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Development and Evaluation of Power Steering System Trainer

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Abstract

Automotive students may be able to understand the lessons more efficiently with the use of functional instructional materials. However, such instructional materials are not readily available in educational institutions. This problem is common not only in state universities and colleges (SUCs), but also in senior high schools offering technology courses like automotive technology. To address such difficulty, this study aimed to (1) design a power steering system trainer, (2) construct and test the device, and (3) evaluate the acceptability and effectiveness of the power steering system trainer. The said trainer was developed through the research and development (R&D) process. After the developmental phase, the evaluation of acceptability and effectiveness of the trainer was administered. As to the acceptability, the respondents rated the trainer 4.75 (out of 5.0) for the functionality, 4.73 for the mobility, 4.83 for safety, and 4.63 for maintainability. Thus, with the general weighted mean of 4.74, the trainer was very highly acceptable. In terms of effectiveness, the statistical result implied that the performance of the students using the power steering system trainer was better than the performance of the students using the conventional instructional device. Hence, it could be deduced that using this trainer as an instructional device provided a better understanding of the topic and enhanced the teaching-learning process.

Keywords: *Automotive Technology, Instructional Materials, Maintainability, Mobility*

Introduction

Instructional materials are tangible trainee-oriented resources, with instructional content. According to Campbell (1999), instructional materials enhance the teaching-learning process by exhibiting information necessary to acquire knowledge and skills. Trainers as instructional materials are necessary for automotive technology education, especially this time that senior high school is fully implemented under the K-12 program of the Philippine education system. Under the vocational track of the K-12 program is the automotive technology course where students need to study the numerous components of an automobile. Aside from the students of the K-12 program, students from different SUCs, Technical Education and Skills Development Authority (TESDA) and other vocational schools have the choice to study automotive technology. These students need effective instructional materials, like in the discussion of the automotive power steering system. Thus, faculty members must strive to produce instructional materials. In fact, according to Nantes (2013), innovating instructional devices for SUCs is one of the primary responsibilities of instructors.

The steering system allows the driver to control the direction of the vehicle's travel (Crouse & Anglin, 2004). This is made possible by a linkage that connects the steering wheel to the steerable wheels and tires. The steering system may be either manual or powered. The steering system has two types of steering gear. These are the recirculating-ball steering gear and the rack-and-pinion gear. Both steering gear types are composed of different parts and require a complicated mechanism to function properly.

With the complexity of the operation of the steering system, the learners must know the position of the parts, their functions, and the know-how to diagnose the possible causes of the problem before servicing or repairing takes place. Consequently, effective instructional materials can empower students by improving skills and concepts through multiple representations and enhanced visualization.

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Unfortunately, instructional materials are not readily available in all automotive schools.

In this premise, the researchers aimed to (1) design a power steering system trainer, (2) construct and test the trainer, and (3) evaluate the acceptability and effectiveness of the power steering system trainer. Considering that the operation of the power steering system is being powered by pressurized fluid, the researchers anchored this study on Pascal's Law. As cited by Mobley (2001), any force applied to a confined fluid is transmitted uniformly in all directions throughout the fluid regardless of the shape of the container. He also added that any change in pressure is transmitted undiminished. Hence, through such principle, the researchers were able to install the hydraulic components of the trainer properly and promote safety for both the instructional material and the users.

To assure that the power steering system trainer would be useful, particularly in schools and training institutions offering automotive technology, the researchers also anchored this study on the Dale's Cone of Experience Model. Dale, as cited by Maheshwari (2016), theorized that learners retain more information by what they "do" as opposed to what is "heard," "read," or "observed." The mentioned model guided the researchers to design a trainer that allows the learners to manipulate ("do") the power steering system of the automobile. Specifically, the researchers arranged the components of power steering in a way that learners would easily grasp and understand the discussion along with the automobile steering system. It also allowed the researchers to identify the necessary activities to be performed using the trainer by considering the propositions of the model.

