



Development of an arduino uno-based on-board diagnostic II trainer for gasoline electronic fuel injection system

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Abstract

This study aimed to examine the usability and cost-benefit analysis of an Arduino Uno-based On-Board Diagnostic II (OBD II) Trainer for Gasoline Electronic Fuel Injection (EFI) System in automotive technology. The study focused on evaluating the trainer's functionality, ease of use, interface design, reliability, maintainability, safety, flexibility, and acceptability. The 20 academic and industrial experts answered a series of evaluation sheets that was adapted from Cardino and Namoco (2016) [8]. The data obtained from product testing to evaluation were analyzed using descriptive analysis. The study specifically concentrated on creating an OBD-II trainer that could be utilized for teaching and learning in the automotive classroom, as well as, to discover and understand the pros about gasoline electronic fuel injection electronic management systems using a local area network. The findings of this study revealed that Arduino Uno-based On-Board Diagnostic II (OBD II) Trainer for Gasoline Electronic Fuel Injection (EFI) System in automotive technology could be considered as a possible method for teaching automotive technology students. Furthermore, the comprehensive cost-benefit analysis of the study showed the OBD Trainer as a sound investment for the organization. The cost-benefit analysis weighed the initial and ongoing cost against the potential efficiency gains, cost savings, and other benefits associated with having an OBD Trainer. Together with this, the OBD Trainer was found to be significant for skill development and staying current with advancements in automotive technology. It provided a platform for hands-on learning, making it an essential tool for anyone involved in automotive diagnostics and repair.

Keywords: Arduino uno on-board diagnostic II trainer, gasoline electronic fuel injection (EFI) System, educational trainer, automotive technology

Introduction

Automotive Technology is undergoing rapid change. Learners and Instructors are expected to adapt to the rate at which automotive technology advances. They must both remain current and continuously expand their knowledge. Bachelor of Science in Autotronics is an innovative bachelor's degree program in automotive servicing that enables students to investigate the complex studies being incorporated into contemporary vehicles. Students are introduced to advanced technologies and their operations, powered by various mechatronics devices. These mechatronics devices are computer-controlled with the help of microcontrollers. According to studies, the majority of State Universities and Colleges (SUCs) lack the equipment, facilities, and personnel required to provide quality education in this field. In order to tackle this concern, the Philippine government has instituted initiatives aimed at enhancing the competencies of automotive industry personnel, which encompass SUC training. It is imperative to improve the caliber of automotive technology programs provided by SUCs to satisfy industry and national requirements, as well as, to generate proficient personnel for the automotive sector (Torres, 2023) [35].

Modern science and technology necessitate instruction of the highest caliber. The development of innovative interactive educational systems utilizing the progress made in information technologies presents a formidable undertaking. The implementation of augmented reality

technology represents a prospective approach to enhancing the educational process (Elivera & Palaoag, 2020) [12].

The modern automotive industry is experiencing transformations that will inevitably revolutionize the road transportation industry in the coming years. Autonomous Driving (AD) is emerging as a game-changing technology of the near future, alongside electric vehicles, and sophisticated vehicular communication systems (Korta *et al.*, 2021) [22]. These constant changes significantly impacted the learning strategies that students had to develop. Old mockups of prototypes are still useful, but they are insufficient to provide the most up-to-date skill-learning knowledge-based current work-based practices. The troubleshooting of faults using the analog (traditional) method of sight, hearing, feeling, touching, and smell by trial and error gave rise to research into modern auto fault detection devices. From On-Board Diagnostics I, On-Board Diagnostics II, Multi-Purpose Diagnostic Machines, and All Data Machines are the result of the research conducted thus far. These machines produce exact, empirical, reproducible, and precise results.

Any of these machines properly installed on a compliant vehicle would now, with the press of one or two buttons, display the vehicle's fault and even print it out on paper. Before this, troubleshooting and fault detection procedures utilized the elimination method (Ezeora, B. U., & Ehimen, T. E., 2021) [13]. To enable the user to read the necessary data, one must access an On-Board Diagnostic scan tool.

