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Instructional Automotive Charging System with Automatic Voltage Regulator and Integrated Circuits

Rene M. Chavez

Abstract: ***This research investigated the effectiveness of the mock-up innovation as instructional material for teaching among the third-year automotive technology students at Bukidnon State University, Malaybalay, Bukidnon, during the first semester of the school year 2018-2019. It highlighted the profile of the students considering: academic status (e.g. regular, irregular); program status (e.g. first course, second course); unit load; family income and size; and major subjects. It also evaluated the pre-test and post-test scores in written and practical examinations on the topics of Test and Repair Wiring/AVR Charging Systems; Test and Repair Wiring/IC Charging Systems; and Servicing Car Batteries, as well as their performance during activities and simulations. External evaluations in written and practical examinations were also done on the 3 topics. Finally, it assessed the effects or influence of all the input and process variables on the output variables of the study with the outcome of a trainer model on a Project Development for the Instructional Trainer Innovation for Automatic Voltage Regulator and Integrated Circuit Charging System. A descriptive research method was used, employing the survey questionnaire and written and practical examinations, to gather the data. Findings revealed the academic and socio-economic profile of the respondents; the results of the pre-and post-test in the written and practical evaluation on the 3 topics where improvements in scores are seen in the post-tests after the utilization of the Trainer Model as instructional materials. However, there were no significant effects of the input variables on the written and practical scores of the respondents.***

Keywords: ***Instructional Automotive Charging System; Automatic Voltage Regulator; Integrated Circuit***

I. INTRODUCTION

The methods of instruction used to teach car service are numerous. These include conventional classroom instruction, manuals, practical shop practices, and computer-based resources. As a result, industrial technology is required to use instructional materials that can simulate, test, and obtain specific data for the operation, specifically in the study of both gasoline and diesel-fueled automobiles and associated components. (Saliside, 2002, [12]) constructed the development of an electrical sequential control device for instructional purposes.

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According to (Balbin, 2012, [3]) an instructional trainer/model improves students' knowledge and abilities in charge of system troubleshooting and installation. The trainer model plays a big role in developing the cognitive and tactile skills of the students. The installation or connection of actual wire circuits presents challenges for automotive technology students, which are frequently caused by specific electrical system component damage (Balbin, 2015, [2]). While discussing the vehicle mock-up model, (Van Hooser, 2010, [15]) asserts that the sort of instructional materials utilized depends on the teaching style and the student's learning preferences. Additionally, according to (Edey and Gomez, 2011, [4]), using the car mock-up model is linked to excellent exam scores as well as favorable attitudes and sentiments among automotive students toward science. Teaching *Automotive Technology* may not be a simple task and may pose difficulties if there is an enormous shortage of books and other instructional devices that can facilitate the acquisition of knowledge and skill development of the learner (Fernandez, 2006, [6]). The automotive electrical system is one of the most complex systems in the vehicle because a single mistake could damage the entire system. That is why the trainer model should be designed carefully to make sure that the learning exercise runs smoothly (Ellington, 1987, [5]). Immersive learning environments called simulations reproduce a situation, event, or place from the current world (Bulger, Mayer, Almeroth, & Blau, 2008, [11]). (Alessi and Trollip, 2001, [1]) emphasized that a simulation gives the student the chance to engage with a representation of a scenario or action that occurs in real life. [10] Simulator are "technology-enabled settings developed to assist learning through immersion, engagement, and adaptable environments that eventually give direction and constructive feedback to the learner," according to (Hartley, 2006, [7]). Simulators, as opposed to traditional textbooks, are said to be better at putting knowledge and ideas to be learned into a real-world context (Taylor & Chi, 2000, [13]). (Scherly, Roux, and Dillenbourg, 2000, [14]) highlighted that simulations can aid in the creation of scenarios that are similar to those that are experienced in real life.

According to (Kirkley and Kirkley, 2005, [9]), simulators might help students "feel more authenticity and realism" and "interact with and participate in a virtual workplace." (Taylor & Chi, 2000, [13]). The benefits of employing simulations in educational contexts are frequently cited as being student involvement and motivation (Kirkley & Kirkley, 2005, [9]).

The beginner learner can better visualize the system depicted in the simulation with the aid of functional diagrams (Jonassen & Hung, 2006, [8]). The study develops automobiles' trainer model charging systems. The charging system is the generating system that keeps the vehicle's battery in a fully charged condition. There are two types of charging systems, namely: The Automatic Voltage Regulator (AVR) and the Integrated Circuit type (IC). The AVR type is generally utilized by old-designed automobiles, while the IC type is used by modern automobiles. Thus, two types of charging systems are utilized in automobiles.

This trainer model would be developed by integrating the two types of charging systems. The hands-on activities for the skills development of the students are based on the Philippine Qualification Framework level and the competencies required by the TESDA for the Automotive Servicing NC2 under the Philippine Technical Vocational Education and Technology (TVET) Competency Assessment and Certification System—ALT723308 (service charging system). This trainer model offers opportunities for the learners to perform actual, hands-on automotive charging system installations.

