



Redesigning Automotive Tool: Usability of an Improvised Combination Wrench for Practical Education

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ABSTRACT

The automotive industry's rapid technological shift presents a challenge for vocational education, as traditional tools may not align with modern needs. Thus, this study evaluates the acceptability of an Improvised Combination Wrench (ICW) as a cost-effective instructional tool for automotive technology. Using a mixed-methods approach with 60 participants (students, instructors, and experts) the research assessed the tool's design, functionality, and safety. The findings indicate the ICW is highly acceptable and usable, with high ratings for its functionality (grand mean: 4.60), aesthetics (4.63), and users' safety (4.63). It is consistently perceived the tool as a natural extension of the hand, appreciating its effectiveness, durability, and ergonomic design. However, a significant difference in perception was found among the three user groups ($F=166.1522$, $p<.001$), highlighting varied views based on experience. The main challenges identified were a lack of sufficient torque, non-standard sizing, and tool slippage. In conclusion, the ICW is a viable and effective teaching tool despite these limitations. It is recommended that the university formally adopt a standardized, redesigned version of the wrench, with enhancements to address the identified challenges, and implement a comprehensive training module to ensure its proper and safe use in the curriculum.

Keywords

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Technology Education
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Introduction

The global automotive sector is undergoing an unprecedented transformation, driven by rapid technological evolution, shifting market forces, and the reorganization of global supply chains [1]. This period of change is characterized by a major shift toward electrified and software-defined vehicles, which demand new methods of product development and integration into digital ecosystems. Concurrently, evolving market dynamics (including the entry of new players and non-traditional companies) and changing consumer preferences toward shared mobility services are pressuring established manufacturers to innovate [2], [3]. These industry-wide shifts necessitate a fundamental re-evaluation of the skills and tools required for maintenance, repair, and foundational knowledge in the modern automotive environment.

This profound sectoral transformation directly impacts technical and vocational training programs. As vehicles become more complex and integrated with advanced systems, the tools and competencies required in the workshop are also changing rapidly. Educational institutions, especially those in resource-constrained settings, often face challenges in acquiring and maintaining state-of-the-art equipment [4], [5]. Consequently, instructors and learners frequently rely on improvised tools, such as wrenches fabricated from local or repurposed materials, to bridge the equipment gap. While these makeshift instruments offer a cost-effective solution, their true instructional value is not guaranteed by affordability alone; rather, it hinges on their usability and acceptance by the students who must utilize them for hands-on learning [6].

The successful integration of any tool, whether commercially produced or locally improvised, into a vocational curriculum depends first and foremost on its acceptability to the learners [7], [8]. If a tool is perceived as unreliable, cumbersome, or ineffective, students will be reluctant to use it consistently, thereby undermining opportunities for essential skill development and practical application. Conversely, a design that addresses the qualities students value (such as accurate performance, intuitive handling, and consistent reliability) can foster confidence and a behavioral intention to adopt the tool in future work [9], [10].

Despite the pervasive use of improvised workshop instruments in practical education, no comprehensive effort has critically evaluated these implementations through the rigorous lens of user acceptance and usability. The prevailing focus has often been limited to cost-savings or basic function, overlooking the critical student perspective which determines actual integration into practice. Without empirical evidence on user perception, curriculum developers lack the necessary guidance to make informed investment decisions regarding tool fabrication, redesign, or acquisition.

Hence, the current study addresses this critical research gap by focusing on the usability of an improvised combination wrench used for practical education. A locally-fabricated combination wrench based on user-centered principles was redesigned and then empirically assessed its acceptability among automotive students [7], [11]. Through structured measurement of student perceptions, the research explores how learners view the tool's usefulness for completing standard workshop tasks, how easily they can manipulate it under typical instructional conditions, and whether they form a strong intention to adopt the tool in subsequent exercises.

By foregrounding acceptability and student experience rather than solely cost or rudimentary ergonomics, this research offers a practical pathway for resource-limited institutions to enhance the effectiveness of their hands-on automotive training. The resulting design recommendations and empirical insights are intended to help technical educators make data-driven decisions about tool development and integration, ultimately contributing to a more effective preparation of students for industry readiness.

Literature Review

A. Foundational Role of Ergonomics and User-Centric Design

Effective tool usability involves assessing the functional needs and user experience of various tools, such as the finding that various wrenches like manual "clicker" and powered hydraulic/pneumatic tools apply axial load to Bolted Flanged Joint Assemblies (BFJA's) and this paper analyzes their accuracy against standards [12]. Furthermore, handle design influences comfort, as evidenced by the finding that handle diameter didn't affect torque strength, but 3cm diameter improved comfort, and higher torque was achieved with a 1.0SS handle distance, in the frontal plane, and at shoulder/knuckle heights [13]. In any fastening task, the underlying components matter, as threaded fasteners are popular because they are cheap, easy to use for assembly/disassembly, join diverse materials, and provide necessary clamp force to prevent failure modes like leakage [14]. Hence, tools must be engineered from a user-centered perspective, as design elements directly dictate tool comfort, precision, and efficiency during maintenance tasks.

B. Safety, Performance, and Physiological Advantage

Focusing on safety outcomes, assembly quality greatly impacts final products in precision industries; defects from personnel oversight can cause product malfunction and potentially lead to user loss of life or property [15]. To counter these risks, the diagrammatic, tabular, and textual information is intended for workshop personnel and engineers, focusing on agricultural engineering safety to highlight adherence and prevent common workshop accidents [16]. Overall,

addressing both design and process is vital, since Lean Manufacturing often overlooks worker impact, and companies use Risk Management to assess injury risk; integrating Lean and Ergonomics is vital to simultaneously boost productivity and improve working conditions [2]. Nevertheless, integrating ergonomics is non-negotiable for improving safety and performance, directly contributing to user health and reducing costly assembly defects.

C. Data-Driven Assessment and Digital Evaluation

Digital methods provide crucial, objective performance data, starting with the fact that analysis of manual nut wrench testing schemes leads to a proposed improved bench test, and this scheme uses a device to simulate the operator's action during nut/bolt fastening and unfastening [17]. For process observation, a novel online pipeline recognizes handheld tools in two stages: using skeletal data to find the wrist/ROI, then cropping and classifying the tool within that specific area [18]. Additionally, the torque sensor measures time delay from shaft twist using a counter IC, enabling real-time, noise-free digital torque and rotation speed measurement even at high speeds [19]. Ultimately, this precise data collection aims to improve process control, with an IMU and neural network system hypothesized to detect assembly micro-activities, which will reduce product errors, provide real-time quality control assistance to workers, and map the assembly workflow stages [7]. Somehow, utilizing digital, real-time data from tools and motion tracking is essential for objective usability assessment and minimizing assembly errors.

D. Cognitive and Behavioral Integration in Usability

Beyond commercial tools, the usability of redesigned, specialized instruments is also tested; for instance, the adjustable wrench's design utilized CAD and FEA, with fabrication and testing assessing load-bearing capacity and durability, confirming suitability for light-to-medium-duty applications [20]. For consistent results, torque wrench values met manufacturer standards and the handheld driver and torque wrench showed insignificant internal thread change differences, with post-treatment values varying slightly (ANOVA $p < 0.01$) [21]. A key element in design is error reduction, illustrated by the project that engineered a digital torque wrench with a real-time tracker for aircraft maintenance, significantly reducing human error in rotation counting and torque value checks [3]. Finally, the process of using the tool is guided by clear procedures, and assembly instructions require an assembly sequence and visual illustrations; designers currently define the sequence manually, and illustrations are costly to generate without feasibility checks [22]. Nonetheless, a new tool's design must holistically address user experience, combining mechanical superiority with intuitive usability and clarity of procedure.

E. Alignment with Modern Vocational Education

The need for automotive education stems from societal needs, as cars are now a necessity for families, providing transport for daily chores, commuting, reaching various destinations, and

delivering items over greater distances [23]. However, educational institutions face challenges, as a descriptive survey assessed mechanical engineering workshop facilities in technical colleges across North Central States, Nigeria, guided by two questions using 113 teachers and instructors [24]. These challenges are compounded by resource gaps, since laboratory facility gaps between vocational high schools and colleges hinder learning; this paper assesses the condition and availability of automotive practice labs, particularly workshop equipment and SSTs, to understand the disparity [4]. Addressing these gaps requires incorporating modern methods; for example, emerging technology (new or developing) is studied comparatively to assess its impact against conventional tools and processes in an automotive service industry like Toyota Dasmarinas-Cavite [1].

Virtual reality is a key modern tool, as immersive VR assembly training success depends on multiple factors, and a field study comparing VR-trained workers to conventionally trained ones showed positive skill transfer and performance improvement over time [10]. Moreover, Virtual Reality has broad educational potential, reducing costs and increasing engagement, and this project utilizes the Unity 3D engine to develop VR software for simulated car engine disassembly and assembly training [25]. Ultimately, these educational efforts aim for real-world application, demonstrated by practical work at PT Suzuki Indomobil Motor focused on car body assembly, where students learned the automotive industry's work system and assembly methods via sequential assembly and adherence to SOPs [26]. Therefore, addressing lab facility gaps and integrating immersive technology like VR are necessary steps to enhance practical education and student industry readiness.

Over and above, the comprehensive literature review establishes that ergonomics and user-centric design are foundational for ensuring tool safety and performance. This design process relies on data-driven digital assessment for objective validation, while success in training requires integrating cognitive and behavioral usability factors. Ultimately, these steps align the redesigned wrench's features with the goals of modern vocational education, preparing students for industry readiness.

Methods

A. Rationale of Innovation

The Improvised Combination Wrench (ICW) project addresses a critical pedagogical and economic constraint in technical education. Specifically, the high acquisition cost and limited accessibility of commercially manufactured tools often impede practical skill development in automotive technology curricula. This barrier restricts students' exposure to essential hands-on training, directly affecting their proficiency as future mechanics and technicians. The ICW,

therefore, is driven by the need to develop a cost-effective, hands-on instructional solution that simultaneously mitigates these economic disadvantages and enhances learning outcomes. The innovation involves the deliberate utilization of readily available or repurposed materials in its fabrication. This approach fosters a deeper, holistic understanding that transcends simple tool usage, compelling students to grasp fundamental principles of design, material science, and engineering fabrication. By integrating this sustainable and pragmatic approach, the project not only offers an accessible training tool but also instills critical thinking regarding tool engineering, functionality, and resource management, which is paramount for innovation in the field. The primary objective of this work is to formally recommend the integration of the redesigned wrench as a sustainable, technically effective, and pedagogically sound component within the existing automotive technology curriculum.

B. Materials

The fabrication of the Improved Combination Wrench (ICW) utilized a defined set of materials, primarily consisting of donor tools and structural components. The core of the design involved modifying one heavy-duty box wrench and one heavy-duty open wrench, which served as the base jaw elements. The primary structural material was a steel flat bar, specified at 1 inch by 12 inches with a thickness of 1/8 inch. Fastening elements included one ordinary 5mm by 50mm bolt and two corresponding 5mm hexagonal nuts, along with four 2mm by 6mm screws for supplementary connections. The assembly process required 0.5kg of welding rod for permanent joining. Finally, the tool's finish was achieved using one piece of sandpaper for surface preparation and a single lot of paint and associated accessories for corrosion protection and visual identification.

C. Shop Drawings

Both Fig. 1 and Fig. 2 illustrate the detailed design of the Improved Combination Wrench (ICW), a tool essential for automotive work, particularly for the loosening and tightening of bolts. The system's dimensions are 437.5mm (width), 63mm (height), and 92 mm (depth), reflecting its compact nature. This compact design allows users to tighten and loosen bolts by simply adjusting the screws, eliminating the need for frequent tool changes. The top view in the technical drawing displays the organized arrangement of internal components. It also indicates that the parts are placed safely and compactly within the assembly, ensuring adequate internal clearance. As shown in the front view, the wrench tips are arranged in a compact design, emphasizing both accessibility and organization.

Also, the wrench's head features a V-grooved and flat surface jaw designed to firmly grip various hexagonal and square bolt heads. A tapered neck connects the head to the handle, a feature that improves structural integrity and optimizes force distribution during operation. The

tool is adjustable via a sliding jaw that traverses the handle's threaded shaft, allowing it to accommodate different fastener sizes. The handle incorporates an ergonomic design with a textured grip, which effectively minimizes slippage and ensures comfortable use. The design mixes an integrated ruler on the handle, which facilitates quick and convenient measurement of bolt sizes.

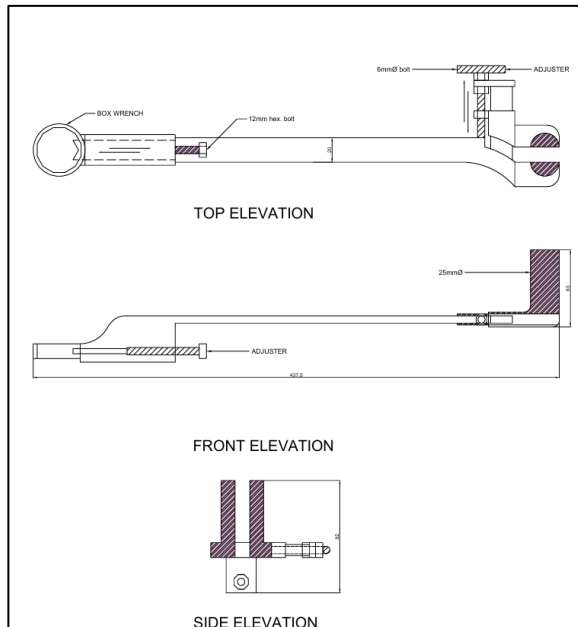


Fig. 1. The detailed design 1

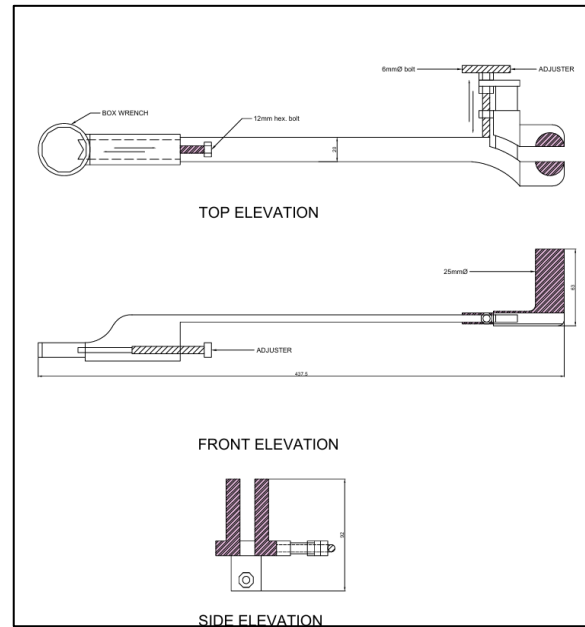


Fig. 2. The detailed design 2

D. Fabrication Process

The fabrication of the Improved Combination Wrench (ICW) commences with the meticulous preparation and laying out of materials, where all structural components, donor tools, and auxiliary hardware are collected and positioned onto the workbench. This initial phase is crucial for ensuring resource availability prior to commencement. Following preparation, the overall process flows through a defined sequence: laying out and cutting, mounting, assembling, and testing. Specifically, the researcher undertakes the hand-fabrication of the ICW components, beginning with the accurate marking and sizing of the structural steel flat bar and the subsequent preparation of the heavy-duty box and open wrench heads, which serve as the base jaw elements, setting the stage for subsequent physical integration and final adjustment. For purpose of viewing the finished product, Fig. 3 is exhibited below, too.



Fig. 3. Final Product

E. Research Design

The study utilized a mixed-methods research design, incorporating both descriptive and experimental methods to evaluate the development of an improvised adjustable open-ended wrench. The descriptive component documented the process of redesigning and fabricating the tool. This included detailed specification of the tool's technical design, materials, production procedures, and estimated manufacturing cost. To ensure the design's practicality for educational settings, technical details were refined through consultation with professional workshop supervisors. Prior to experimental testing, a survey instrument was administered to gather feedback for subsequent refinement and validation of the tool.

F. Research Environment

The investigation was conducted within the facilities of a large, government-funded institution of higher learning located in a highly populated urban center. The selection of a prominent campus in this urban area was undertaken to capture the diverse perspectives and cultural dynamics present across various university settings, thereby providing a more representative context for the study's underlying motives. The institution is recognized as a top-tier, autonomous university system with a multitude of satellite and extension campuses, indicating a broad geographic and demographic reach. The study's premise was that relying on the culture of a single institution would not provide a complete understanding of the necessary information.

G. Respondents

The study participants comprised subject-matter experts and a group of student end-users. The experts included instructors from academic technology and education departments, as well as technical personnel with professional experience in the automotive industry. These experts provided critical insight into the improvised tool's design and operational functionality. Additionally, a sample of at least 50 students from both the technology and education

departments participated in an experimental task. These students were instructed to use the newly fabricated adjustable wrench to assemble and disassemble an engine's cylinder head. The data collected from the students' usage was subjected to appropriate statistical analysis to evaluate the tool's usability and overall effectiveness. In total, the study involved 5 expert instructors, 5 industry technical experts, and 50 student users

H. Research Instrument

To achieve the research objectives, a custom-developed survey instrument served as the principal method for data acquisition. The instrument's development was grounded in a comprehensive review of relevant literature, particularly the Technology Acceptance Model (TAM), and an analysis of information concerning improvised tool design. This rigorous approach ensured the instrument's theoretical relevance and empirical soundness for systematically collecting data on the improvised wrench's design specifications, aesthetics, operational functionality, safety features, and user acceptance.

The survey was structured into multiple sections, each designed to address a specific research inquiry. Initial sections focused on the tool's foundational attributes, such as technical requirements, constituent materials, and aesthetic properties (e.g., balance and visual appeal). The core of the questionnaire utilized the TAM framework to quantify user perceptions, assessing perceived usefulness, ease of use, attitude toward use, and intention for continued use. Moreover, the instrument included specialized sections dedicated to evaluating user-perceived risks, reliability, and ergonomic comfort, along with open-ended questions concerning specific challenges encountered and user-applied coping mechanisms. This multi-faceted structure facilitated a holistic evaluation of the improvised wrench's acceptability.

I. Data Gathering

The data collection process commenced with the submission of a formal request letter to the head administrator of the university's main campus, seeking permission to conduct the study. The request included a copy of the research-developed questionnaire pertaining to the improvised adjustable open-ended wrench. Following administrative approval, the principal investigator personally administered the survey to the selected students, instructors, and technical experts. Prior to the completion of the instrument, the investigator provided a detailed explanation of the study's purpose and demonstrated the operational mechanism of the improvised tool. This ensured all participants possessed a clear understanding of the research context and the instrument under evaluation.

Upon completion, the survey forms were immediately collected by the investigator and prepared for subsequent analysis. The accumulated feedback from the student, instructor, and technical expert groups was used to assess the improvised wrench's performance metrics and

utility within the institution's automotive training facility. This data collection phase, conducted within the university's designated automotive workshop, provided valuable empirical feedback essential for refining the hands-on learning experience and ensuring the successful pedagogical integration of the redesigned tool.

J. Data Treatment and Analysis

The empirical data collected via the survey instrument underwent standard preparatory procedures, including tallying, collation, and tabulation. Subsequently, the data was subjected to various statistical treatments, which included frequency counts, simple percentage calculations, weighted mean determination, ranking procedures, and analysis of variance (ANOVA).

K. Ethical Standards

The study adhered to rigorous ethical standards throughout all phases of the research. