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Development and Evaluation of Hydro-pneumatic Power Brake System Trainer

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Abstract

Effective instructional materials can empower students by improving skills and concepts through multiple representations and enhanced visualization. It can also engage students in higher-order thinking, builds strong problem-solving skills, and develops a deep understanding of concepts and procedures when properly used. Hence, the researchers developed an automotive hydro-pneumatic power brake system and evaluated its effectiveness as an instructional device through the research and development (R&D) process. The finished product was presented to purposively selected respondents to assess its level of acceptability. After this, it was utilized in an actual teaching-learning (T-L) process to determine its effectiveness as an instructional device versus the traditional approach of instruction. The design of a trainer was a simulation of a real hydro-pneumatic power brake system used widely in most automobile nowadays. It was constructed using actual components to focus primarily on the purpose, operation, construction, and servicing of a brake system. It was supported by a manual of operation that facilitated the teaching-learning on this particular subject matter. The result of the evaluation of the effectiveness of the hydro-pneumatic power brake system trainer showed that there is a significant difference between the performance of the control group and the experimental group. Hence, the trainer is an effective instructional material that significantly improved the T-L process. It is recommended that institutions offering automotive technology courses should provide instructional devices to improve performances and consider design calculation if there are standard measurements to serve as basis in using the size or dimension of such material.

Keywords: *automotive technology, instructional device, effectiveness, developmental research, mockup, hydro-pneumatic power brake system*

Introduction

The under chassis is indeed vital in an automobile. It comprises of a brake system, steering system and the suspension system which allow the user to travel safely and comfortably. Truly, these two systems of under-chassis operate in a complicated way. Therefore, before the learners could service or repair any of the systems, learners should first identify the parts, position, operation, and function to diagnose the problem well. Hence, learners in automotive technology could not become competitive auto technicians to perform the said job competently without proper instructional materials for these systems. Effective instructional materials can empower students by improving skills and concepts through multiple representations and enhanced visualization (Sankey, 2003). It also engages students in higher-order thinking, builds strong problem-solving skills, and develops a deep understanding of concepts and procedures properly. Functional instructional materials are very necessary for automotive technology education, especially that such is included in the senior high school under the K-12 program of the Philippine education system aside from Technical Education and Skills Development Authority (TESDA) institutions and state universities and colleges (SUCs) offering such viable program.

Automotive brakes are designed to slow and stop a vehicle by transforming kinetic (motion) energy into heat energy. The brake linings create friction when they contact the drum/disks, which enables them to slow down and momentarily stop the vehicle. Most automotive service brakes are hydraulic brakes because they operate hydraulically by pressure applied through a liquid (Crouse & Anglin, 1993). Nowadays, most vehicles have power-assisted braking where pressure applied on the pedal is multiplied by air to increase braking action while the engine is running. This helps the driver to stop the vehicle with a relatively light force applied to the pedal. However, the system is more complicated in terms of construction, operation, and servicing.

Many vehicles have pneumatic assists provided by the vacuum brake booster. The vacuum boosters are mounted between the brake pedal pushrod and the master cylinder, and receive engine vacuum through a hose and check valve (one-way valve) (Swargiary *et al*., 2013). The check valve holds vacuum pressure and assures power-assist capability during times of low engine vacuum (i.e., the engine quits). With the check valve in place, a booster will have enough reserve vacuums for two to three brake applications after the engine vacuum is lost. Hydro-pneumatic brake systems are used on many vehicles with limited under-the-hood space or vehicles with engines that cannot consistently produce sufficient vacuum to operate a vacuum power boost system. These include diesel engines, turbocharged engines, and engines that operate at high load (low vacuum), such as truck applications.

In this premise, the researchers developed a hydro-pneumatic power brake system trainer composed of drum brake and disk brake assembly and other components to demonstrate the hydro-pneumatic principle applied in the brake system.

The hydro-pneumatic brake system is a combination of the hydraulic brake system and pneumatic principle application. On the pneumatic components, atmospheric pressure on the backside and vacuum on the front side moves the diaphragm; and on the hydraulic components, a master cylinder pushrod pushes forward to apply the brakes and forcing the brake pads and shoes to contact with the rotating drum and disk using the hydraulic principles to move its parts. The resulting friction slows or stops the wheels and the vehicle. Many vehicles use a vacuum brake booster (for hydro-pneumatic) that has a single diaphragm, with only a relatively light pedal force that is required to slow or stop the vehicle (Crouse & Anglin, 1993). This operation is more difficult compared to a hydraulically operated brake system, but is very efficient in terms of braking action.

This research is a follow-through of Balbin (2015) on multisystem automotive engine electrical trainer, in which findings showed that it is possible to combine several automotive systems in one trainer in order to improve its functionality and provide economic advantages. The present undertaking likewise designed an instructional device by combining several interrelated automobile systems to simulate primarily its components, construction, operation, and functions and thereby facilitate the T-L process and improve the educational output through the help of this device. Further, Balbin (2012) served as a basis in developing the present device for instructional use by considering the safety feature of the instructional device to the users and the machine itself. Both pieces of research utilized an electric motor as a prime mover of other components in the system instead of a petrol engine that emits pollutants harmful to man and the environment.

Materials and Methods

This study used the developmental method of research, particularly the research and development (R&D) process, to develop and validate educational products. The experimental type of research using the pre-test and post-test design was likewise applied in evaluating the level of effectiveness of the research outputs as instructional devices. There were 10 BS Automotive Technology (BSAT) students in the experimental group who used the newly developed instructional device and another 10 BSAT students in the control group using the traditional model, or the commonly available materials in the automotive shop. They comprised the subjects of the experimental study. Figure 1 reflects the flowchart illustrating the developmental process from design through evaluation stages of the trainer.

Due to the highly technical machining process, the researchers contracted labor of expert metalworkers with tools and equipment (Table 1) to fabricate the system. The researchers closely supervised the entire procedure to ensure that the design was properly observed. The finished trainer was presented to the automotive technology students for evaluation. It was used in the actual teaching-learning process of an automobile hydro-pneumatic power brake system. After the pre-test was administered to both groups, the experimental group was allowed to manipulate the trainer with the guidance of the teacher during the laboratory activity. The control group had their laboratory works using the available non-functional hydro-pneumatic brake system materials in the laboratory shop. After the laboratory activity, both

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Table 1. Bill of Materials Used in Developing the Power Brake System

Quantity	Unit	Description	Unit Cost	Total Cost (Php)
2	Pc	Drum Brake Assembly	6,500.00	13,000.00
2	Pc	Disk Brake Assembly	7,000.00	14,000.00
30	Ft	3/16 Copper Tube	45.00	1350.00
10	Pcs	Copper Tube Fittings	30.00	300.00
4	Pcs	Flexible Hose	200.00	800.00
1	Pc	Brake Vacuum Booster	5,300.00	5,300.00
1	Pc	Alternator with Vacuum Pump	8,000.00	8,000.00
1	Pc	Brake Pedal	1,500.00	1,500.00
1	Liter	Brake Fluid	190.00	190.00
1	Liter	Oil SAE 40	180.00	180.00
1	Pc	1/8x1" angle bar	600.00	600.00
2	Pcs	2" GI Pipe	900.00	1,800.00
7	Kls	Welding Rod	90.00	630.00
8	Pcs	Hacksaw Blade	75.00	600.00
1	Pc	220VAC 1hp Electric motor	3,500.00	3,500.00
			Total	**51,750.00**

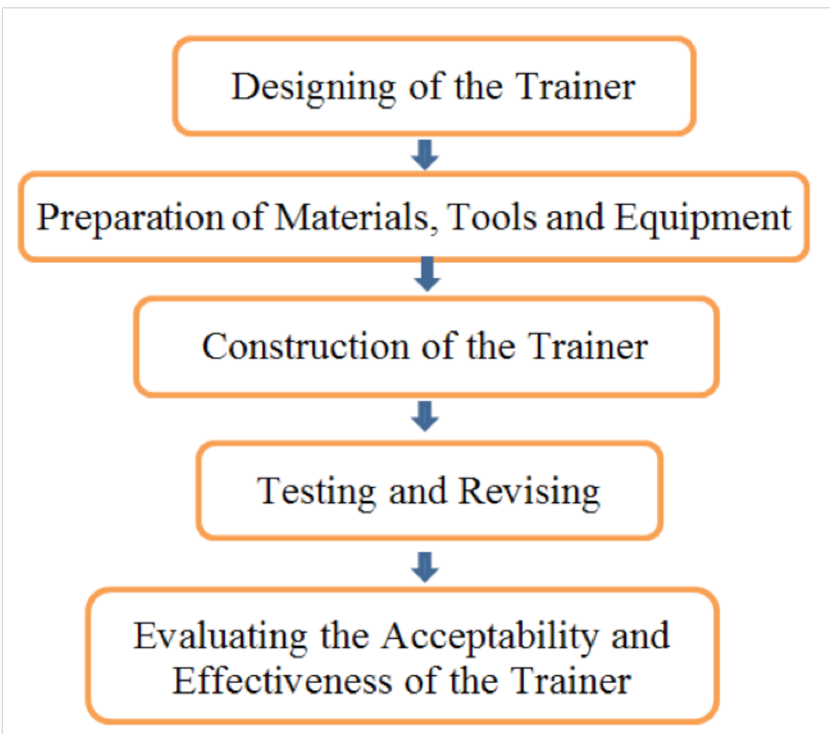

Figure 1. Research Flowchart

groups were administered with the post-test. The pre-test and post-test were developed by the researcher and submitted to a panel of experts for validation prior to use. The data gathered through their responses was tallied and treated statistically using a t-test.