Materials and Methods

In finding a clear understanding and analysis of the study, the researchers used three research methods. These were the design and developmental, descriptive, and experimental research methods.

The design and developmental research method was used to develop the trainer. During the developmental phase, the processes under the R&D, namely designing, constructing, testing and revising, and evaluating were followed. The ideas from both Dale's Cone of Experience Model and Pascal's Law were also considered in the said developmental phase. Using the locally available materials, the fabricator skillfully constructed the trainer with the researchers closely supervising the entire procedure to ensure that the design was properly followed using the materials listed in Table 1.

The descriptive research method was utilized to document the level of acceptability of the trainer as instructional materials. Respondents evaluated the said acceptability of the trainer using a questionnaire checklist. The checklist included four criteria namely: functionality, mobility, safety, and maintainability (Table 2). Each criterion has several indicators to assure that there is objectivity and accuracy on the respondents' ratings. To achieve consistency in the interpretation of the quantified data using the questionnaire checklist, the Likert rating scale was used. This scale provided a standard basis for the degree of evaluation. The Likert items simply is a statement that the respondents were asked to evaluate according to any kind of subjective or objective criteria. Generally, the level of agreement or disagreement was measured. It is considered symmetric or balanced because there were equal amounts of positive and negative positions.

The questionnaire was validated by three jurors who are experts in their field and have experience in determining the appropriateness of the questionnaire to the objectives of the study. During the validation

Table 1. Materials used in the Development of the Power Steering System Trainer

Quantity	Unit	Description
2	pcs	power steering pump
1	pc	recirculating ball gear box
1	unit	rack and pinion gear box
1	set	recirculating ball steering linkages
1	set	rack and pinion steering linkages
2	set	steering wheel assembly
8	pcs	flexible hose and fittings
2	liter	power steering fluid
2	unit	220vac 1hp electric motor
2	pcs	¼ x 1 angle bar
1	pc	2" gi pipe
5	kls	welding rod
3	liter	steel paint
4	pcs	caster wheel

Table 2. Definitions of the Parameters

Parameters	Definition
Functionality	It is how the trainer operates or function according to its use and purpose.
Mobility	It is the state of being easy to be moved around or to be carried from one place to the other easily.
Safety	It is the state of being protected from or not being exposed to the risk of harm of injury.
Maintainability	This refers to the ease and speed with which the trainer can be restored to operational status if a failure occurs

process, the jurors unanimously rated the questionnaire as high under all seven parameters. Specifically, these are the correctness of the statements, accuracy of the information, consistency and appropriateness of the items or statements to the objectives of the study, comprehensiveness or clarity of instructions or directions, sufficiency of information being presented or solicited, attainability or relevance of given indicators and information, and provision for other information.

The respondents were composed of 30 individuals. Five of them were professors from Bicol University (BU), five were automotive teachers from the Department of Education (DepEd), and five were automotive servicing teachers from TESDA. The remaining 15 respondents were all students from BU, DepEd High School Department, and TESDA who are taking automotive technology. The respondents were purposively selected since they are the direct beneficiaries of this study.

During the evaluation phase, the researchers demonstrated the operation and technical background of the trainer to the respondents. The respondents were then given a chance to manipulate the trainer and see what it can offer to them. They were also allowed to ask questions and clarifications. The questionnaire checklist was distributed to them for the rating.

The researchers also utilized the experimental method with a pre-test–post-test design to determine the level of effectiveness of the trainer as instructional material. The post-test questionnaire contained the same questions as what the pre-test questionnaire had, however, questions were rearranged to make sure that learning will be measured and not merely what they remember during the pre-test. The questionnaire was designed based on the table of specification to assure that all components under the power steering system would be covered. The researchers also carefully followed the guidelines in creating an effective and accurate questionnaire.

