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Development of an Automatic Gear Transmission System Teaching Aid

Adewale Kamalideen Ejalonibu [1], Michael Ayomide Olaomi [1,*], Tunde Isaac Ogedengbe [1], Akeem Abiodun Rasheed [2] and Amos Babatunde Osasona [1]

[1] *Department of Mechanical Engineering, Federal University of Technology, Akure, Ondo State, Nigeria.*
[2] *Department of Industrial and Production Engineering, Federal University of Technology, Akure, Ondo State, Nigeria.*

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Abstract

This study presents the development of an innovative educational tool designed to enhance the comprehension of automatic transmission systems. The teaching aid features a 2004 Toyota Corolla automatic gearbox integrated with a variable-speed electric motor, which is connected to the torque converter through a system of pulleys. A gear position shifter is paired with a programmed Arduino-based display panel that includes a gear position indicator and an LCD screen linked to a magnetic sensor on the output shaft. This setup provides real-time feedback on rotational speed, enabling students to analyze the relationship between engine speed, torque converter dynamics, and output performance. The project is aligned with core Mechanical Engineering courses such as Automotive Systems Engineering and Transmission System Design, fulfilling key learning objectives like understanding planetary gear mechanisms and torque converter operations. Its primary aim is to provide students with a hands-on learning platform that replicates the functional behavior of an actual automatic transmission while allowing direct comparison with manual transmission systems. By using the electric motor to emulate engine input power, learners can visualize and investigate how variations in engine speed influence torque converter behavior. Overall, this project offers a practical, interactive, and effective resource for both educators and students, bridging theoretical knowledge and real-world automotive applications.

Keywords: Gear; Automatic Gear Transmission; Teaching Aid; Arduino; Mechanical Engineering Education

1. Introduction

In recent years, the advancement of automotive engineering has transformed vehicle performance and reliability through improvements in transmission systems. Transmission systems serve as the mechanical interface responsible for power transfer between the engine and the wheels, optimizing torque, efficiency, and speed ratios under diverse operating conditions [1]. Automatic transmissions, in particular, have gained prominence due to their ability to enhance driving comfort, fuel efficiency, and adaptability across varied terrains. According to Mashadi et al., the automation of gear shifting reduces driver workload and mechanical wear, contributing to extended drivetrain lifespan [2]. The introduction of electro-hydraulic control systems and torque converter innovations has further enhanced transmission smoothness and performance.

Engineering education increasingly emphasizes practical learning experiences to complement theoretical instruction. Studies such as that by Wankat and Oreovicz [3] underscore the significance of simulation-based and hardware-assisted teaching in developing problem-solving and analytical skills among engineering students. Moreover, the incorporation of digital tools like Arduino and microcontroller-based systems allows learners to visualize complex mechanical processes, thereby strengthening conceptual understanding [4]. Educational teaching aids designed for mechanical systems are now recognized as effective pedagogical tools that facilitate deeper engagement and foster innovation.

* Corresponding author: Michael Ayomide Olaomi

The application of teaching aids in automotive engineering enhances comprehension of core principles such as torque transfer, planetary gear operations, and electronic control systems. A study by Morecroft et al. [5] demonstrated that students who interact with physical models of transmission systems exhibit higher retention and understanding of system dynamics. Similarly, integrating computer-aided design (CAD) and embedded sensor technology in engineering learning environments supports experiential education and skill acquisition[6]. Recent trends also emphasize sustainable design and modular learning tools to ensure longevity, adaptability, and relevance in engineering training institutions.

Successful movement of any automobile vehicle largely depends on its transmission system/gear. A transmission system is a mechanism that transmits the power developed by the engine of automobile to the driving wheels [7]. Gear is one of the most important and widely used element in mechanical transmission. Consequently, the performance of the gear directly affects the performance of the entire transmission system. In particular, precision gears are widely used in mechanical transmission systems such as wind turbine gearboxes and aero engines with high reliability requirements. A gear is a component that is used to transfer torque from a rotating input. It uses teeth to mesh together with other gears in order to transmit movement as shown in Figure 1. A desired output of speed and torque can be obtained by controlling different geometry sizes between the two gears. The mechanical transmission system has the capability to enable the engine turning effect and its rotational speed output to be adjusted by choosing a range of under and overdrive gear ratios.

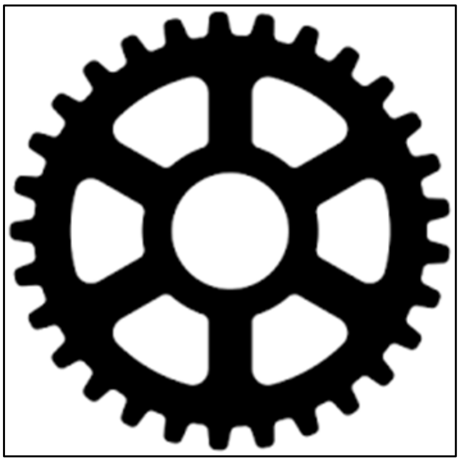

Figure 1 Typical gear [8]