II. MATERIAL AND METHODS

The research study utilized the descriptive research method, employing the survey questionnaire and written and practical examinations in gathering the data, and it was conducted at Bukidnon State University, Malaybalay City. The respondents of the study are all third-year automotive students taking AT321: Advance Automotive Electrical Systems with the laboratory at Bukidnon State University, who were purposively chosen as the respondents of the study. There was a total of 30 students who participated in this study. Most of the students are regulars, taking the course as first-timers, and carrying a load of 21 to 25 units. A researcher-made survey questionnaire was used in the collection of data in this particular study. The questionnaire looked into the profiles of the respondents in terms of academic status, program status, unit load, family income, family size, and the number of major subjects. The researcher also prepared a test questionnaire for the written examination on *Test and Repair Wiring of Charging System; Servicing AVR Type Alternator; Servicing IC Type Alternator*; and activities like participation and simulation assessments. Likewise, the researcher also made the practical examination in a checklist and rubric format on *Test and Repairing the Wiring of the Charging System; Servicing AVR Type Alternator, and Servicing IC Type Alternator*. These written and practical exams served as pre-test and post-test instruments. The instruments were validated by three experts: The evaluators included one from the industry, one from TESDA, and one from academia. They looked into the content and content accuracy, appropriateness and relevance, and clarity of the materials. All three evaluators find the instrument to have content accuracy, appropriateness and relevance, and clarity. Descriptive statistics such as percentage, frequency count, and weighted mean were used to describe the respondents' scores and responses in written and practical examinations. The t-test was used to test the difference between the pretest and post-test, and regression analysis was used to test the effects of input and process variables on output variables.

A. Designing and Planning

The study is considered a necessity in the hands-on part of explaining the automotive charging system. The proper connection and arrangement of components and terminals were ensured to avoid losing contact and minimize the wire connector. Component terminal symbols were installed to guide the wiring. The design is considered a safety feature in the use of the device. It included protection against short-circuit and emergency shutdown. The frame was made up of locally available materials, preferably round bars, flat bars, and angle bar steel. The simulation board was made of a ply board where the components and connecting terminals are mounted. The base was designed to be attached to the frame vertically for ease of mobility. Matrix 1 shows the materials and tools and their operational function for the trainer model.

Matrix 1 shows the materials and tools and their operational function for the trainer model.

Materials/Tools	Functions
Ignition switch	Use to as the main switch of the entire system.
Alternator IC Type	Driven by motor in demonstration.
Alternator AVR Type	Driven by motor in demonstration on AVR System
Voltmeter	Use to measure voltage present in the circuit.
Motor	Use to drive both alternators in two systems.
Pulley	The belt's carrier
Wiring harness	Electrical path throughout the circuit
Binding post	Use as the hole for attaching and detaching electrical wires in the circuit.
Ammeter	Use for measuring electron flowing within the circuit.
Electrical tape	Use to insulate electrical wires after splicing.
Cart wheel	Use as wheels of trainer model so it can be carried easily
Angle bar	Use as the frame of the trainer model.
Welding rod	Use for assembling the body and connecting metal
Cutting disc	Use for cutting metals
Ply-board	Use electrical circuit board frame and for tool compartment
Hack saw blade	Use for cutting metal and ply-board
Acrylic and Enamel paint with paint brush	Use for painting trainer model and to metal frame.

B. Mechanical Design

The development of Instructional Trainer Innovation for Automatic Voltage Regulator and Integrated Circuit Charging System will be composed of an electric motor as a driving device using 220 volts (AC) with one (2) horsepower (hp) output motor. The AVR-type alternator and IC-type alternator serve as a generator set in the charging system of the trainer model. The wires, switches, circuit breakers, AVR, and alternator are part of the control device. The voltmeter, ammeter, light indicators, and ignition switch are the components that will be connected using the biding post (male) and binding post (female) as a connector.

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An angle bar serves as a bar where the circuit board is supposed to be located above, and a platform is made of a 3/16" by 1" angle bar and the structural frame is made of 3/16" by 2" steel angle bars. The plywood board stands for the cover of a metal frame with a size of 34" by 4' by 8' to fabricate one set of the structural frame. As shown, the metal frame is equipped with an IC-type alternator, an AVR-type alternator, an AC motor, a frame as a base, a circuit board assembly, and a rubber wheel for easy mobility anywhere in the laboratory room. This is a solid made of black iron (angle bar and plate). The bottom part of the trainer serves as a compartment for the tools. This is made up of two openings that allow the tools to easily enter and exit the compartment. The trainer provides highly organized wiring, educationally formed and technologically developed for automotive students. Moreover, the trainer can be used safely for further practical activities.

Figure 1: Perspective Design of the trainer model

C. Circuit Design

In figures 2 and 3, the automotive electrical system contains two (2) different circuits, e.g., an Integrated circuit and an Alternator Voltage Regulator circuit. Electrical power and control signals must be parallel to the electrical motor to make them safe for the users or learners. This goal is accomplished through careful circuit design, prudent component selection, and proper training.

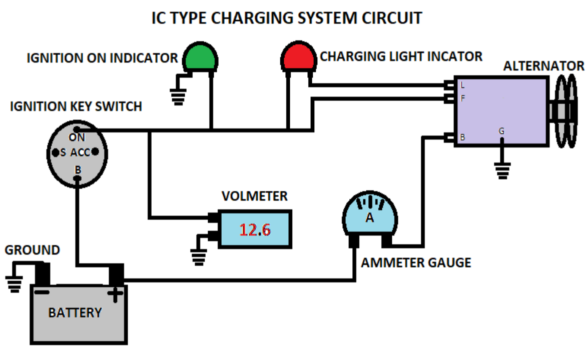

Figure 2: IC-type charging system circuit diagram for the trainer model

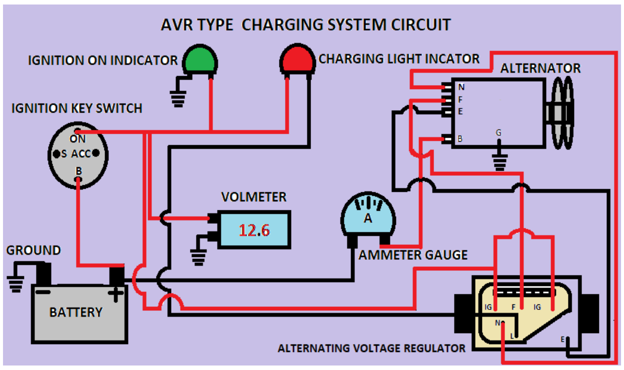

Figure 3: AVR type charging system circuit diagram for the trainer model.