Students of Bicol University–College of Industrial Technology (BUCIT) studying Bachelor of Science in Automotive Technology (BSAT) enrolled in the course auto-power train and under chassis were selected for the experimental phase of the study. The subjects were purposively selected since the developed instructional material was intended for second year automotive students. Using the fishbowl technique, the students were divided into two groups—the control and the experimental groups. Both the control and experimental groups were subjected to pre-test and post-test activity to determine the degree of learning between the two groups.

The researchers administered the lecture based on the objectives of the lesson. The researchers briefly oriented the class about the activity. Before the discussion proper, the researcher gave the pre-test to both groups. The post-test was later given after the discussion using the newly developed instructional material for the experimental and the conventional IMs for the controlled group. Through the result of the pre-test and post-test, the significant difference between the scores of the experimental and control group was computed using t-test. The Simplified Statistics for Beginners (SSB) program was utilized.

Results and Discussion

Design of the Power Steering System Trainer

The design of the power steering system trainer has different components wherein the rack and pinion power steering and recirculating-ball power steering systems are being held together in a single frame (Figure 1). The power steering system trainer was specially designed for instruction in familiarizing its operation, identifying the parts, and troubleshooting of the automotive power steering system, namely recirculating ball-and-rack and pinion-type power steering. The frame (11) was made of angle bars and GI pipes assembled using the Shielded Metal Arc Welding (SMAW) process. To provide mobility to the trainer, plurality of caster wheels (12) was attached to the four

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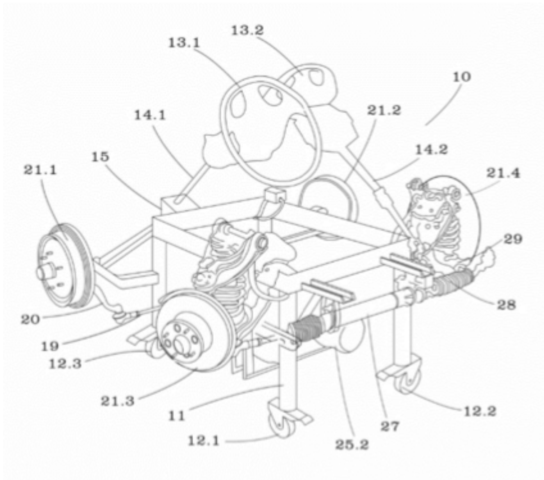

Figure 1. Isometric View of Power Steering System Trainer

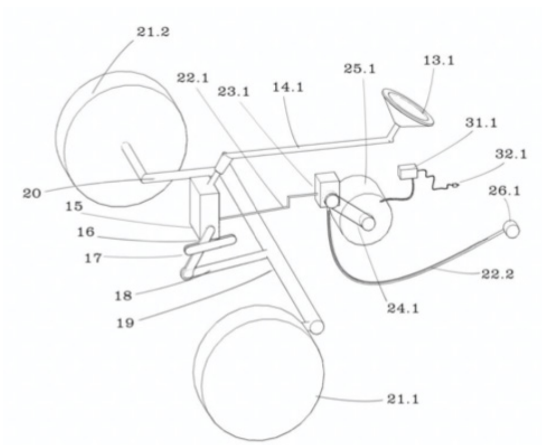

Figure 2. Sectional View of Recirculating Ball Power Steering System

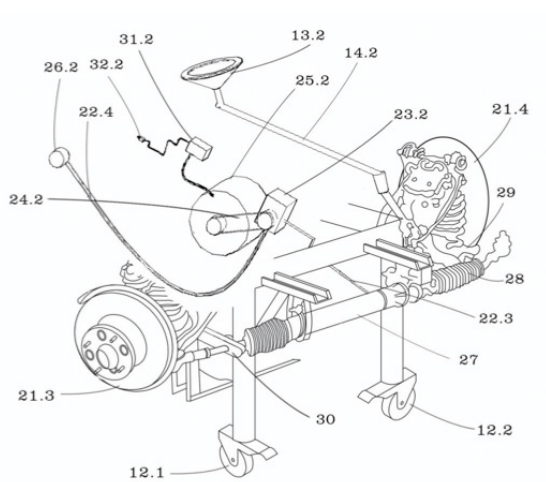

Figure 3. Sectional View of Rack and Pinion Power Steering System

legs of the frame. These caster wheels have a locking mechanism that will halt the trainer in place while in use.