The development of the standard tool was the effect of the pursuit of vehicle makers to protect the environment by clean emissions.

The United States established the on-board diagnostic (OBD) standard primarily to aid in detecting engine faults. The major purpose of such a system is to identify any increase in dangerous gas emissions that surpass certain permitted thresholds. The system operates by continuously monitoring specialized sensors that give electrical impulses as feedback to the vehicle's primary Electronic Control Unit (ECU). These sensors monitor the engine management activities; specifically, they detect air/fuel volume for the ECU to precisely determine the correct mixture in real-time. In addition to the oxygen sensor and MAF sensor, several sensors contribute to the air/fuel ratio. A vehicle's ECU is communicated using an OBD scanner (Abukhalil *et al.*, 2020)^[3].

OBD scanners diagnose vehicle electrical and emission systems. The Electronic Control Unit records the failure code for the scanner to read. Repairing and maintaining vehicles requires computer-aided diagnosis. With this enhancement and change, these gadgets affect trainers and learners. Thus, with the help of these advanced diagnostic tools, hybrid, electric, and driverless cars can be the future of automotive technology.

Many major automakers are creating vehicles with at least some degree of automated driving capability. These vehicles range from those equipped with adaptive cruise control to fully autonomous ones. These vehicles are referred to collectively as automated vehicles. Consumer adoption of automated vehicles is poorly understood. The initial purchasers are likely to be fully autonomous ones. They are consumers with different lifestyles, attitudes, and socio-demographic profiles than the general population. One study investigated the attitudes of early adopters of one automotive technology, plug-in electric vehicles (PEVs), using a questionnaire survey of 2,715 consumers in 36 states in U.S. (Hardman *et al.*, 2019)^[17]. OBD Data Link Connector is designed to have ease of access to users that intend to diagnose OBD2-ready vehicles.

The researcher of the present study has been teaching as an Autotronics Technology Instructor, and the biggest challenge is letting the learners experience autotronics computer systems diagnosis. This observation encouraged him to develop a solution to this problem which involved the constant need to deliver and bridge the needs of both learners and instructors. In this respect, he felt that there was a need to develop a device that would enable the user to access the vehicle's computer system for effective diagnosis. The vehicle should be serviced by skilled and knowledgeable professionals to ensure prompt repairs and accurate diagnosis of machine failures. Without specialized instruction, they would be unprepared to carry out this task. During training, students learn the fundamentals of operating technological equipment and the laboratory work on computer models or working apparatus. Difficulties develop during training is a result of the characteristics of the equipment used for diagnosing vehicles (Ivanov *et al.*, 2020)^[20].

The researcher considered three perspectives that served as bases for this study.

First, the absence of an On-Board Diagnostic trainer might have multiple effects on both students and instructors. One

of which would be the limitation of students to solve problems encountered in modern vehicles. For instructors, it would be difficult for them to encourage students to learn the Gasoline Electronic Fuel Injection diagnostic procedure in the absence of a trainer. Furthermore, in the absence of simulation-based learning, instructors would struggle to instill a realistic approach to gasoline EFI diagnosis.

Second, in terms of economics and employability of future automotive graduates, employers might view the students as a liability due to their lack of fundamental diagnostic tool-handling skills. They might perceive this as incompetence of the institution which, in the future, could be used as reason for not hiring its students as future technicians.

Third, employers select personnel based on their competencies, knowledge of the industry's required knowledge and skills, specialized training, and specific fields.

Given the preceding studies and concepts, the present study aimed primarily to investigate the usability of an On-Board Diagnostic scanning system to students and instructors based on the following factors: Functionality, Ease of Use, Interface Design, Reliability, Maintainability, Safety, Flexibility, and Acceptability. Next, was to determine the strengths and weaknesses of the trainer using cost-benefit analysis. This would include exploring the advantages of using ICT-enhanced facilities to teach and learn in the Motor Vehicle Mechanics trade and other trades in Technical Colleges. The ability for students and instructors to gain additional knowledge through hands-on experience as well as new specialized skills and knowledge related to the trainer was also considered. Finally, the study would explore the risk factors or disadvantages of having a newly introduced tool to students and instructors and how this might affect them.