D. Prototype of the Trainer Model

Innovative Instructional Trainer for Automatic Voltage Regulator and Integrated Circuit Charging System. This is a multifunction trainer simulator for the two types of charging system principles. This trainer model is designed for six (6) operational purposes: 1. Electrical circuit for an IC charging system 2.AVR-type charging system electrical circuit 3. Anatomy of a two-charging system 4. A cabinet for storing tools and other materials 5. A rotating motor safety guard 6. Movable design. The proper connection and arrangement of components and terminals were ensured to avoid losing contact and minimize the wire connector. Component terminal symbols were installed to guide the wiring. The design is considered a safety feature in the use of the device. It included protection against short-circuit and emergency shutdown. The frame was made up of locally available materials, preferably steel bar, flat bar, and angle bar. The simulation board was made of a ply board where the components and connecting terminals are mounted. The base was designed to be attached to the frame vertically for ease of mobility.

Figure 4: Isometric view

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Figure 5: Front view

III. RESULTS AND DISCUSSION

A. Respondent's Profile

The data shows that the majority of the respondents are regular students. This course is also the respondent's first course. However, the data also shows that there were irregular students. The data shows that the majority of the respondents are regular students. This course is also the respondent's first course. However, the data also shows that there were irregular students. Because the three irregular students took this subject as their second course, they have already accumulated subjects and thus have a lower unit load. The highest number of frequencies in the unit load is from 25 to 26. This is followed by 21–22-unit loads. In terms of the number of major subjects, the data shows that the majority of the student's load in major subjects is 3. The data further shows that 79% of the respondents belong to a family whose monthly income is between 10,001 and 20,000. Also, 68% of the respondents' family size is from 4 to 6 siblings in the family. The data further shows that there is an extreme number of family sizes, such that three percent (3%) have a family size of 1-3 siblings in the family, while there is also three percent (3%) that have 13 or above siblings in the family. Given the respondents' family monthly income, they are considered *average*. The average family income in 2015 was assessed to be P 22,000 per month by the National Statistics Office (2016). According to the study findings, Filipino households make an average yearly family income of about 267,000 pesos. The average yearly family expenditure during the same year was 215,000 pesos, in contrast. Consequently, an average Filipino household saves 52,000 pesos annually.

Table 2: Distribution of the Respondents' Profile

Respondents Profile in terms of:	Specifications	Frequency	Percentage
Academic Status	Regular	31	91.18%
	Irregular	3	8.82%
	Total	34	100.00%
Program Status	First Course	31	91.18%
	Second Course	3	8.82%
	Total	34	100.00%
Number of Unit Load	27 and up	1	2.94%
	25-26	15	44.12%
	23-24	5	14.71%
	21-22	11	32.35%
	20 and below	2	5.88%
	Total	34	100.00%
Family monthly Income	30,0001 and above	2	5.88%
	20,001-30,000	2	5.88%
	10,001-20,000	15	44.12%
	5,0001-10,0000	12	35.29%
	5,000 and below	3	8.82%
	Total	34	100.00%
Family Size	13 and above	1	2.94%
	10-12	2	5.88%
	7-9	7	20.59%
	4-6	23	67.65%
	1-3	1	2.94%
	Total	34	100.00%
Number of Major Subjects	4	4	11.76%
	3	19	55.88%
	2	11	32.35%
	Total	34	100.00%

B. Respondents' pre-test scores in the written exams

Table 4 presents the distribution of the frequency, percentage, mean, and standard deviation of the respondents on the pretest results of the test and repair of the Alternating Voltage Regulator (AVR) System. The data shows that the majority of ninety-one percent (91%) of respondents' pre-test on the test and repair Alternating Voltage Regulator (AVR) system *is from* poor to fair. The overall rating is *poor* (mean = 4.41). The standard deviation of 1.23 indicates that the respondents' pre-test on the test and the repaired Alternating Voltage Regulator (AVR) system varied a lot from each other.

Table 3: Distribution of Frequency, Percentages, Mean, Standard Deviation, and Percentage of Correct Responses of Respondents Pre-test on Alternating Voltage Regulator (AVR) System Testing and Repair

Description	Alternator Voltage Regulator (AVR)	Frequency	Percentages
Very Good	09-Oct	0	0.00%
Good	07-Aug	1	2.94%
Fair	05-Jun	17	50.00%
Poor	03-Apr	14	41.18%
Very Poor	0-2	2	5.88%

Mean: 4.41; Standard Deviation 1.23

Table 5 shows the distribution of the frequency, percentages, mean, and standard deviation of the respondent's pretest on the Test and repair Integrated Circuit (IC) System Alternator. The data shows that the majority of seventy-nine percent (79%) of respondents' pretest on testing and repairing Integrated Circuit (IC) System Alternators is from *very poor to poor*. The overall rating is *poor* (mean = 3.15). The standard deviation of 1.79 indicates that the respondents' pretest on Integrated Circuit (IC) System Alternators varies a lot from each other.

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Table 4: Distribution of the frequency, percentages, mean, and standard deviation of the respondent's pretest on the Test and repair Integrated Circuit (IC) System Alternator.

Description	Integrated Circuit (IC) Charging System	Frequency	Percentage
Very Good	9-10	0	0.00%
Good	7-8	1	2.94%
Fair	5-6	6	17.65%
Poor	3-4	15	44.12%
Very Poor	0-2	12	35.29%

Mean 3.15; Standard Deviation 1.79

Table 6 shows the frequency, percentages, mean, and standard deviation distribution of the respondents' pretest on servicing car batteries. The data shows that the majority of fifty-nine percent (59%) of respondents' pretest on servicing car batteries is *fair*. The overall rating is considered *fair* (mean = 4.65). The standard deviation of 1.54 indicates that the respondents' service car batteries vary a lot from each other.

Table 5: Distribution of Frequency, Percentages, Mean, and Standard Deviation of the respondents' Pretest on Servicing Car Batteries.

Description	Servicing Car Battery	Frequency	Percentages
Very Good	9-10	0	0.00%
Good	7-8	3	8.82%
Fair	5-6	20	58.82%
Poor	3-4	6	17.65%
Very Poor	0-2	5	14.71%

Mean 4.65; Standard Deviation 1.54

C. Respondents' pre-test scores in the self-practical evaluation

Table 7 presents the distribution of the frequency, percentage, mean, and standard deviation of the respondents on the pre-practical self-evaluation of the test and repair of the Alternating Voltage Regulator (AVR) System. The data shows that the majority of fifty-five percent (55%) of respondents' pre-practical self-evaluation on the test and repair alternating voltage regulator (AVR) system is *poor.* The overall rating is also *poor* (mean = 3.35). The standard deviation of 1.23 indicates that the respondents' pre-practical self-evaluation on repairing Alternating Voltage Regulator (AVR) systems varies a lot from each other.

Table 6: Distribution of the Frequency, Percentages, Mean, and Standard Deviation of the respondents on the pre-practical self-evaluation of the test and repair of the Alternating Voltage Regulator (AVR) System.

Description	Alternating Voltage Regulator (AVR) System	Frequency	Percentages
Very Good	9-10	0	0.00%
Good	7-8	0	0.00%
Fair	5-6	7	20.59%
Poor	3-4	19	55.88%
Very Poor	0-2	8	23.53%

Mean 3.35; Standard Deviation 1.23

Table 8 shows the distribution of the frequency, percentages, mean, and standard deviation of the respondents' pre-practical self-evaluation on the Test and repair Integrated Circuit (IC) System Alternator. The data shows that the majority of fifty-six percent (56%) of respondents' pre-practical self-evaluation on the test and repair of the Integrated Circuit (IC) System Alternator is *poor*. The overall rating is also *poor* (mean = 3.53). The standard deviation of 1.31 indicates that the respondents' pre-practical self-evaluation on the test and repair of Integrated Circuit (IC) System alternators varies a lot from each other.

Table 7: Distribution of the frequency, percentages, mean, and standard deviation of the respondents' pre-practical self-evaluation on the Test and repair of Integrated Circuit (IC) System Alternator

Description	Integrated Circuit (IC) System Alternator	Frequency	Percentages
Very Good	9-10	0	0.00%
Good	7-8	0	0.00%
Fair	5-6	10	29.41%
Poor	3-4	19	55.88%
Very Poor	0-2	5	14.71%

Mean 3.53; Standard Deviation 1.31

Table 9 shows the frequency, percentages, mean, and standard deviation distribution of the respondents' pre-practical self-evaluation on servicing car batteries. The data shows that the majority of fifty-six percent (56%) of respondents' pre-practical self-evaluation on servicing car batteries is *poor*. The overall rating is also *poor* (mean = 3.32). The standard deviation of 1.17 indicates that the respondents' pre-practical self-evaluation on servicing car batteries varies a lot from each other.

Table 8: Distribution of frequency, percentages, mean, standard deviation of the respondents' pre-practical self-evaluation on Servicing Car Battery

Description	Servicing Car Battery	Frequency	Percentages
Very Good	9-10	0	0.00%
Good	7-8	0	0.00%
Fair	5-6	7	20.59%
Poor	3-4	19	55.88%
Very Poor	0-2	8	23.53%

Mean 3.32; Standard Deviation 1.17

D. Performance of the Respondents in Activities and Simulations

Table 10 shows the distribution of the frequency, percentages, mean, and standard deviation of the respondents' written and quiz simulation scores on the test and repair wiring/AVR charging system. While Table 11 shows the distribution of the percentage of correct responses to respondents' practical, quiz simulation scores on test and repair wiring/AVR charging systems, the data shows that fifty-nine percent (59%) of respondents' written Quiz Simulation Scores on the Test and Repair Wiring/AVR Charging System are *fair*. The overall rating is also *fair* (mean = 3.15). The standard deviation of 0.70 indicates that the respondents' Quiz Simulation Scores on Test and Repair Wiring/AVR Charging System still vary from each other.

Table 9: Distribution of the Frequency, Percentages, Mean, Standard Deviation of the respondents' written, Quiz Simulation Scores on Test and Repair Wiring/ AVR charging System

Description	Test and Repair Wiring/ AVR charging System	Frequency	Percentages
Very Good	5	1	2.941%
Good	4	8	23.53%
Fair	3	20	58.82%
Poor	2	5	14.71%
Very Poor	1	0	0.00%

Mean 3.15; Standard Deviation 0.70

Table 11 shows that fifty percent (50%) of respondents' practical and quiz simulation scores on test and repair wiring/AVR charging systems are from fair to good. The overall rating is *fair* (mean = 3.56). The standard deviation of 0.86 indicates that the respondent's practical, quiz simulation scores on test and repair wiring/AVR charging system vary from each other.

Table 10: Distribution of the Percentage of Correct responses of respondents' practical, Quiz Simulation Scores on Test and Repair Wiring/AVR Charging System

Description	Test and Repair Wiring/ AVR charging System	Frequency	Percentages
Very Good	5	6	17.647%
Good	4	9	26.47%
Fair	3	17	50.00%
Poor	2	2	5.88%
Very Poor	1	0	0.00%

Mean 3.56; Standard Deviation 0.86

Table 12 shows the distribution of the frequency, percentages, mean, and standard deviation of the respondents' written and quiz simulation scores on the Test and Repair Wiring/IC Charging System. The data shows that the majority of fifty percent of respondents' written Quiz Simulation Scores on Test and Repair Wiring/IC Charging System were *good* and 9% were *very good.* The overall rating is also *fair* (mean = 3.62). The standard deviation of 0.74 indicates that the respondents' Quiz Simulation Scores on Test and Repair Wiring/IC Charging System still vary from each other.

Table 11: Distribution of the Frequency, Percentages, Mean, Standard Deviation of the respondents' written, Quiz Simulation Scores on Test and Repair Wiring/IC charging System

Description	Test and Repair Wiring/IC charging System	Frequency	Percentages
Very Good	5	3	8.824%
Good	4	17	50.00%
Fair	3	12	35.29%
Poor	2	2	5.88%
Very Poor	1	0	0.00%

Mean 3.62; Standard Deviation 0.74

Table 13 data shows that fifty-three percent (53%) of respondents' practical and quiz simulation scores on the Test and Repair Wiring/IC Charging System were *good* and 21% were *very good*. The overall rating is almost *good* (mean = 3.91). The standard deviation of 0.75 indicates that the respondent's practical, quiz simulation scores on test and repair wiring/IC charging systems still vary from each other.

Table 12: Distribution of the Percentage of Correct responses of respondents' practical, Quiz Simulation Scores on Test and Repair Wiring/IC charging System

Description	Test and Repair Wiring/IC charging System	Frequency	Percentages
Very Good	5	7	20.588%
Good	4	18	52.94%
Fair	3	8	23.53%
Poor	2	1	2.94%
Very Poor	1	0	0.00%

Mean 3.91; Standard Deviation 0.75

Table 14 shows that fifty-eight percent of the respondents' written Quiz Simulation Scores on servicing car batteries are *good* and 26% are *very good*. The overall rating is *good* (mean = 4.12). The standard deviation of 0.64 indicates that the respondent's practical and quiz simulation scores on servicing car batteries are closer to each other.

Table 13: Distribution of the Frequency, Percentages, Mean, Standard Deviation of the respondents' written, Quiz Simulation Scores on Servicing Car Battery

Description	Servicing Car Battery	Frequency	Percentages
Very Good	5	9	26.471%
Good	4	20	58.82%
Fair	3	5	14.71%
Poor	2	0	0.00%
Very Poor	1	0	0.00%

Mean 4.12; Standard Deviation 0.64

The data shows that fifty percent (50%) of respondents' practical Quiz Simulation Scores on servicing car batteries are good and 29% are very good. The overall rating is *good* (mean = 4.09). The standard deviation of 0.71 indicates that the respondent's practical and quiz simulation scores on servicing car batteries still vary from each other.

Table 14: Distribution of the Percentage of Correct responses of respondents' practical, Quiz Simulation Scores on Servicing Car Battery

Description	Servicing Car Battery	Frequency	Percentages
Very Good	5	10	29.412%
Good	4	17	50.00%
Fair	3	7	20.59%
Poor	2	0	0.00%
Very Poor	1	0	0.00%

Mean 4.09; Standard Deviation 0.71

E. Respondents' external evaluation scores in written Posttest Examination and practical examination score

Table 16 illustrates the distribution of frequency, percentages, mean, and standard deviation of the respondent's written post-test on the test and repaired Alternating Voltage Regulator (AVR) System. The data shows that the majority of fifty-nine percent (59%) of respondents wrote a post-test on the test and the repaired Alternating Voltage Regulator (AVR) system is *very good*. The overall rating is *good* (mean = 8.59). The standard deviation of 1.29 indicates that the respondents wrote a post-test on the test and the repaired Alternating Voltage Regulator (AVR) system varied from each other.

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Table 15: Distribution of frequency, percentages, mean, standard deviation of the respondents written Post-test on Test and repair Alternating Voltage Regulator (AVR) System

Description	Alternator Voltage Regulator (AVR)	Frequency	Percentages
Very Good	9-10	20	58.8%
God	7-8	12	35.3%
Fair	5-6	2	5.9%
Poor	3-4	0	0.0%
Very Poor	0-2	0	0.0%

Mean: 8.59; Standard Deviation 1.29

As observed from the table, there is an increase in the percentage of students obtaining correct scores on the post-test after the introduction of innovative instructional materials. While in the pretest, there were no students who got a perfect score, in the posttest, 58% obtained the correct responses to the written test in this lesson on repairing Alternating Voltage Regulator (AVR) systems.

