15	1.12	3.19	0.99
3	Identify problems and consider suggested improvements	2.80	1.02	3.02	1.10
4	Train operators (students) on system debugging	**3.50**	**0.96**	3.36	0.97
5	Establish an Early Management system	3.43	0.96	**3.40**	**1.00**
6	Build a troubleshooting system for all machines and equipment	3.33	1.19	3.32	1.03
	Grand $\overline{X}$ /SD	**3.18**		**3.19**	

Table 1 shows that the mean and standard deviation on the response of instructors and experts on the processes of utilization of early equipment maintenance techniques for quality improvement in electrical workshops in technical colleges in Rivers State were 3.18, SD=1.06 and 3.19, SD=1.03 for instructors and students respectively. The most utilized early equipment maintenance techniques for quality improvement in electrical workshops in technical colleges in Rivers State for instructors was Train operators (students) on system debugging (M=3.50, SD=0.96) while that for experts was to "establish an Early Management system" (M=3.40, SD=1.00). In general, Table 4.1 shows that items 1, 2, 3, 4, 5 and 6 which are questionnaire items on the response of instructors

and experts on the processes of utilization of early equipment maintenance techniques for quality improvement in electrical workshops in technical colleges in Rivers State had the weighted mean ratings which are individually above the criterion mean of 2.5 and are therefore accepted. Hence, both experts and instructors agreed that the identified early equipment maintenance can be utilized for quality improvement in electrical workshops in technical colleges in Rivers State.

Research Question 2: What are the mean responses of instructors and experts on the process of utilization of TPM in safety health and environmental techniques for quality improvement of the electrical workshops in technical colleges in Rivers State?

Table 2: Mean Responses on Utilizing utilization of TPM in Safety Health and Environmental Techniques

		Instructors, N=40		Experts, N=391	
S/N	TPM Safety health and Environment (SHE) Techniques for quality improvement	Mean	SD	Mean	SD
1	Develop procedures that enable safe work performance	3.30	1.20	3.34	1.04
2	Application of individual protection means	3.20	0.99	**3.36**	**0.97**
3	Maintaining cleanness standards to influence safety of work	3.28	0.96	3.34	1.12
4	Inculcate safety behaviours among staff and students in the workshop	2.93	1.05	2.81	1.04
5	Machines should have safety features	3.28	1.13	3.19	0.98
6	All SHE pillar activities should be aligned to relevant external quality standards	2.95	1.18	3.11	1.19
7	Safety as a management philosophy should be built into the workshop	**3.33**	**0.86**	3.24	0.89
	Grand mean	**3.18**		**3.20**	

Table 2 shows that the mean and standard deviation on the response of instructors and experts on the processes of utilization of TPM in safety health and environmental techniques for quality improvement in electrical workshops in technical colleges in Rivers State were 3.18, SD=1.05 and 3.20, SD=1.03 for instructors and students respectively. The most utilized TPM in safety health and environmental techniques for quality improvement in electrical workshops in technical colleges in Rivers State for instructors Safety as a management philosophy should be built into the workshop (M=3.33, SD=0.86) and that for experts was Application of individual protection means (M=3.36, SD=0.97). In general, the result shows that items 1, 2, 3, 4, 5, 6 and 7 which are questionnaire items on the response of instructors and students on the processes of utilization of TPM in safety health and environmental techniques for quality improvement in electrical

workshops in technical colleges in Rivers State had the weighted mean ratings which are individually above the criterion mean of 2.5 and are therefore accepted. Hence, both experts and instructors agreed that the identified TPM in safety health and environmental techniques can be utilized for quality improvement in electrical workshops in technical colleges in Rivers State.

Discussion of Findings

Utilization of TPM-Early Equipment Management Techniques for Quality Improvement of Electrical Workshops in Technical Colleges

Findings from analsysis shows that the mean and standard deviation on the response of instructors and experts on the processes of utilization of early equipment maintenance techniques for quality improvement in electrical workshops in technical colleges were 3.18, SD=1.06 and 3.19, SD=1.03 for instructors and experts respectively. The most utilized early equipment maintenance techniques for quality improvement for instructors was Train operators (students) on system debugging (M=3.50, SD=0.96) while that for experts was to Establish an Early Management system (M=3.40, SD=1.00). The result depicts that the respondents collectively posits that the processes of utilization of early equipment management techniques for quality improvement of electrical workshops in technical colleges was appropriate. This result is in line with that of Bupe and Charles (2015b) who carried out research again on an assessment of the effectiveness of equipment maintenance practices in public hospitals and found a high rate of equipment unavailability attributed by high failure rates due to unreliable schedule systems for equipment, high equipment breakdowns and shortage of manpower.

Utilization of TPM in Safety, Health and Environment Techniques for Quality Improvement of Electrical Workshops

Result of analysis reveals that the mean and standard deviation on the response of instructors and experts on the processes of utilization of TPM in safety health and environmental techniques for quality improvement in electrical workshops in technical colleges in Rivers State were 3.18, SD=1.05 and 3.20, SD=1.03 for instructors and experts respectively. The most utilized TPM in safety health and environmental techniques for quality improvement in electrical workshops in technical colleges in Rivers State for instructors Safety as a management philosophy should be built into the workshop (M=3.33, SD=0.86) and that for students was Application of individual protection means (M=3.36, SD=0.97). The result depicts that the respondents collectively posits that the processes of utilization of TPM in safety, health and environmental techniques for quality improvement of electrical workshops in technical colleges in Rivers State was moderately appropriate. This result is supports that of Beako, Flagg, Okorieocha and Kooli (2018) who investigated effective utilization of power tools by students of metal works in technical college workshops in Rivers State and identified 10 benefits of effective utilization of power tool which include reduction of hazards, save materials from wastage. The study also identified 20 safety precautions to be observed when using power tools in Technical College Workshops which include; putting on hand gloves to protect hands and use of safety shoes during operations.

Conclusion

The study identified processes of implementing TPM in early equipment maintenance as well as TPM in safety, health and environmental techniques. The study concludes that both experts and instructors agreed that the identified items on early equipment and safety are TPM pillars that can be utilized by electrical workshops for maintenance. The study concludes that the identified steps in early equipment maintenance as well as TPM in safety, health and environmental techniques are valid TPM pillars for utilization by technical education workshops.

Recommendations

Based on the findings and conclusions of the study the following recommendations were made:

i. The identified TPM in safety, health and environmental techniques should be implemented by technical education workshops as key TPM pillars that deepens the maintenance culture of students and instructors.
ii. The identified TPM early equipment maintenance technique should be adopted by technical education workshops as key TPM pillars that deepens the maintenance culture of students and instructors.
iii. School administrators should ensure they incorporate TPM in their day to day administrative dealings.

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