In determining the acceptability of the device in terms of functionality, mobility, safety, and maintainability, the researchers sought help from the respondents to give their rating based on the criteria set on the evaluation sheet. The respondents are instructors of automotive technology in different government institutions. The researchers selected respondents purposively from the following: five from TESDA, five from the Department of Education (DepEd), and five from Bicol University (BU). Likewise, the researchers also gathered responses from automotive students: five from TESDA, five from DepEd, and from BU.

Results and Discussion

Design of Hydro-Pneumatic Power Brake System Trainer

Figure 2 shows the design of the hydro-pneumatic brake system. The frame holds its components. It is made up of angle bar and 2” GI pipe forming a rectangular shape with four legs. The brake master is attached to the frame, the master cylinder is equipped with hydraulically assisted boosters for the brakes, and has two pistons moving back and forth to apply pressurized fluid in the system. The primary piston is directly operated by the pushrod from the brake pedal.

As the pressurized fluid travels on the brake lines, it passes through the splitter and splits the pressurized fluid into two: the left side and right side of the disc brakes. When the driver presses the brake pedal, the two-way valve also moves. This movement closes the passage to the rear of the diaphragm, and vacuum applies only to the front. Simultaneously, atmospheric pressure flows into the rear. Atmospheric pressure pushes the diaphragm and the vacuum pulls it forward. The pushrod also moves to apply the brakes through the master cylinder attached to the front of the booster. Releasing the brake pedal allows the internal spring to push the diaphragm and pushrod back and operates the two-way valve. This valve blocks atmospheric pressure to the rear chamber. Simultaneously, it opens the chamber to vacuum. This evacuates the rear chamber and assists in returning the booster to a state of rest. Since it has moving parts, the oil reservoir circulates as the vacuum pump rotates. The vacuum pump is driven by a 220V AC motor instead of an automotive engine.

The proposed dimension of the hydro-pneumatic brake system is 90 cm x 50cm x 60cm, enough to accommodate the basic automotive brake system components. It included revisions of some problems observed during a series of tests (Table 2). It is a table-type instructional device with wheels for mobility. Furthermore, the existing trainer uses the actual engine to drive the vacuum pump while the hydro-pneumatic brake system trainer uses a 220V electric motor to drive the vacuum pump for the booster. Also, the existing trainer uses an actual automotive engine to lubricate the moving parts of the vacuum by means of oil pressure of the engine while the hydro-pneumatic brake system trainer has a tank that supplies oil to its vacuum pump, and the vacuum pump itself circulates the oil from the tank to its moving parts.

Figure 3 shows the three circuits of the hydro-pneumatic brake system trainer. These are the electrical circuit, pneumatic circuit, and the hydraulic circuit. The electrical circuit is the driving mechanism composed of AC switch and AC motor 220V. The pneumatic circuit is the one that creates and supplies vacuum pressure to

Table 2. Results of Test and Revision

Observation	Cause	Revision	Result
The tension on the belt was not properly set	Not enough holes for the 220VAC motor to be adjusted	Add additional holes on 220VAC motor mounting for belt adjustment	Easy to adjust belt tension
Difficult to rotate brake drum when the brake is not engaged.	Brake shoe lining too thick	Excess brake shoe lining was smoothed.	Brake drum rotates when the brake system is not engaged.

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the brake system to assist the driver's foot during the brake operation. The hydraulic circuit operates once the driver steps on the brake pedal during the hydraulic brake action; the piston pushes the fluid out of the master cylinder allowing the wheel cylinders to move outward to create braking action to stop the rotating motion of the wheel (Figure 4).