Table 16: Comparative Results of the pre- and posttest written exam in Test and repair Alternating Voltage Regulator (AVR) System

Description of Ratings	Pretest on Test and repair Alternating Voltage Regulator (AVR) System		Posttest on Test and repair Alternating Voltage Regulator (AVR) System	
	frequency	percent	frequency	percent
Very Good	0	0.00%	20	58.8%
Good	1	2.94%	12	35.3%
Fair	17	50.00%	2	5.9%
Poor	14	41.18%	0	0.0%
Very Poor	2	5.88%	0	0.0%

Table 17 shows the distribution of frequency, percentages, mean, and standard deviation of the respondent's written post-test on the test and repair of the Integrated Circuit (IC) System Alternator. As observed in the table, the overall rating is *good* (mean = 8.18). The standard deviation of 1.49 indicates that the respondents have written a post-test on the test and the repair of the Integrated Circuit (IC) System Alternator varies a lot from each other.

Table 16.2: Distribution of frequency, percentages, mean, standard deviation of the respondents written Post-test on Test and repair Integrated Circuit (IC) System Alternator

Description	Integrated Circuit (IC) Charging System	Frequency	Percentage
Very Good	9-10	15	44.1%
Good	7-8	15	44.1%
Fair	5-6	4	11.8%
Poor	3-4	0	0.0%
Very Poor	0-2	0	0.0%

Mean 8.18; Standard Deviation 1.49

As reflected in the pre-and post-test results, the inclusion of the innovations in the lesson has brought about better results in the written examination results of the students. The good and very good percentages of obtaining correct responses dominated the scenario. There were no responses anymore from the poor and very poor percentages.

Table 17: Pre- and Post-Test Written Exam Results in Test and Repair Wiring/IC Charging System

Description of Ratings	Pretest on Test and Repair Wiring/IC charging System		Posttest on Test and Repair Wiring/IC charging System	
	frequency	percent	frequency	percent
Very Good	0	0.00%	15	44.1%
Good	1	2.94%	15	44.1%
Fair	6	17.65%	4	11.8%
Poor	15	44.12%	0	0.0%
Very Poor	12	35.29%	0	0.0%

Table 18 shows the frequency, percentages, mean, and standard deviation distribution of the respondent's written post-test on servicing car batteries. The data shows that seventy-six percent of respondents' post-test written on servicing car batteries is *good*. The overall rating is *good* (mean = 7.62). The standard deviation of 0.92 indicates that the respondent's post-test on servicing car batteries varies a lot from each other.

Table 17.2: Distribution of frequency, percentages, mean, and standard deviation of the respondent's written post-test on servicing car batteries

Description	Servicing Car Battery	Frequency	Percentages
Very Good	9-10	4	11.8%
Good	7-8	26	76.5%
Fair	5-6	4	11.8%
Poor	3-4	0	0.0%
Very Poor	0-2	0	0.0%

Mean 7.62; Standard Deviation 0.92

As reflected in Table 18.2, the percentages of obtaining correct responses have improved in the post-test after the innovative instructional material was introduced. The scores were primarily *good*, and there were no poor or *very poor* results.

Table 18: Comparative Results of the pre- and posttest written exam in car servicing

Description of Ratings	Pretest on *car servicing*		Posttest on *car servicing*	
	frequency	percent	frequency	Percent
Very Good	0	0.00%	4	11.8%
Good	3	8.82%	26	76.5%
Fair	20	58.82%	4	11.8%
Poor	6	17.65%	0	0.0%
Very Poor	5	14.71%	0	0.0%

F. Respondents' external evaluation scores in the practical examination score

Table 19 shows the frequency, mean, and standard deviation distribution of the respondents' post-practical experts' evaluation of the test and repaired Alternating Voltage Regulator (AVR) System. The data shows that seventy percent (70%) of respondents' post-practical experts' evaluation of the *test and repair Alternating Voltage Regulator (AVR)* system is *very good*. The overall rating is also *very good* (mean = 9.14). The standard deviation of 0.85 indicates that the respondents' post-practical experts' evaluation of the repaired *Alternating Voltage Regulator (AVR) system* varies from each other.

Table 18.2: Distribution of Frequency, Percentages, Mean, Standard Deviation and Percentage of the respondents' Post-practical experts' evaluation on Test and repair Alternating Voltage Regulator (AVR) System

Description	Alternating Voltage Regulator (AVR) System	Frequency	Percentages
Very Good	9-10	24	70.59%
Good	7-8	10	29.41%
Fair	5-6	0	0.00%
Poor	3-4	0	0.00%
Very Poor	0-2	0	0.00%

Mean 9.14; Standard Deviation 0.85

Table 19.2 shows that the post-test results from the external evaluation showed a *very good* performance from the 20 respondents and a *good* performance from the other 12 respondents. There was no poorer or very poor performance from the respondents, indicating that the introduction of innovative instructional materials could enhance their learning in this area.

Table 19: Comparative Results of the pre- and posttest in the external evaluation scores in the practical examination on the Test and repair Alternating Voltage Regulator (AVR) System

Description of Ratings	Pretest on *external evaluation scores in the practical examination on the Test and repair Alternating Voltage Regulator (AVR) System*		Posttest on *external evaluation scores in the practical examination on the Test and repair Alternating Voltage Regulator (AVR) System*	
	frequency	percent	frequency	percent
Very Good	0	0.00%	20	58.8%
Good	0	0.00%	12	35.3%
Fair	7	20.59%	2	5.9%
Poor	19	55.88%	0	0.0%
Very Poor	8	23.53%	0	0.0%

Table 20 shows the distribution of frequency, mean, and standard deviation of the respondents' post-practical experts' evaluation of the test and repair of the Integrated Circuit (IC) System Alternator. The data shows that sixty-five percent (65%) of respondents' post-practical experts' evaluation of the Test and Repair Integrated Circuit (IC) System Alternator was *very good* and 35% was *good*. The overall rating is also *very good* (mean = 9.09). The standard deviation of 0.90 indicates that the respondents' post-practical experts' evaluation of the Test and Repair Integrated Circuit (IC) System Alternator varies from each other.