The recirculating ball power steering system included a steering wheel (13.1) for manipulation by the students to any desired direction of the car. Steering wheel (13.1) is connected with a steering shaft (14.1) to transmit the action from the steering wheel (13.1) to the recirculating ball steering gearbox (15). As in the actual automotive power steering system, the steering gearbox (15) is attached with a pitman arm (16) to convert the rotary motion into a back and forth motion of the drag link (18). However, in this trainer, recirculating ball power steering system tensioner (17) was added on the pitman arm (16) to provide harder movement to simulate actual stiff operation to be overcome by the power steering system.

A drag link (18) is connected from steering gearbox (15) to the steering bar (19) while the steering bar (19) is then connected to steering arm (20) thereby causing the motion to the front wheel (21.1) and eventually obtaining car direction while turning the steering wheel (13.1) left or right (Figure 2). A rubber hose (22.1) is connected from steering gearbox (15) to a power steering pump (23.1) thereby creating pressure to assist the driver in operating the system. A power steering pump (23.1) being driven by a 220V AC electric motor (25.1) and by a tension belt (24.1) are included to simulate the construction and operation of a recirculating ball power steering system. A rubber hose (22.2) is connected from the power steering pump to fluid reservoir (26.1) to maintain the proper amount of fluid supplied in the system. An on-off switch (31.1) is provided to control the operation of the electric motor (25.1)

The sectional view of the rack and pinion power steering system (Figure 3) includes a steering wheel (13.2) and a steering shaft (14.2) to operate the rack and pinion steering assembly (27), being the second type of power steering embodied in the trainer. A steering rod (29) is connected from the rack and pinion assembly (27) to 21.3 and 21.4 front wheels causing each left and right movement. A rack and pinion power steering system tensioner (30) is adapted thereof to cause harder motion for the rack and pinion power steering system to overcome the stiff operation.

A rubber hose (22.3) is attached from the rack and pinion assembly (27) to the real automotive power steering pump (23.2) thereby creating pressure to assist the driver in operating the system. The flexible rubber boots or bellows (28) were also installed in the assembly to protect the steering gear from dust and water. A power steering pump (23.2) being driven by a 220V AC motor (25.2) and by a tension belt (24.2) were included to simulate the construction and operation of a recirculating ball power steering system. A hose (22.4) is connected from the power steering pump to fluid reservoir (26.2) to maintain the proper amount of fluid supplied in the system. An on-off switch (31.2) is provided to control the operation of the electric motor (25.2).

The presented design is essential to assure the level of functionality, mobility, safety, and maintainability as main characteristics of the trainer. According to Iwasaki and co-workers (1993), when designing a device, the final product of the design process is usually considered to be a physical specification of a device. However, the design of the causal mechanism underlying the physical specification (i.e., how the device is intended to work to achieve its function) is a product just as important as the physical specification, if not more. They also added that capturing this knowledge of causal mechanism is necessary in order to understand the physical specification of the device as well as to evaluate and refine the specifications during the design process.

As presented, the trainer includes mechanical components, but it does not require design calculations since the components of power steering that will be used are the actual components being attached to a functional and running vehicles. Likewise, the mechanical integrity of said components were already tested by the car manufacturing companies.

The power steering system trainer has a total dimension of 61cm x152cm x 122cm (H x L x W) (Figure 4). The trainer is considered as two-in-one where the rack and pinion steering system and recirculating-ball power steering system are both placed in one frame, but each has separate components to function individually. In other words, one will have two trainers in one set-up but still usable synchronously. The difference between the two systems will be observable since they are operating a few centimeters away from each other. Since the parts are exposed, students can easily identify them while understanding its functions and the relation to other parts. In addition, according to Balbin (2012), the availability of electric motor in any instructional materials to power its operation affirms that such electric motor provides economic and environmental advantages as it will not use expensive petrol engine

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that emits harmful gases.

Acceptability of the Power Steering System Trainer

According to Mengel (1986), if instructional designers are to achieve widespread success by reaching large numbers of students, they have to develop learning materials that are not only effective in producing the desired learning outcomes but are also accepted and used by teachers. Thus, the level of acceptability of the power steering system trainer was evaluated by the target users of the instructional material developed (Table 3).

The general weighted mean of the trainer which is 4.74 indicates that the trainer is indeed very highly acceptable. Such high rating of the trainer can be linked to the completeness of the power steering parts where students can familiarize and enhance their servicing skills on the steering system. The trainer also provided ease in manipulation, which leads to facilitation of the learning process. The appropriateness of the height and weight of the trainer despite its completeness of parts and the availability of two steering systems in one unit may also have contributed the positive perception of the respondents. Added also is the existence of the caster wheels in the trainer, which allows even a single person to transfer it from one place to another.

The result of evaluation may also imply that the respondents appreciated the way that the moving parts were guarded, and the wiring harnesses were installed. Likewise, the respondents believed that the trainer requires low maintenance and that the components are very available in the locality in case maintenance work needs replacement.

Table 3. Evaluation of the Power Steering System Trainer in terms of Acceptability

Criteria	Average Weighted Mean	Interpretatic
Functionality	4.75	VHA
Mobility	4.73	VHA
Safety	4.83	VHA
Maintainability	4.63	VHA
General Weighted Mean	4.74	VHA

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

Such result affirms the findings of the study conducted by Bernaldez (2015), when he found that the instructional materials that he developed was acceptable

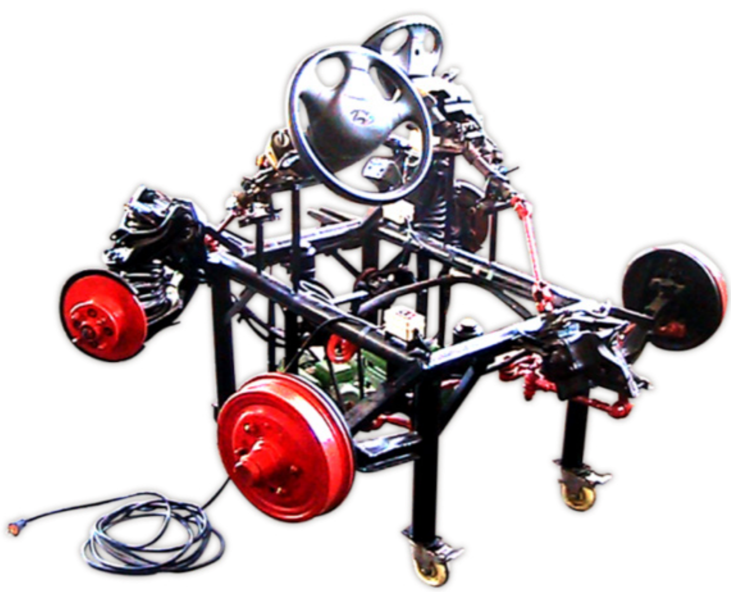

Figure 4. The Power Steering System Trainer

to the respondents. Such similarities in results could be associated with the research methodologies that the former and present researchers have used. This implies that a carefully designed and developed instructional materials would take interest of students and teachers.

Acceptability of the Power Steering System Trainer

Regardless of the care used in their preparation, all types of instructional materials must be evaluated prior to general use (Campbell, 1999). Hence, the instructional materials being presented undergone evaluation of its effectiveness (Table 4).

The t-test of the student's pre-test and post-test results show that there is a significant difference between the performances of the two groups, where the experimental group has a mean score that is almost twice as compared to the mean score of the controlled group. In effect, such statistical result shows that the null hypothesis that states "there is no significant difference between the performance of the control group and the experimental group" is hereby rejected. Such result affirms the findings of Balbin (2015) when he stated that the performance of the students using the newly developed instructional materials (IMs) was better than the performance of the students using the conventional IMs. Hence, it implied that the performance of the students using the newly developed IM (Power System Trainer) is better than the performance of the students using the conventional instructional device. Likewise, it could be deduced that using this trainer as an instructional material provided a better understanding of the topic and enhanced the teaching-learning process.

Table 4. Evaluation of the Power Steering System Trainer in terms of Effectiveness

Indicators	Values
Mean of Controlled	2.7
Mean of Experimental	5.0
Mean Difference	2.3
Degree of Freedom	88
Computed Value	3.08
Critical Value	2.101
Conclusion	Reject H_o

Conclusion and Recommendations

The design of the power steering system trainer is a two-in-one functional instructional material since it included the power recirculating ball-and-rack and pinion steering system in a single unit of instructional device. It is complete with all components for both the two types of steering systems and is useful in simulating the operation, function, construction, and servicing procedures of an automobile power steering system. The construction was made possible by following the predetermined procedure and with the use of available materials in the market. The trainer was very highly acceptable in terms of functionality, mobility, safety, and maintainability. The trainer is a helpful instructional material on automobile power steering discussion. Likewise, the trainer was effective as an instructional material in the teaching-learning process as shown by the performance of the controlled group and experimental group.

With the result of this study, the components of the trainer may be replaced by the parts from the smaller, recent model, and locally available cars to further improve its mobility, safety, maintainability, and functionality. Electric power steering system (EPS) can be used also for another trainer since it is being utilized by small to medium automobile nowadays.

It is also highly recommended that instructors teaching automotive technology subjects must develop similar instructional material using locally available materials to boost the learning process. The school administrator should also allocate a reasonable budget to support the production of such an effective instructional material. The reproduction of this trainer for commercial purposes is also highly recommended.

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journal.bicol-u.edu.ph

References

Balbin, N. B. (2012). Development of an automotive charging system trainer with safety device. International Journal of Mathematics, Engineering & Technology, 3, 44–59. doi: hhp://dx.doi.org/10.7718/iamure.ijmet.v3il.410

Balbin, N. B. (2015) Development of a multi-system automotive engine electrical trainer. International Journal of Mathematics, Engineering & Technology, 11, 108–123. doi: hhp://dx.doi.org/10.7718/iamure.ijmet.v11i1.961

Bernaldez, R. R. (2015). Development of a prototype training device in electrical installation and maintenance: Equipping electrical technology students for Philippine National Competency Assessment. International Journal of Mathematics, Engineering & Technology, 11, 145–171. doi: hhp://dx.doi.org/10.7718/iamure.ijmet.v11i1.963

Campbell, C. (1999). Instructional Materials: Their preparation and evaluation. Journal of Europian Training, 23(2), 57–107.

Crouse, W., & Anglin, D. (2004). Automotive mechanics (10th ed). McGraw-Hill School Publishing Company.

Iwasaki, Y., Fikes, R., Vescovi, M., & Chandrasekaran, B. (1993). How things are intended to work: Capturing functional knowledge in device design. IJCAI, 13, 1516–1522.

Maheshwari, V. K. (2016). Edgar Dale's cone of experience. http://www.vkmaheshwari.com/WP/?p=2332

Mengel, N. S. (1986). The acceptability and effectiveness of textbook material revised using instructional design criteria. Journal of Instructional Development, 9(2), 13–18. doi:10.1007/bf02905209

Mobley, R. (2001). Plant engineer's handbook. Butterworth-Heinemann. https://doi.org/10.1016/B978-075067328-0/50042-2

Nantes, G. (2013). An engine remote control system: A trainer for instruction. Asian Educational Research Association, 3(1), 16–20.