In today's automobiles, the use of automatic gear transmission system (AGTS) is rapidly expanding. It is a type of gear train arrangement that can change gear ratios automatically as the vehicle drives, eliminating the need for the driver to manually shift gears. Planetary gearsets replace the manual transmission's arrangement of gears lined up along input, output, and intermediate shafts in a hydraulic automatic transmission [9]. Recently, many researches have been carried out to overcome some problems in the balancing of theoretical teaching and learning to practical knowledge and some teaching aids are already available in the educational sector but may not be ideal in some instance especially in the engineering sector. The process of teaching and learning depends upon the different type of equipment available. As said, [10] "Visual aids help learners explain thoughts and facts". The use of visual aids in teaching learning process has multifarious values. Some individuals are prone to forgetfulness and hold on more to memories of things they have seen than heard and the rapid increase of students with different and diverse educational needs in mainstream schooling is a reality with multiple costs requiring new educational practices. Transmission in engineering is a complex section and the working principle is better explained and understood by a visual learning process [11]. In automatic transmission, the mode of gear selection may be theoretically learnt but the planetary gearset which the automatic gearbox uses is better understood by visually accessing the process. Many engineering institutes in the country lacks essential teaching aids for some of the practices that are required in the proper passage of knowledge. Previous development of a teaching aid for a manual gear set up has been done and reviewed. Hence, the development of a teaching aid for an automatic gear transmission system (AGTS) to facilitate learning activity becomes imperative since these are the two main modes of transmission system. A study was conducted that investigated the auto transmission dynamics system and the effects of clutch pressure on planetary gear to optimize the output speed which provided insights into the technical aspects of automatic gear transmissions, including control mechanisms and power flow optimization [12,13]. The primary goal of an AGTS is to achieve automated shift so that the vehicle can start more smoothly and the ride comfort can be considerably improved. Unlike a manual transmission, an automatic transmission uses a hydraulic torque converter to connect the engine to the transmission system for power transfer, allowing the driver to adjust the speed merely by pressing the accelerator pedal. Furthermore, hydraulic transmissions have a specific damping performance and can increase the transmission system's service life. Automated transmissions in vehicles have been widely developed and used. The automatic transmission is mainly composed of hydraulic torque converter, transmission mechanism, shift actuators, hydraulic control system and electronic control system [14]. Several institutions generally have the challenge of unavailability of effective teaching and learning aids, especially in the engineering sector. Based on an extensive review of previous studies on manual and automatic gearboxes, it is evident that researchers have primarily focused on investigating manual transmission systems. Automatic transmission systems, characterized by components such as torque converters and planetary gears, simplify this process, eliminating the need for manual gear shifting [15]. Despite their importance, many engineering institutions lack adequate teaching aids to demonstrate automatic transmission principles, limiting students' practical understanding. This study addresses this gap by developing an Automatic Gear Transmission System (AGTS) teaching aid. This teaching aid aligns with key Mechanical Engineering learning objectives, such as; understanding planetary gear mechanisms, analyzing torque converters and their operation, and comparing automatic and manual transmission systems. These objectives are integral to courses like "Transmission System Design" and "Automotive Systems Engineering." This research work when implemented will help to achieve sustainable institutional development and enhance critical thinking amongst engineering teachers and learners.

Overall, the study offered a comparative evaluation of the teaching aid, enriching the comprehension of welding procedures used in the fabrication of the teaching aid stand, the driving and driven pulley system via the variable speed electric motor, the automatic gear box sectioning and assembly, and the programming phase of the gear position indicator and output speed using Arduino. The main objectives are to design and develop a teaching aid for an automatic gear transmission system (AGTS) to facilitate teaching and learning in automobiles while comparing to the manual gear transmission system previously done and evaluate the performance of the developed teaching aid. The originality of this study is rooted in its thorough scrutiny of various similar research previously done which are very few and thus opening the path to investigating the possibilities of the research. Teaching aids have been done on manual gearbox, which also include a manual gearbox teaching aid done at the mechanical automobile workshop in the Federal University of Technology Akure (FUTA). Since there has roughly been little or no automatic transmission teaching aid done, most especially in the universities, this research gap was intended to be filled so as to facilitate teaching and learning and also compliment the Manual transmission teaching aid already done in FUTA.

2. Materials and methodology

2.1. Materials

The materials used in this study included a sectioned automatic gearbox from a 2004 Toyota Corolla (1.8L/108 hp), a compatible Toyota corolla gear shifter, a variable speed (VS) electric motor (1hp 3360rpm), a 48-inch V-belt, driven and driving pulleys (Ø152.4 mm and 88.9 mm respectively), angle steel bars (50mm x 50mm x 4mm), 3.2mm E6013 mild steel welding electrode usually coated with Nickle-potassium coating, gear hanger bolts (M17), various bolts and nuts, a DIGITEN tachometer LCD and sensor, a gear seat, gear hangers, black gloss paint, an electric plug, a plastic circuit board, screws, a hacksaw blade, a bearing, shafts, Arduino components (Arduino board, LCD screen with i2c module, jumper wires, DC connector, battery, DC battery connector, press switches), caster tyres, ATF lubricating oil, MBF plywood, and associated electrical cables and connectors. The angle steel bars, stainless steel electrodes, electric plug, plastic circuit board, screws, hacksaw blade, bearing, and black gloss paint were purchased from the local market area of Akure metropolis, Ondo State. The variable speed (VS) electric motor, gear shifter cable, and caster tyres were procured from suppliers in Lagos State. The V-belt, pulleys, gear seat, gear hangers, gear hanger bolts, various bolts and nuts, and shafts were sourced from a local automobile market in the Ilesha garage area of Akure metropolis, Ondo State. The DIGITEN tachometer LCD and sensor were ordered and purchased from an online store. The Arduino components, including the Arduino board, LCD screen with i2c module, jumper wires, DC connector, battery, DC battery connector, and press switches, were all procured from a computer and programming store in Ilara metropolis, Ondo State. The automatic gearbox was obtained from the automobile laboratory at the central engineering workshop and was sectioned at mechanical engineering machining laboratory, Federal University of Technology Akure, Ondo State, Nigeria. The machine tools employed in this research were pillar drilling machine, angle grinding machine, electric arc welding machine, hand drilling machine, lathe machine. While the precision, electrical measuring instruments, and cutting tool were vernier caliper, multimeter, and hacksaw respectively. These materials were chosen for their durability, efficiency, cost-effectiveness, and alignment with engineering recommendations. The selection criteria followed established guidelines for automotive teaching equipment development [16].