Table 19.2: Distribution of Frequency, Percentages, Mean, Standard Deviation of respondents' Post-practical experts' evaluation on Test and repair Integrated Circuit (IC) System Alternator

Description	Integrated Circuit (IC) System Alternator	Frequency	Percentages
Very Good	9-10	22	64.71%
Good	7-8	12	35.29%
Fair	5-6	0	0.00%
Poor	3-4	0	0.00%
Very Poor	0-2	0	0.00%

Mean 9.09; Standard Deviation 0.90

As observed from the table, the good and very good scores occupied 44% of both categories, indicating that the post-test results showed much improvement from the pretest results. This is an indication that the introduction of innovation in teaching Automotive has facilitated their learning in this area.

Table 20: Comparative Results of the pre- and posttest on the external evaluation scores in the practical examination on the Test and repair Integrated Circuit (IC) System Alternator

Description of Ratings	Pretest on *external evaluation scores in the practical examination on the Test and repair Integrated Circuit (IC) System Alternator*		Posttest on *external evaluation scores in the practical examination on the Test and repair Integrated Circuit (IC) System Alternator*	
	frequency	percent	frequency	percent
Very Good	0	0.00%	15	44.1%
Good	0	0.00%	15	44.1%
Fair	10	29.41%	4	11.8%
Poor	19	55.88%	0	0.0%
Very Poor	5	14.71%	0	0.0%

Table 21 shows the distribution of the frequency, percentages, mean, standard deviation of respondents' Post-practical experts' evaluation on Servicing Car Battery. The data shows that majority or seventy nine percent (79%) of respondents' Post-practical experts' evaluation on Servicing car batteries are *very good*. The overall rating is also *very good* (mean = 9.44). The standard deviation of 0.82 indicates that the respondents' post-practical experts' evaluation of Servicing Car Batteries varies a lot from each other.

Table 20.2: Distribution of the Frequency, Percentages, Mean, Standard Deviation of respondents' Post-practical experts' evaluation on Servicing Car Battery

Description	Servicing Car Battery	Frequency	Percentages
Very Good	9-10	27	79.41%
Good	7-8	7	20.59%
Fair	5-6	0	0.00%
Poor	3-4	0	0.00%
Very Poor	0-2	0	0.00%

Mean 9.44; Standard Deviation 0.82

As shown in Table 21.2, 76% obtained good scores in this area. The introduction of the innovations using the instructional materials in this study has facilitated the learning of the students. This could be because the students have the actual hands-on materials. Learning by doing could help students retain what they learned, especially since most of their senses are applied in the process.

Table 21: Comparative Results of the pre- and posttest on external evaluation scores in the practical examination on servicing car battery

Description of Ratings	Pretest on *external evaluation scores in the practical examination on servicing car battery*		Posttest on *external evaluation scores in the practical examination on servicing car battery*	
	frequency	percent	frequency	percent
Very Good	0	0.00%	4	11.8%
Good	0	0.00%	26	76.5%
Fair	7	20.59%	4	11.8%
Poor	19	55.88%	0	0.0%
Very Poor	8	23.53%	0	0.0%

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G. Effects on students' profiles (Input) and the written tests/activities and simulation (Process) on the external evaluation/written posttest (Output)

Table 22 illustrates the multiple linear regression analysis between the whole set of input and process variables and the respondents' post-test written scores. It is shown that except for the variable on "*number of major subjects,"* the effects/influences are not significant for most of the variables.

Table 22: Multiple linear regression analysis between the whole set of input and process variable and respondent's post-test written score

Input and Process Variable	Regression coefficient	P- Value	T- Value
Pretest score	0.017	0.908	0.117
Academic Status	0.573	0.330	0.994
Program Status	0.795	0.190	1.346
Number of Unit Load	0.336	0.367	0.919
Number Major Subject	0.794	**0.009***	2.820
Family income	-0.057	0.483	-0.712
Family size	0.007	0.927	0.093
Formative quiz	0.307	0.685	0.411

NS Not significant * *Significant*
Constant: 4.87 Adjusted R: 0.13 F- Value: 1.62
P-value: 0.166
Significance Level: Not significant
Regression model: $\hat{y} = mx + b$

The written post-test scores of respondents increase by 0.017 points for every unit that their pre-test scores rise. However, it has a negligible impact.

The post-test writing score of respondents increases by 0.573 points for every level rise in their academic level (from irregular to regular). The impact is negligible, though.

The post-test writing score of respondents increases by 0.795 points for every unit improvement in respondents' program level (from the second to the first course). However, it has a negligible impact.

The post-test writing score of respondents increases by 0.336 points for every unit increase in the respondents' unit load. However, it has a negligible impact.

The post-test writing scores of respondents improve by 0.794 points for every 100-unit increase in the number of key subjects reported by respondents. However, the impact is quite important.

The post-test writing score of respondents decreases by 0.057 for every unit rise in respondents' household income. However, it has a negligible impact.

The post-test writing score of respondents increases by 0.007 for each unit that the respondents' families grow. However, it has a negligible impact.

There is a 0.307-point rise in the post-test writing score for every unit increase in the respondents' formative quiz. However, it has a negligible impact.

The table demonstrates that the regression's findings are not noteworthy. The null hypothesis is thus accepted. This means that the respondents' post-test writing scores were unaffected significantly by their pretest results on the formative exam, academic status, program status, number of unit loads, family income, and family size.

However, the variable on the *number of major subjects* has a highly significant effect on respondents' post-test written scores. This means that if the respondent has a more major subject, there is a high probability that the respondent's post-test written score is also high.