Acceptability of the Hydro-Pneumatic Power Brake System Trainer

Shown in Table 3 are the weighted mean (x) responses of the respondents on the acceptability of the hydro-pneumatic power brake system trainer in terms of functionality, mobility, safety, and maintainability. The highest average weighted mean was on functionality and maintainability which is 4.82 with an interpretation of very much acceptable. It could be deduced from this finding that the design of the trainer satisfied the expectations of the respondents as an instructional material. Further, the respondents observed some potential for a simple and manageable maintenance program for the trainer as the need arises. On the other hand, although mobility and safety garnered the lowest average weighted mean of 4.79, this is still interpreted as very much acceptable. Mobility got that rating considering the weight of actual brake system components used in constructing the trainer since the researchers reserved the idea of using actual components to simulate the operation, construction, and appearance of a real brake system. Rating on safety was due to the unsecured moving parts such as 220V AC motor, exhauster pump, and belt. However, these were intentionally done so that learners may observe the operations of these components.

To facilitate the individual learner in using this trainer, the researchers prepared the manual of operation (Figure 5). This manual contains information on parts of the machine and its functions, instructions on how to use the machine, and the safety precaution to be observed in using the hydro-pneumatic power brake system trainer. Topics included were the brake system components, function and how it operates during braking action. The manual also discusses common brake troubles and possible repairs or servicing procedures in case of brake system failure.

Table 3. Result of Evaluation of the Level of Acceptability of the Hydro-Pneumatic Brake System Trainer. (x - weighted mean; I - interpretation).

Criteria	x	I
Functionality		
The design is easy to manipulate	4.83	VMA
Have complete parts of the brake system for students to identify and familiarize.	4.7	VMA
All the vital components of the brake system are visible.	4.87	VMA
The trainer is useful to all educational institutions offering automotive courses.	4.9	VMA
Mobility	4.82	VMA
Provide wheels to move the device easily.	4.63	VMA
The total weight is minimal that can be movable by one person.	4.8	VMA
The device has an appropriate height and width to be movable.	4.93	VMA
Safety	4.79	VMA
Safety guards were provided for rotating parts.	4.73	VMA
Safety switches were used for electrical components.	4.87	VMA
Safety rules were provided for the user.	4.77	VMA
Maintainability	4.79	VMA
It requires low maintenance.	4.73	VMA
Any fault in the trainer can easily be identified and fix.	4.83	VMA
Components are very available in the market in case of replacement.	4.9	VMA
General Weighted Average	4.81	VMA

Legend:
4.5–5.0 - Very Much Acceptable (VMA)
3.5–4.49 ¬- Much Acceptable (MA)
2.5–3.49 - Acceptable (A)
1.5–2.49 - Least Acceptable (LA)
1.0–1.49 - Not Acceptable (NA)

The Effectiveness of the Hydro-Pneumatic Power Brake System Trainer

The researchers utilized the hydro-pneumatic power brake system trainer in actual teaching-learning

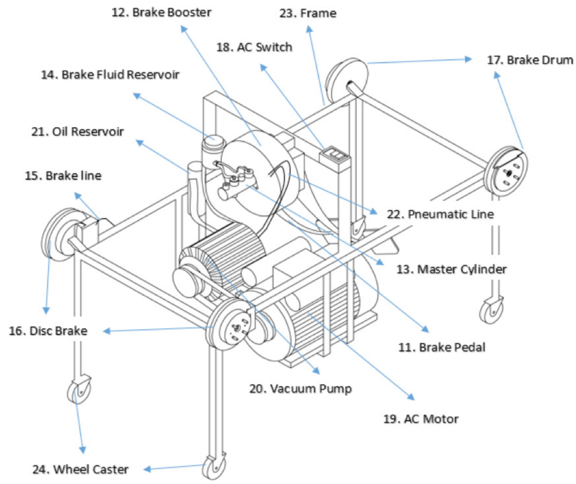

Figure 2. Isometric View of the Design of Power Brake System Trainer

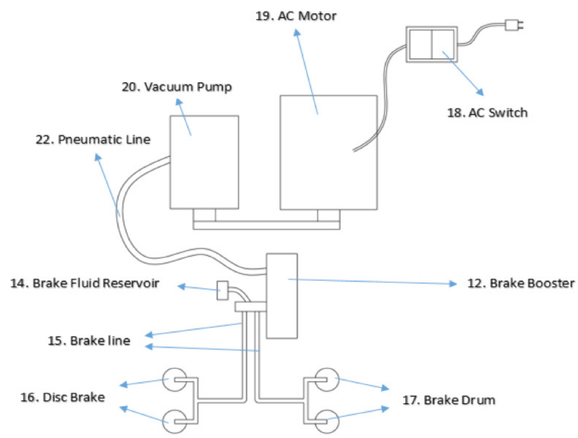

Figure 3. The Hydro-Pneumatic Brakes Circuits

Figure 4. The Hydro-Pneumatic Power Brake System TrainerBrake System Trainer

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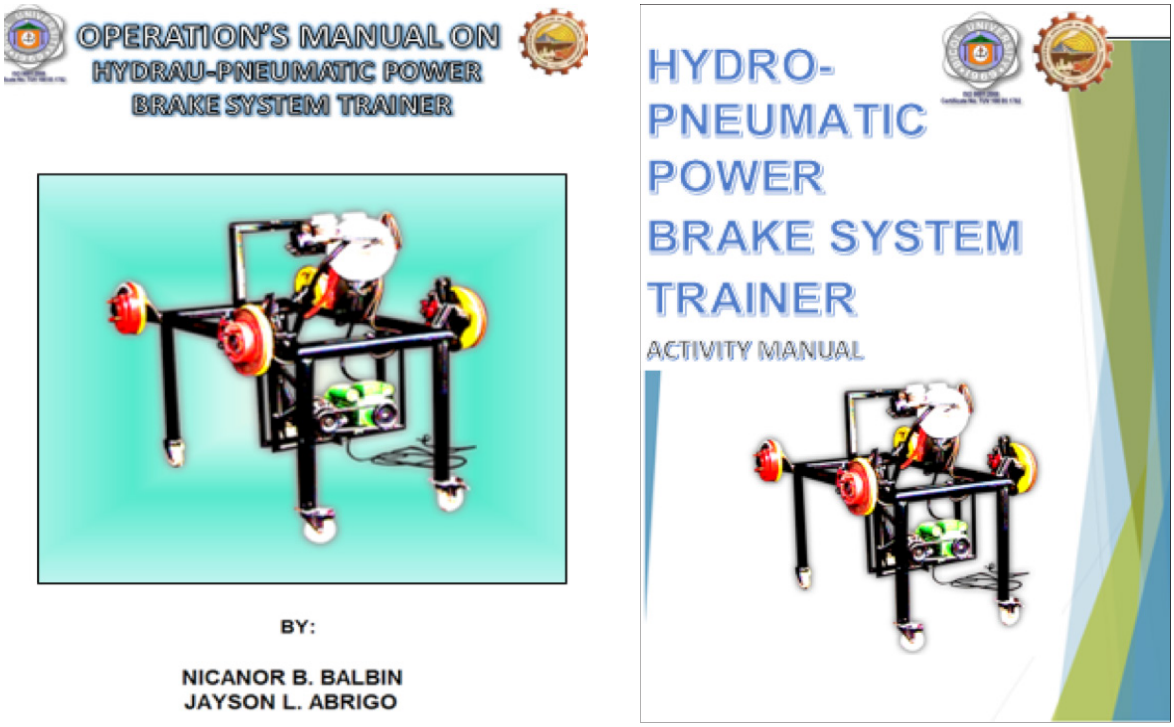

A B

Figure 5. Operation's Manual (A) and Activity Manual (B).

Table 4. T-test Result on the Difference Between the Performance of the Controlled and Experimental Group

Respondent	Mean	Mean Difference	Degree of Freedom	Level of significance	Computed Value	Critical Value	Decision
Experimental Group	4.8	2.5	18	0.05	3.24	2.101	Reject H_o
Control Group	2.3						

activity to determine the level of its effectiveness as an instructional device. As shown in Table 4, the null hypothesis was rejected. The experimental group has a mean score of 4.8, which is twice higher as compared to the 2.3 scores of the controlled group. This implied that the performance of the students using the hydro-pneumatic power brake system trainer was better than the performance of the students using a conventional method of instruction. Hence, the use of this trainer is helpful for automotive technology students in order to improve their effectiveness as automotive technicians in the future.

Conclusion and Recommendations

Based on the foregoing findings, the following conclusions were formulated:

1. the design of the hydro-pneumatic power brake system trainer is a functional instructional device in simulating the operation, function, construction, and servicing procedures of an automobile power brake system;

2. the trainer is made possible by following its

design with some minor revisions on the original plan and with the use of available materials in the market. It was very highly acceptable as assessed by the respondents in terms of functionality, mobility, and safety. The operational and activity manuals were prepared as a guide for the users in manipulating the trainer in order to improve the teaching-learning process; and

3. the trainer is effective as an instructional device in the teaching-learning process as shown by the performance of the controlled group and experimental group.

In light of findings and conclusions, the researchers recommend the following:

1. consider design calculation to serve as a basis in using the size or dimension of such material;

2. further developmental studies could be conducted for the improvement of its quality especially on the safety features of the trainer;

3. institutions offering automotive technology courses should provide an instructional device to facilitate the T-L process; and

4. the packaging and affordability of the device should be improved for commercialization purposes.

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