2.2. Conceptual Design

An exhaustive literature study was carried out to identify the need for this study. Essential components of an Automatic gear transmission system (AGTS) were established from the existing studies. This knowledge and those required to facilitate teaching and learning of relevant aspect of an AGTS was utilized to generate a conceptual design of the AGTS developed herein (see Figure 2 and 3). The computer aided design consists of a (a) standing frame on which all the components are assembled, (b) a gearbox, (c) driving pulley, (d) v- belt, (e) driven pulley, (f) an electric motor (g) gear shifter, (h) display panel, (i) tachometer LCD, (j) tachometer sensor (k) gear shift position LCD indicator and (l) electric push button switch. The design and construction as well as the evaluation were done at the Central Engineering Workshop FUTA. The CAD approach aligns with modern engineering design practices that emphasize visualization and iterative refinement [17].

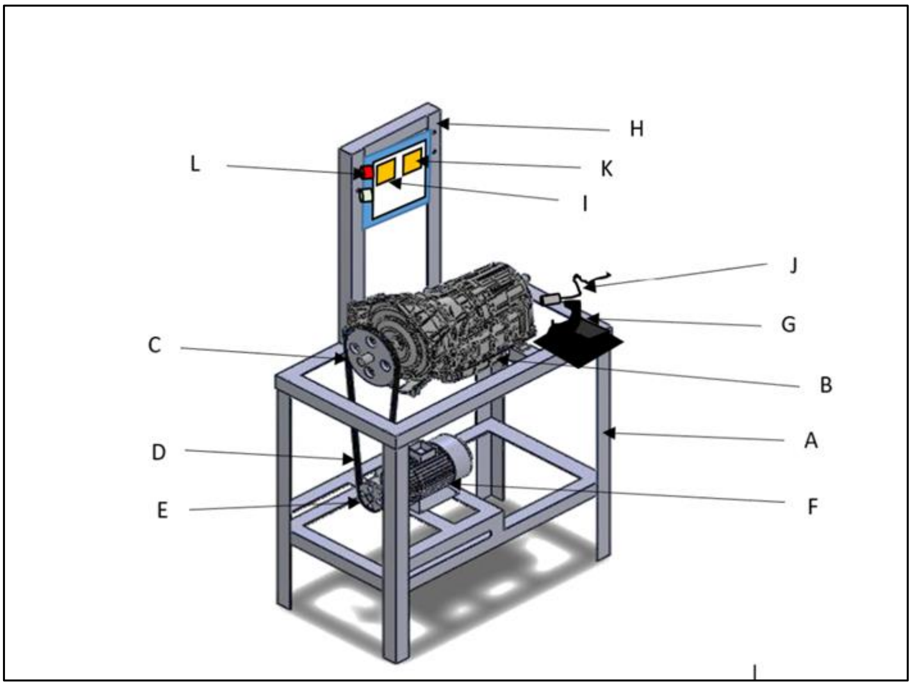

Figure 2 Conceptual Design of the AGTS Teaching Aid

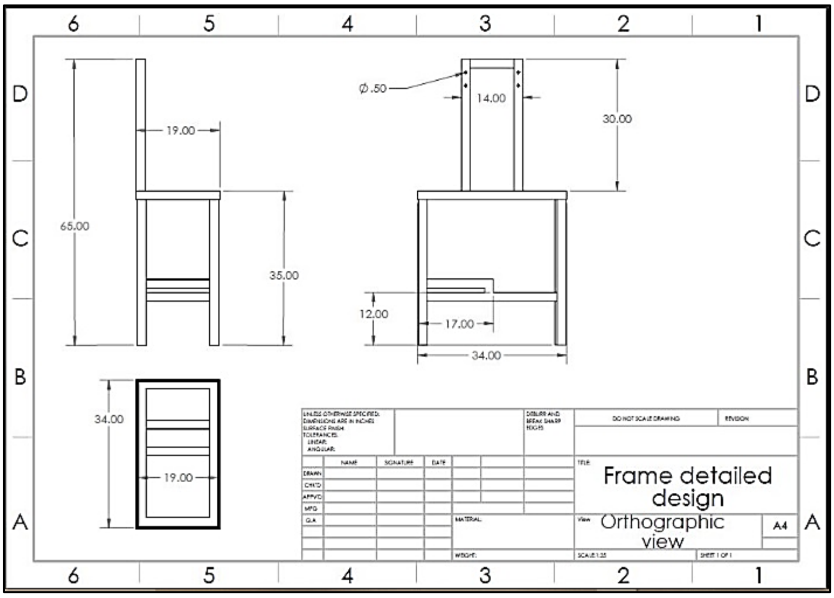

Figure 3 Frame Design

2.3. Shaft diameter

The shaft diameter which connects the driven pulley to the torque converter of the automatic gearbox was determined using a vernier caliper to measure the diameter of the protruding shaft on the torque converter.