The adjusted coefficient of multiple determination has a value of 0.13, meaning that variations in the pretest score, academic status, program status, number of unit's load, family income, family size, and formative quiz account for 13% of the variation in the post-test written results of the respondents. Other factors or causes can account for the remaining 87% of the total.

Table 23: Multiple linear regression analysis between the whole set of input and process variable and respondents score from experts' practical evaluation

Input and Process Variable	Regression coefficient	P- Value	T- Value
Pretest score	0.099	0.316	1.023
Academic Status	0.179	0.644	0.468
Program Status	0.160	0.686	0.409
Number of Unit Load	-0.068	0.781	-0.280
Number Major Subject	0.117	0.538	0.624
Family income	0.024	0.656	0.450
Family size	-0.036	0.494	-0.694
Formative quiz	0.059	0.906	0.120

NS Not significant * *Significant*
Constant : 9.21
Adjusted R : 0.19
F- Value: 0.317
P-value: 0.951
Significance Level: Not significant
Regression model: $\hat{y} = mx + b$

There is a comparable rise of 0.099 in respondents' scores from experts' practical evaluations for every unit increase in respondents' pre-test scores. However, it has a negligible impact.

The ratings from the experts' practical evaluation of the respondents improve by 0.179 for every unit increase in the respondents' academic standing (from irregular to regular). However, it has a negligible impact.

There is a 0.160 rise in respondents' ratings from experts' practical evaluation for every unit improvement in respondents' program status (from the second course to the first course). However, it has a negligible impact.

There is a commensurate decline of 0.068 in respondents' ratings from experts' practical evaluation for every unit increase in respondents' unit load. However, it has a negligible impact. There is a commensurate rise of 0.117 in respondents' scores from experts' practical evaluation for every unit increase in respondents' number of major topics. However, it has a negligible impact.

According to the practical judgment of specialists, there is a commensurate fall of 0.024 in the respondents' ratings for every unit rise in family income. However, it has a negligible impact. There is a commensurate loss of 0.036 in the respondents' scores from the practical evaluation of experts for every unit increase in the respondents' family size. However, it has a negligible impact.

There is a comparable rise of 0.059 in respondents' scores from the expert's practical evaluation for every unit increase in the formative quiz scores of respondents. However, it has a negligible impact. The table demonstrates that the regression's findings are not noteworthy. We accept the null hypothesis. This shows that the pretest results on the respondents' scores from the expert's practical evaluation had no discernible impact on the pretest results on the respondents' academic status, program status, number of unit loads, number of main subjects, family income, family size, and formative quiz. The adjusted coefficient of multiple determination has a value of 0.19, meaning that variations in the pretest score, academic status, program status, number of units loaded, family income, family size, and formative quiz account for 19% of the total variation in respondents' scores from the expert's practical evaluation. Other factors or causes can account for the remaining 81% of the total.

IV. CONCLUSION

From the findings of the study, the following conclusions are drawn:

1. The profile of the respondents in terms of their academic status, program status, and the number of unit loads are ideal for their course in automotive.
2. Since the students' pre-test scores in the written examinations and practical examinations are poor, they would need innovative instructional materials to facilitate their learning of the automotive course.
3. Since the performance of the students during the activities and simulations on the pre-practical self-evaluation revealed that these were poor, they would need innovative instructional materials to enhance their skills in these topics.
4. The overall external evaluation in the post-test written examination showed that the external evaluation scores are good and, in the post-test, practical examination the external evaluation scores are very good. Therefore, the Instructional Trainer's Innovation of an Automatic Voltage Regulator and Integrated Circuit Charging System is effective in improving students' performance.
5. The pre-test written scores and the expert's practical evaluation of the variables in this study had no significant effect on respondents' post-test written scores, therefore these could not influence the results of their performance in the automotive course.

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AUTHORS PROFILE

Dr. Rene M. Chavez, honed himself as a professional automotive technician, educator, researcher, and innovator. He started his career in the academe in 2012. When he entered the institution, he saw that there were no instructional materials for automotive students to be utilized for instruction. Due to his initiative, he created instructional mock-ups and modules for students to learn how to repair vehicles. He was a part-time instructor at that time. He spends almost all his time creating instructional devices and books. Because of his hard work and determination, he accomplished twelve (12) instructional materials, both mock-ups and modules. These instructional materials were used by the automotive students up to the present day. In his 9 years and 9 months of government service, he was able to perform consistently and demonstrate excellence in his work. He even worked beyond the regular hours that were required by the government to make innovations that could be utilized by the students. As a matter of fact, he has risen from being an instructor in automotive technology in 2012, to a chairperson of the automotive technology department in 2021 because of his hard work, dedication, and integrity towards his work. Before Dr. Chavez engaged in the academic profession, he was already an inventor and owned several businesses, like an automotive repair shop. He also assembled passenger jeepneys. In addition, he is the designer of the first aerodynamic passenger jeepney in northern Mindanao. In 2008, he invented the Oxygen 20, a gasoline fuel saver that helps drivers and operators save fuel.

Dr. Chavez finished his Bachelor of Science in Automotive Mechanical Technology (BSATM) major in Automotive Mechanical Technology in 2012 at the Mindanao University of Science and Technology in Cagayan de Oro City. He completed his Master of Arts (MA) in Technician Teacher Education (MTTE) major in Automotive Technology in 2017 at the University of Science and Technology of Southern Philippines. He finished his doctorate degree (with dissertation) in Technology Management (Ph.D. TM) this year (2022) at Cebu Technological University, Cebu City.