Theoretical Framework

The Input-Process-Output (IPO) framework proposed by Joseph McGrath (1964) is a model composed of concepts that are broadly defined and organized to provide a focus for the study. Using flowcharts and process diagrams, this framework emphasizes the study's flow and specifies the relationship between Input, Process, and Output variables. IPO framework is an outline of potential courses of action or a preferred method for presenting an idea or set of thoughts. The researcher employed the Input-Process-Output (IPO) and Outcome framework as general guidelines and the primary structure for the development of this study (Naelga & Labrada, 2019)^[25].

The raw data, pre-existing data, and any pertinent information provided by the external system were the input variables. The Input data of this study were the creative product development and benchmark product design. The Process variables act as a mediator between the association, the result, and the input. In this study, the data collected following product testing and actual product evaluation to determine the Arduino-based OBD Trainer for Gasoline Electronic Fuel Injection applicability and acceptability were the Process variables. The Output variables are the data collected after the intervention process. In this study, the Output variable represented the prototype of the final product presentation which would be the Arduino Uno-Based On-Board Diagnostic Trainer.

Developmental framework

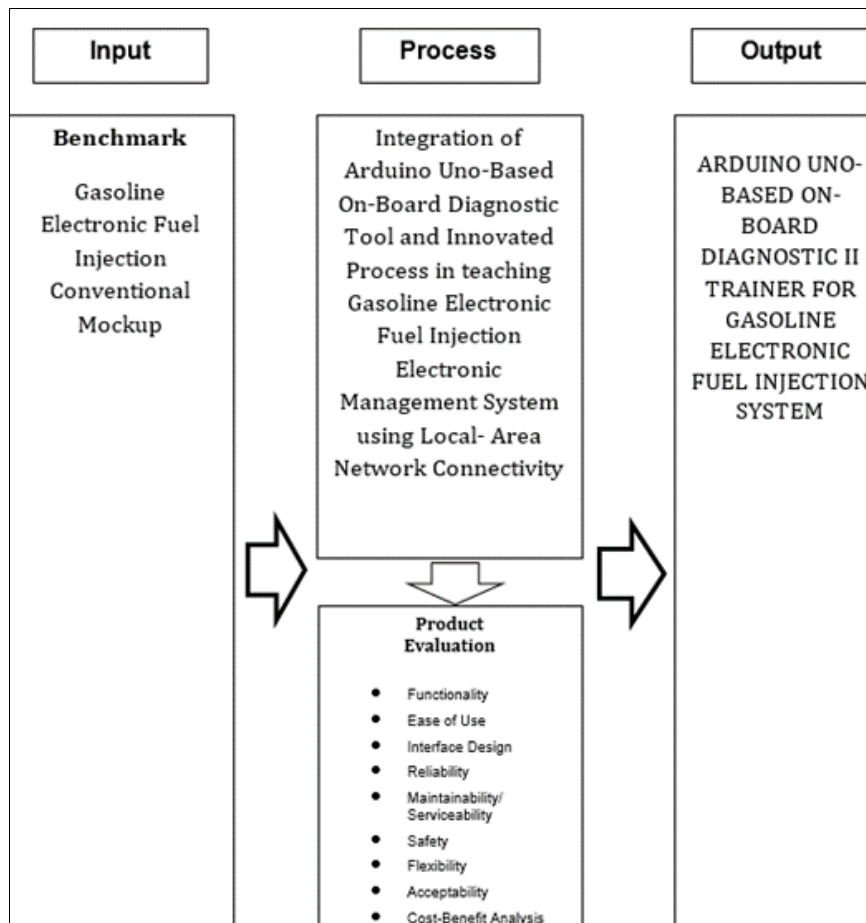


Fig 1: Schema of the Study

Methods

Research Design

This study investigates the usability of the Arduino Uno-based On-board Diagnostic II Trainer in instructing automotive technology students in the diagnosis of Gasoline Electronic Fuel Injection System. The method used was Descriptive-Developmental which works primarily on the description, comparison, analysis, and interpretation of data, and the development of the trainer itself as an output of this research. This research design involves designing, developing, and evaluating the instructional trainer. According to Richey and Klein (2005), it is the most appropriate research design for creating model designs and theorizing. They averred that developmental research could be of two distinct types depending on the structure and intent of the study. This study would fall under Type II Developmental research as it aimed to study the design, development, and evaluation processes, tools, or models. It also aimed to develop new design and evaluation procedures and models that facilitate use.

Research Setting

The researcher conducted the study at the University of Science of Technology of Southern Philippines. Specifically, in the College of Technology.

Respondents of the Study

The participants of the study consisted of automotive technology experts and instructors in relation to model development. Twenty (20) experts with experienced

instructing and training students on electronic fuel injection System was selected using a purposive sampling (Omachinski, 2017) [28]. Industry experts in the field of automotive technology and instructors of automotive courses at the university are the respondents to the study.

Data Gathering Procedure

Phase-by-phase development approach for an Arduino Uno-based On-Board Diagnostic II Trainer for Gasoline Electronic Fuel Injection System in Automotive Technology

Phase 1: Preliminary Analysis

Defined the purpose and goals of the On-Board Diagnostic II Training with Arduino Uno. Created a literature review of existing gasoline electronic fuel injection electronic management tools and system diagnostics. Conducted a feasibility analysis to determine the viability of the project and to calculate the required resources.

Phase 2: Requirements Collection

Described the required features and capabilities of the On-Board Diagnostic II Training. Conducted interviews and surveys with auto mechanics and industry specialists to understand their diagnostic tool needs. Conduct a focus group with prospective users to gather their comments and suggestions.

Phase 3: Design and Prototypes

Using the identified criteria, created the conceptual design for the On-Board Diagnostic II Training. Built a prototype

of the On-Board Diagnostic II Trainer using an Arduino Uno board and the other necessary components. Conducted preliminary testing and evaluation of the prototype to identify design flaws and potential for improvement.

Phase 4: Testing and Validation

Confirmed that the On-Board Diagnostic II Trainer adheres to requirements and performs as expected by performing functional testing. Conducted usability studies to verify that the On-Board Diagnostic II Training is easy and user-friendly. Verified the use and dependability of the On-Board Diagnostic II Training in a real-world scenario through field testing.

Phase 5: Documentation and Assessment

Created documentation for the On-Board Diagnostic II Trainer, including user guides, technical specifications, and training materials. Evaluated the project's achievement of its objectives and compliance with the collected requirements. Highlight areas for improvement and provide suggestions for future development.

Phase 6: Evaluation

The most critical characteristics of an evaluation process are the reliability and validity. Instructional designers may use any approach that is suitable for conducting their evaluation. In this study, the reaction evaluation was used in the evaluation process. The evaluators measured the satisfaction rate of the model. Positive reactions were fundamental for the continuation of the model while negative reactions did not entail that no learning took place. However, it is indicative of less motivation to learn.

The Research Instrument

A research instrument designed by Cardino *et al.* (2016) [8] was used in this study to evaluate the integration of the development of a particular trainer. However, the researcher provided an additional section of the questionnaire which included the demographic profile of the respondents, such as name, gender, job description, and civil status; the second part included a series of evaluation sheets where the adapted usability evaluation criteria were used along with its considered parameters. Experts in the field of model development provided answers to these evaluation sheets which consisted of a 23-item reaction evaluation sheet for the model and a reaction evaluation sheet.

Instrument Validation

The instrument was examined, assessed, and validated by the three experts from technology education academes.

Statistical Treatment of the Data

Descriptive analysis was used in the analysis and treatment of data using SPSS version 20. Financial aspects is vital thus the results of the model was evaluated based on the financial or statistical reports and SPSS was used.

Results and discussion

Problem number 1: What is the usability of the Arduino-based OBD trainer for Gasoline Electronic Fuel Injection System in automotive technology in terms of the following: Functionality, Ease of Use, Interface Design, Reliability, Maintainability, Safety, Flexibility and Acceptability?

Table 1: Mean Responses in terms of the Factors considered in assessing the Usability of Arduino Uno-based On-board Diagnostic II Trainer for Gasoline Electronic Fuel Injection System.

Evaluation Criteria	Average Mean Rating
Functionality	5
Ease of Use	5
Interface Design	5
Reliability	5
Maintainability	5
Safety	5
Flexibility	5
Acceptability	5

Table 1 shows the mean ratings of the evaluation of OBD trainer based on the above-mentioned factors. As indicated in the table, the factor on Functionality has an average mean of 5. This implies that experts and instructors who responded to the study perceived that the usability of the trainer in terms of functionality was high and that through the trainer an average user would be able to efficiently explain and understand the system diagnostic principles and operations as well as its troubleshooting exercises. The set-up time and procedures taken when used in a laboratory could be accomplished with greater accuracy compared to the conventional mockups. The same table shows an average mean of Ease of Use which is also 5, implying that the serviceability was high, less time was needed to set up the trainer, and its remote features were easier to use. For the factor on Interface Design, the average mean is also 5, which implies that the appropriateness of wiring connections and standard symbols were being used. The effectiveness and accuracy of labels as well as the aid colors in presenting the elements of the OBD helped a lot on its serviceability. The Reliability factor also has a mean of 5, indicating that the OBD trainer could provide a consistent performance every time it would be put into use. Maintainability with an average mean of 5 indicates that the OBD trainer provided easy access for maintenance and servicing. Its design implementation was proven to have highly considered future updates and enhancements making it adaptable to evolving technologies. Safety factor, which also has an average mean of 5, indicates that the OBD trainer was safe to use and did not pose any serious risk in terms of physical injury during practical exercises as well the risk for potential damage of EFI system components. Factor on Flexibility also has an average of 5. This implies that the Arduino Uno-based On-board Diagnostic II Trainer for Gasoline Electronic Fuel Injection System allowed the experts and instructors to adapt to different training scenarios and teaching styles. The trainer made it easier for the instructors to handle tasks with ease despite the difficulty of the practical exercises. Lastly, for Acceptability, the average mean is 5. This indicates that OBD trainer could be used for Automotive EFI systems as a tool for effective teaching-learning process. They also acknowledged the appropriateness of the Arduino Uno-based OBDT for instructional and training purposes. In summary, the Arduino Uno-based OBDT was highly recommended for users and as appropriate for instructional and training purposes, too.

Problem 2: Cost-Benefit Analysis of the Arduino Uno-based On-board Diagnostic II Trainer for Gasoline Electronic Fuel Injection System. Performing a cost-benefit analysis for an On-Board Diagnostic (OBD) trainer involves

evaluating the potential costs and benefits associated with implementing and using such training tools. Here are some key factors to consider:

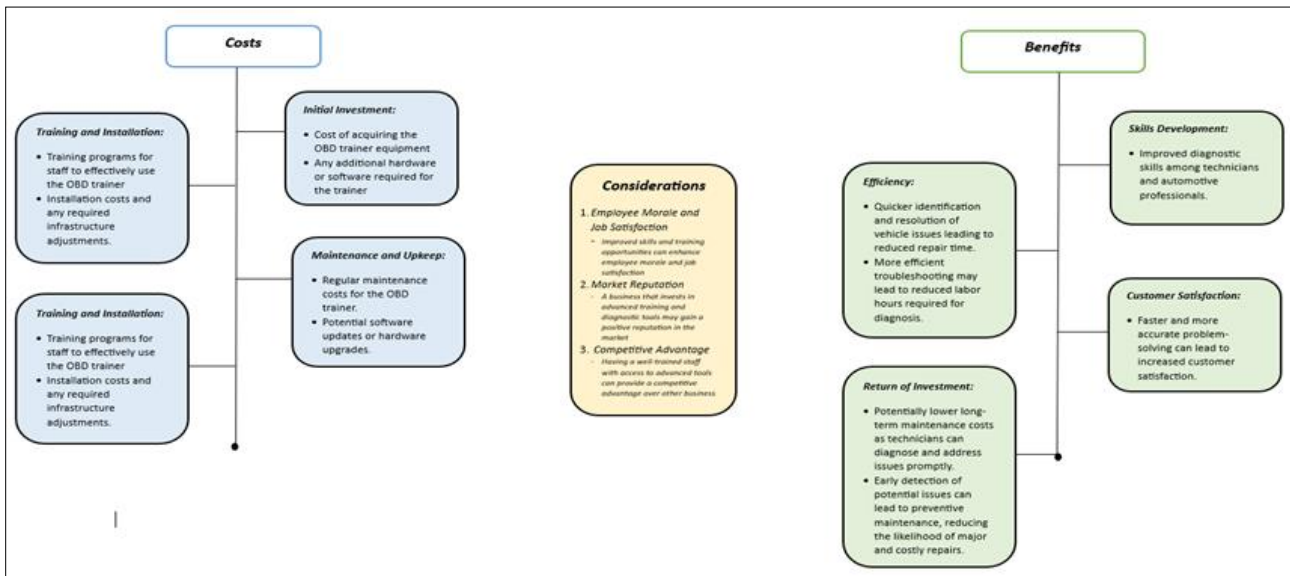


Fig 2: Cost- Benefit Analysis of an Arduino Uno-based On-board Diagnostic II Trainer for Gasoline Electronic Fuel Injection System

A comprehensive cost-benefit analysis weighs the initial and ongoing costs against the potential efficiency gains, cost savings, and other benefits associated with having an OBD trainer. An On-Board Diagnostic (OBD) trainer is a valuable tool in the automotive industry for several reasons. OBD systems have become standard in modern vehicles, and a trainer helps individuals like automotive technicians or students understand and work with these systems effectively.

An OBD trainer is significant for skill development, for understanding OBD systems, and staying current with advancements in automotive technology. It provides a platform for hands-on learning, making it an essential tool for anyone involved in automotive diagnostics and repair. Through this and by systematically evaluating the factors indicated above, an informed decision could be made about whether the implementation of an OBD trainer would be a sound investment for the organization.

Conclusion and recommendations

Based on the results of this study, it is evident that the usability of the Arduino Uno-based On-board Diagnostic II Trainer for Gasoline Electronic Fuel Injection System in terms of Functionality, Ease of Use, Interface Design, Reliability, Maintainability, Safety, Flexibility and Acceptability was highly favored and agreed by the experts and instructors who participated in the study.

The development of the Arduino Uno-based On-board Diagnostic II Trainer for Gasoline Electronic Fuel Injection System in Automotive Technology could be a possible tool for teaching students of automotive technology to diagnose electronic fuel injection systems when implemented and funded. The positive result of adaptability and customizability of the Arduino platform would enable the development of a trainer tailored to specific educational requirements. The results affirm the study of Rodriguez et. al (2018) [31], that its versatility to meet specific

requirements makes it an ideal platform for the development of diagnostic trainers.

The present study was limited only to 20 experts and instructors of automotive technology in the USTP. For future studies, it is suggested that more experts be added and the scope of respondents to represent the total population of automotive technology experts be widened to support the newly developed trainer to help capture its benefit as an additional and effective instructional learning material for automotive technology students, not just in the university, but also to students from other universities as well.

Furthermore, the development of Arduino Uno-based On-board Diagnostic II Trainer for Gasoline Electronic Fuel Injection System could be an advantage both in the automotive industry and the academe. Hence, it is suggested that a comprehensive review and analysis of its advantages and disadvantages in terms of its initial and ongoing costs be undertaken for its potential gains and other benefits of having a trainer.

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