2.4. Speed of rotation

Calculation of rotation ratio on each pulley, the ratio of driving pulley and driven pulley was determined using equation (1). If the gears aren't the same size, the machine or system gains a mechanical advantage, allowing for changes in output speed and torque (i.e., the force which causes an object to rotate).[15]

$$\frac{n_1}{n_2} = \frac{d_1}{d_2} \qquad \ldots\ldots\ldots \qquad (1)$$

2.4.1. Calculation of motor torque

It was established through market survey that the motor had output power specification of 1 hp (745.7 Watts) and 1450 rpm. The torque produced by the motor was calculated using equation (2).

$$P = 2\pi n.T \qquad \ldots\ldots.. \qquad (2)$$

Based on formula (2) above, P = motor power; n = motor rotation, T = torque

Power = 1hp, 1hp = 745.7 Watts

P = 745.7 Watts

n_1 = 1450 rpm (Rotation of driving pulley)

$$T = \frac{P}{2\pi n} = \frac{745.7}{2 \; x \; 3.142 \; x \; 1450}$$

T = 0.08 Nm

Motor Torque = 0.08 Nm

2.4.2. Calculation of v-belt

Calculation of the v-belt length connecting driving pulley on the motor with driven pulley on the transmission shaft. Diameter of the driving pulley is 3.5 inches (90 mm) and diameter of driven pulley is 6 inches (152.4 mm). The distance between driving pulley and driven pulley (x) is 8.7 inches (221.4 mm). The length of the belt was determined by using equation (3):

$$L = \pi(r_1 + r_2) + 2x + \frac{(r_1 - r_2)^2}{x} \qquad \ldots\ldots\ldots \qquad (3)$$

Based on formula (3) above, L = belt length; r_1 = radius of driving pulley; r_2 = radius of driven pulley; x = distance between pulley shafts.

$$L = 3.142(90 + 152.4) + 2(221.4) + \frac{(90 - 152.4)^2}{221.4}$$

$$L = 1219.2 \; mm \; (48 \; inches)$$

2.4.3. Calculation of belt contact angle

The belt contact angle was calculated using equation (4):

$$\sin \propto = \frac{r_1 - r_2}{x} \qquad \ldots\ldots \qquad (4)$$

$$\theta_{12} = 180° - 2\alpha \qquad \ldots\ldots\ldots \qquad (5)$$

The diameters of the driving(d1) and driven(d2) pulleys are 90 mm and 152.4 mm and reciprocating radii are 45 mm and 76.2 mm respectively. Using this data, we could find the contact angle of the belt and pulley according to the equations 4 and 5

$$\sin \propto = \frac{45 - 76.2}{221.4}$$

$$\sin \propto = -\ 0.141$$

$$\propto\ = 8.1057°$$

Contact angle of Pulley (θ)

$$\theta_{12} = 180° - 2\alpha$$

$$\theta_{12} = 163.7886°$$

$$\frac{\pi}{180}\ x\ 163.7886° = 2.86\ rad$$

2.5. Comparison of belt tension

Furthermore, the tension in the belt was searched by looking at the value = 2.86, pulley friction coefficient (= 0.3) and the type A v belt groove angle was sin 40. Using equation (6) the calculation is as follows:

$$2.3 \log \frac{T_1}{T_2} = \frac{\mu\,.\,\theta}{\sin\beta} \quad \dots\dots \quad (6)$$

$$2.3 \log \frac{T_1}{T_2} = \frac{0.3\ x\ 2.86}{\sin 40\ °}$$

$$T_1\ = 21.37\ T_2$$

Where:
T_1 = Tension on the tight side of the belt
T_2 = Tension on the loose side of the belt

2.5.1. Calculation of the tension on the v-belt (T_1, T_2)

To get T_1 and T_2 using torque equation (7) which was affected by the tight side and the slag side of the belt. The torque value was obtained from the motor torque that has been previously known.

$$\text{Motor torque} = (T_1 - T_2)\ x\ r_1 \quad \dots\dots \quad (7)$$

$$0.08\ \text{Nm} = (T_1 - T_2)\ x\ 45\ mm$$

$$(T_1 - T_2) =\ 1.77\ N$$

$$T_2 =\ 0.087\ N$$

$$T_1 = 1.87\ \text{N}$$

2.6. Torque on the gearbox / driven pulley

After T_1 and T_2 are known, the amount of torque working on driven pulley directly connected to the gearbox shaft was determined using equation (8):

$$T\ = (T_1 - T_2)\ x\ r_2 \quad \dots\dots \quad (8)$$

$$T\ = (1.87 - 0.087)\ x\ 76.2\ \text{mm}$$

$$T = 135.86 \text{ Nmm}$$

2.7. Frame ergonomics

Standing eye height: According to the ISO standard ISO 9241-410 "Ergonomics of human-system interaction - Part 410: Human-centered design for interactive systems," the average eye height of an adult when standing is around 57 inches (145 cm).

Reach: The ISO standard ISO 9241-410 mentions that the average reach of an adult when standing is around 40 inches (102 cm).

The sources above provided a good starting point for considering the relevant anthropometric data collected before designing and fabricating the frame stand with good ergonomics at standing eye height. The following data (see Table 1) was obtained from a total number of 50 students of Mechanical Engineering department ranging from 100 level to 500 level.

Table 1 Anthropometric data of students' standing eye heights

Level	Male (cm)					Female (cm)					Average (cm)
100	170	166	160	161	168	160	162	163	162	160	163.2
200	162	178	175	163	162	158	161	160	160	160	163.9
300	177	171	166	161	159	158	160	161	162	167	163.3
400	176	170	168	160	171	164	163	162	165	165	166.4
500	179	167	170	175	168	171	163	168	167	160	168.7
Total Average											165.1

From the data obtained, it was deduced that the average standing eye height of the students is 165.1 cm (1651 mm) thereby making it preferable for "design for average". This data served as guide to the positioning of the display panel on the frame stand that was fabricated.

2.8. Fabrication and Assembly

The AGTS is composed of different parts that was assembled to create a teaching aid for proper understanding of how the mechanism works.

The primary component that was used in the research is the automatic transmission gearbox which was sectioned using an angle grinder with cutting wheels to show the working mechanism of the planetary gears and clutches confined in it.

2.9. Frame fabrication process

The frame stand for the AGTS was constructed using an angle steel bar to ensure sufficient strength and support for the weight and stress of the automatic gearbox and other components. Approximately three lengths of the angle steel bar were used. For the top part of the frame, using an electric cutting machine, two lengths were cut for the width and two lengths for the breadth, with each edge given a 45-degree angle for a perfect fit. Four lengths were cut for the height of the frame stand. Additional lengths were cut to serve as braces at the lower part of the frame, with allowances added to the cut. To divide the top part of the frame and hold the components, two lengths were cut and placed at the top. A mini support for the electric motor was constructed using various lengths and attached to the lower brace. Using the Piller drilling machine, holes were drilled on the appropriate part of the angle iron to secure the electric motor and places where other components were attached. A display panel was constructed by marking out a section in the middle of the top frame and stepping out from both sides. Two longer lengths and two shorter lengths formed the rectangular shape at the top. An MDF plywood panel was cut to fit the display panel, with proper holes drilled for fitting and holding the components. Finally, four wheels were fitted to the legs of the frame stand for support and easy movement. The total length of the angle steel bar used was approximately three lengths, with all sizes and dimensions based on the considerations of other components and anthropometry data.

2.10. Gearbox sectioning

The gearbox was sectioned for teaching purposes (to make the abstract parts apparent as shown in Figure 4) that is to make students understand what seems to be abstract about the gearbox as they would see them physically and know the principle of operation of an automatic gearing system. Using the angle grinder with cutting wheel, the cut-away part of the gearbox was carefully sectioned so as not to damage the internal components in the gearbox. The gearbox was adequately sectioned to display the internal components of the forward and reverse gear mechanisms by firstly considering the type of material used for the gearbox case, a steel gear housing. The front end of the gearbox case was measured and marked to cover the area where the clutches and gear sets are. With the angle grinder and abrasive cutting wheel, the gearbox housing was properly cut to precision. The penetration of the cutting wheel was carefully managed based on the thickness of the gearbox housing to avoid overcutting. Precision cutting techniques are essential when working with hardened steel components to preserve functional integrity [18]. After achieving the proper cut, the edges were smoothened.

Figure 4 Cutaway display model of an automatic gearbox

2.11. Drive System Construction

A shaft (Ø25 mm x 178mm) was welded to the center part of the torque converter after a 4mm thick steel plate was fitted on the round part of the gearbox casing via bolts and nuts and drilled using the hand drilling machine to accommodate the shaft diameter. This steel plate served as a holder to house the pillow bearing via bolts and nuts which assisted the shaft rotation when driven by the pulleys.

Figure 5 Drive System

Several components which consist of a variable speed electric motor, driving and driven pulleys were strung together via v-belt of adopted length of 47 inches (1193.8 mm) to form a drive system used to power the gearbox. The electric motor was placed directly below gearbox as shown in Figure 5.

2.12. Connection of gear position selector

After the drive system was completed, the gear selector was fitted on a 12 x 10 inches (304.8 x 254 mm) MDF plywood and was then positioned at the right edge of the frame using bolt and nuts. The cable of the gear selector was properly fixed to the shifter on the gearbox and was then calibrated to actuate each gear position i.e “P” “N” “D” “2” “L” as shown in Figure 6.

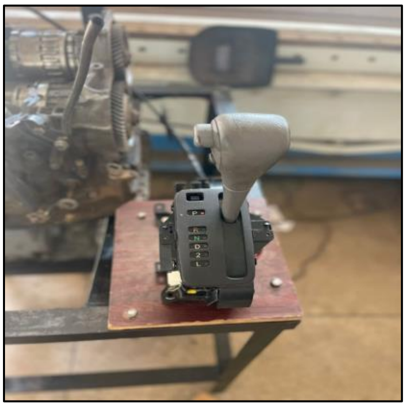

Figure 6 Gear position selector

2.13. Display panel construction

The display panel is the part of the teaching aid component which shows relative information about the output function of the AGTS. This component was constructed with the frame stand as indicated in the frame fabrication and serves as the housing of other output components which would be providing information to the viewers/learners. The display panel housed three major components. The LCD display of the digital tachometer was installed, showing the output speed of the AGTS after completing the electrical connections to the Hall Proximity switch magnet sensor which points directly to the output shaft of the gearbox. The Arduino LCD for the gear shift position indicator was also fixed on the display panel, indicating the gear positions: park, reverse, neutral, drive, second gear, and low as shown in Figure 7. Additionally, two switches were placed on the side of the display board to turn the LCDs on and off.

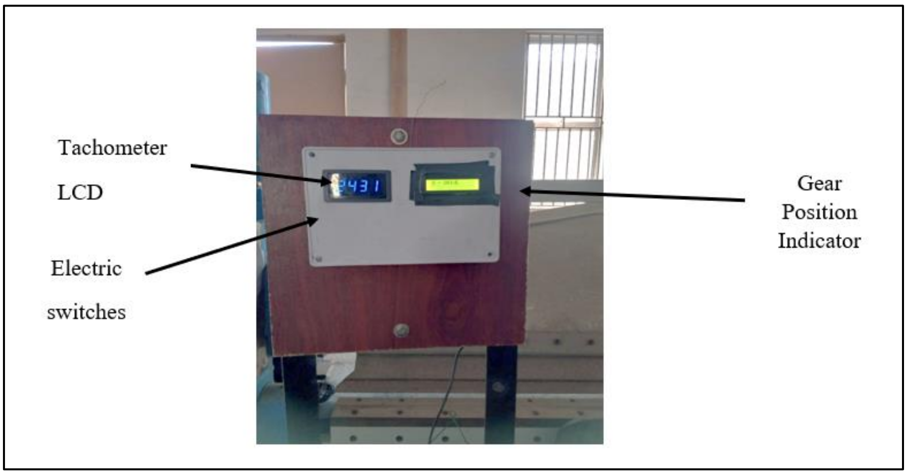

Figure 7 Display Panel

2.14. Tachometer assembly

The gearbox output speed was measured using a hall proximity switch magnet sensor, which was connected to an LCD screen to display the AGTS output speed. The sensor measures the rotational speed of the AGTS output shaft in revolutions per minute (RPM). Hall effect sensors provide reliable, non-contact speed measurement in rotating machinery [19]. The digital tachometer consists of five major components: a 4-digit blue LED tachometer RPM speed meter, a hall proximity switch magnet sensor, a magnet, a sensor mounting holder, and connecting wires.

Firstly, a digital tachometer with full accessories was obtained. A housing for the tachometer was then constructed on the frame stand to hold its digital display. The sensor mount holder, to which the hall proximity magnet sensor was attached, was also fitted on the frame stand, pointing directly at the magnet placed on the end of the output shaft. The distance between the magnet and the sensor was maintained at a standard 2 mm to 3 mm. Electrical connections were made between the digital display board and the switch magnet sensor in Figure 8, connecting the circuit to a DC power source.

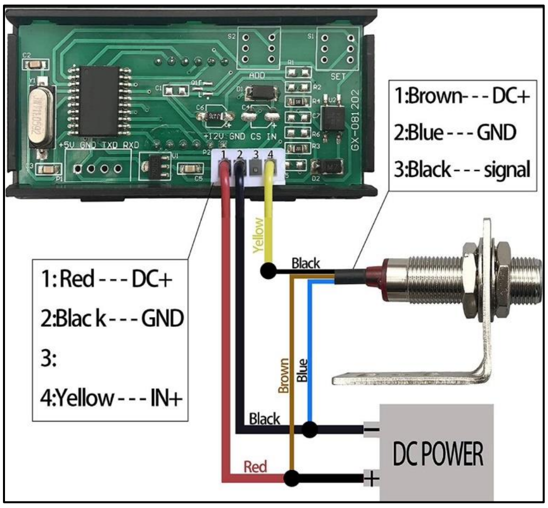

Figure 8 Electrical connection of switch magnet sensor to display and power

2.15. Connection of gear shift position indicator

The gear shift position indicator is a sensor device that detects and signifies changes in the gear position within a transmission system. Whether the gear is in Park (P), Reverse (R), Neutral (N), Drive (D), 2nd gear (2), or Low gear (L), the sensor promptly relays the new position. To accomplish this functionality, an Arduino programming application was employed. Arduino-based systems have become increasingly popular in engineering education due to their versatility and ease of programming [20].The Arduino board and an LCD were interconnected and linked to the gear position selector. The LCD was strategically positioned on the display panel and connected to the gear selector to provide real-time feedback on the gear positions. A meticulous electrical connection was established as shown in Figure 9, incorporating seven connecting wires from the Arduino board's digit pin holes to the gear selector. Each of the first six wires corresponds to a specific gear position, while the seventh connecting wire serves as the ground connection. The utilization of the Arduino module system was deemed optimal for this research, as it represents a cutting-edge gear-shift position technology. This versatile device has the capability to transmit transmission gear position data accurately to a variety of instrument systems, including VFD, VHX, HDX, or RTX, given proper programming implementation. Integration of microcontrollers in automotive applications represents current industry trends toward smart systems [21].

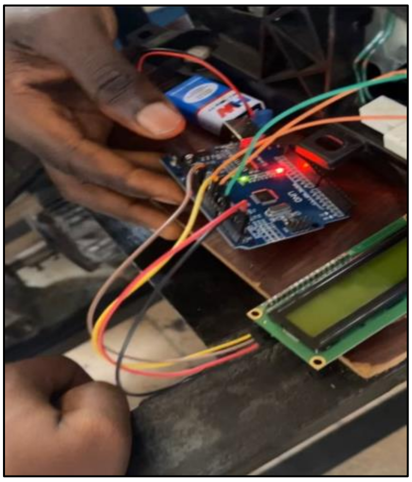

Figure 9 Connection of Arduino, LCD and gear position selector

3. Results and discussion

3.1. Fabricated and Assembled AGTS

The fabricated and assembled automatic gear transmission system teaching aid, which involved fitting and assembly of various components, yielded successful results. The gearbox, v-belt, driving and driven pulleys, variable speed electric motor, gear position selector, gear shifter connecting cable, display panel with tachometer LCD, gear position indicator LCD, switches, and Arduino boards were integrated seamlessly as shown in Figure 10.

Figure 10 Fabricated and assembled AGTS

3.2. Questionnaire Study

To evaluate the teaching aid's effectiveness, a questionnaire was administered to 30 Mechanical Engineering students across 100, 300, and 500 levels. The questionnaire included the following key questions:

- Rate your understanding of automatic transmissions before and after using the teaching aid.
- How engaging did you find the teaching aid?
- Was the teaching aid easy to use?
- Compare the AGTS teaching aid to the manual transmission system aid.
- Detailed questionnaire is included in Appendix A.

- To illustrate how the collected data were represented and demonstrated, the following key areas were visualized:
- Comprehension Improvement
- Engagement and Interest
- Usability and Satisfaction
- Comparison with Manual Gear Transmission System

3.3. Comprehension Improvement

The comprehension improvement analysis focused on the students' understanding of Automatic Gear Transmission System (AGTS) before and after using the developed teaching aid. The data showed a notable shift towards a higher understanding level, with a significant decrease in the number of students that responded "No Understanding" and "Basic Understanding."

Majority of the students moved to "Moderate" and "Good Understanding," implying that the teaching aid effectively enhanced their knowledge of AGTS concepts (see Figure 11). This enhancement emphasizes the teaching aid's potential as a useful educational tool in the automotive engineering curriculum.

Table 2 Before and After Understanding of AGTS

Metric	Before Aid	After Aid
No Understanding	25%	5%
Basic Understanding	35%	10%
Moderate Understanding	30%	50%
Good Understanding	10%	25%
Excellent Understanding	0%	10%

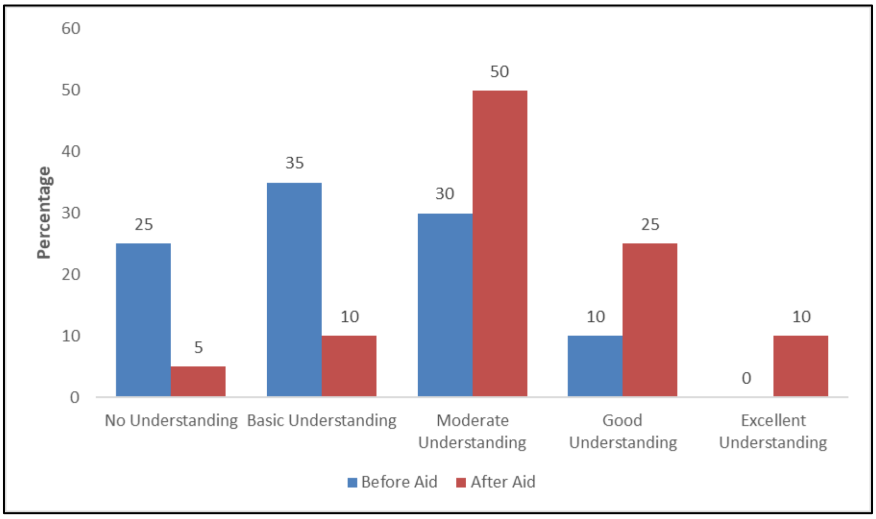

Figure 11 Comprehension Improvement before and after the teaching aid

3.4. Engagement and Interest

Engagement and interest levels were evaluated to investigate how the teaching aid influenced students' motivation and attentiveness during classes or practical sessions. The results showed that a reasonable number of students found the teaching aid to be "Moderately Engaging" to "Extremely Engaging," with few of them reporting low engagement levels as shown in Figure 12.

This high level of engagement is important as it can lead to better retention of information and a more engrossing learning experience due to the aid's interactive elements and clear visualizations adding to its overall effectiveness.

Table 3 Engagement Levels

Engagement Level	Percentage
No Understanding	5%
Basic Understanding	15%
Moderate Understanding	35%
Good Understanding	30%
Excellent Understanding	15%

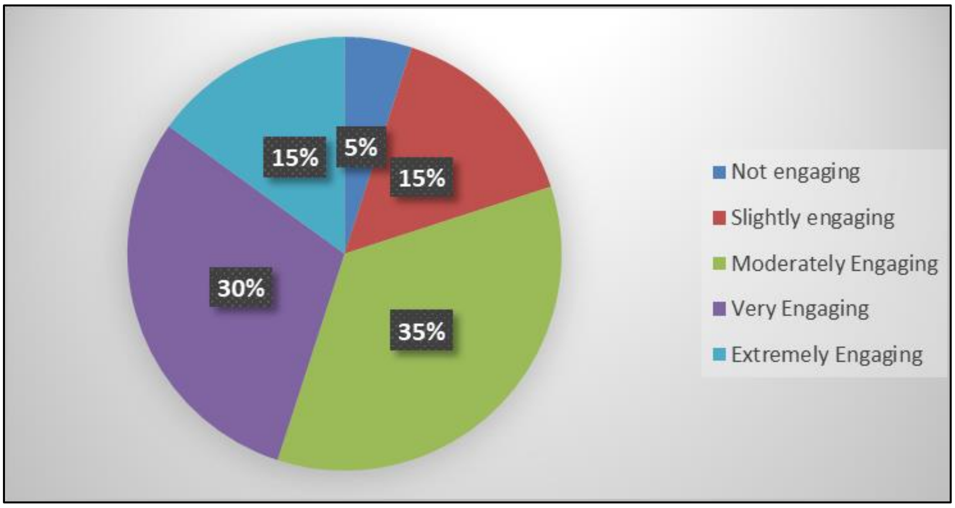

Figure 12 Engagement levels with the teaching aid

3.5. Usability and Satisfaction

The analysis of this key area evaluated ease of using the teaching aid and how delighted the students were with its features. Generally, the students rated the teaching aid highly in terms of usability (see Figure 13) as they became familiar with its functions. Satisfaction levels were also high, with rising positive feedback on the clarity of instructions, the perceptive design and the support of the visual aids. These feedbacks indicated that the teaching aid is user-friendly, making it accessible to a broad audience of learners.

Table 4 Ease of use over time (for different levels)

Levels	Start	Midpoint	End
100 Level	2	3	4.5
300 Level	3	4	5
500 Level	2.5	3.5	4.5

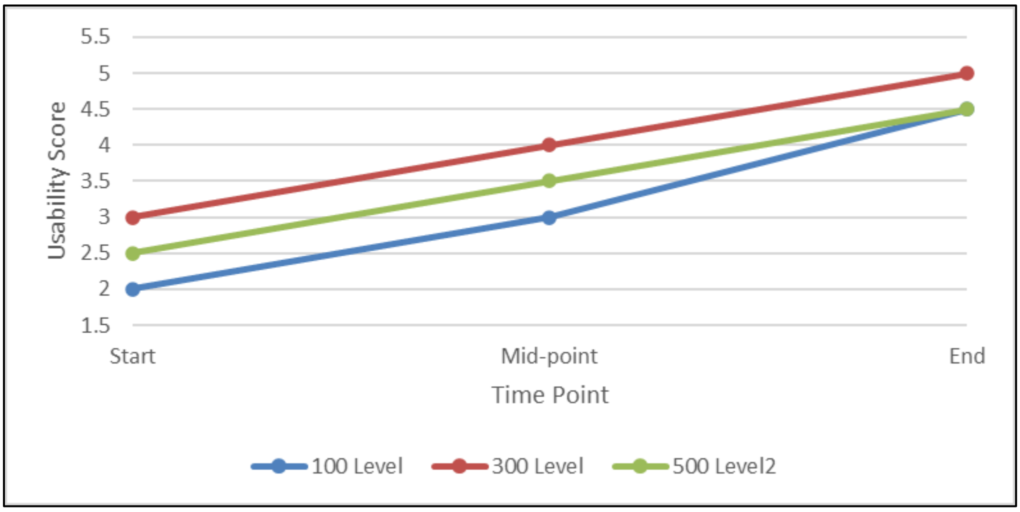

Figure 13 Usability over time

3.6. Comparison with Manual Gear Transmission System

A manual gear transmission system (MGTS) teaching aid had been developed previously, focusing on basic gear operations. However, it lacked features such as visualization of gear positions and real-time rotational speed feedback. The AGTS teaching aid addressed these limitations by:

- Incorporating a gear position indicator using Arduino technology.
- Providing real-time speed feedback via a tachometer.
- Offering a more modern and interactive approach, better aligning with current automotive technologies.

This enhanced functionality ensures students gain deeper insights into automatic transmissions compared to manual systems, bridging the gap between theoretical knowledge and practical application.

When compared to the existing Manual Gear Transmission System (MGTS) teaching aid, the AGTS showed superior performance across several levels such as overall satisfaction, comprehension improvement, and usability as shown in Figure 14. Students reported higher satisfaction with the AGTS, identifying its more detailed explanation, and alignment with modern automotive technologies through introduction of programming for visualization (gear position and rotation speed) via LCDs. The comparative analysis also identified the ergonomics utilized in the AGTS.

Table 5 Comparison of teaching aids

Metric	MGTS	AGTS
Overall Satisfaction	3.1	4.2
Comprehension Improvement	3	4.3
Engagement	3.2	4.6
Usability	3.3	4.5

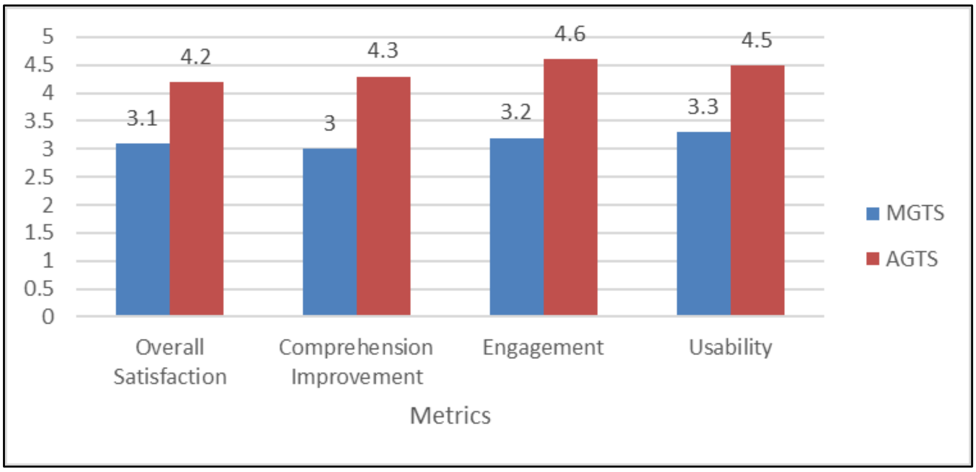

Figure 14 Comparison of teaching aids “MGTS vs AGTS”

4. Conclusions

Conclusively, this project successfully achieved its objectives of designing and developing a teaching aid for an automatic gearbox and providing a hands-on learning experience for students and enthusiasts. The teaching aid was designed to facilitate teaching and learning by allowing a comparison to the manual gear setup, thereby enhancing the understanding of automatic transmissions. The developed teaching aid simulated the behaviour of an actual automatic transmission, enabling users to experience and learn about its functioning and operation. Through hands-on activities, students and enthusiasts gained practical knowledge and a deeper understanding of automatic gearboxes, enhancing their overall learning experience.

The evaluation of the developed teaching aid demonstrated its effectiveness in achieving the intended experimental and educational outcomes. The students' performance and engagement improved, as the teaching aid provided a visual and interactive learning platform. By aligning the learning objectives with the teaching aid's capabilities, students grasp key concepts and develop essential skills related to automatic transmissions. The conceptual design of project was done through SolidWorks, a CAD modelling software. Fabrication and performance evaluation of the teaching aid was subsequently carried by administering questionnaires to group of students used as case study and the aim and objectives of the project was achieved.

Based on analysis, the visualization provided an extensive view of the effectiveness and usability of the AGTS teaching aid. The data also suggested that the teaching aid was impactful and enlightening to the students, with some areas suggested for enhancement. it is recommended that the developed teaching aid be implemented in automotive training programs and educational institutions. The incorporation of this teaching aid can greatly enhance the teaching and learning process, making it more interactive, engaging, and effective. However, as a recommendation for future studies, further improvement of the key areas of the visual aid can be explored.

Compliance with ethical standards

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Disclosure of conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Authors contribution

- K. Ejalonibu (Writing - original draft; Materials; Methodology; Software; Conceptualization)

- M. A. Olaomi (Writing – review & editing; Methodology; Software; Data Curation)
- T. I. Ogedengbe (Supervision; Writing - review & editing; Validation)
- A. Rasheed (Project Administration; Funding Acquisition)
- B. Osasona (Methodology; Supervision)

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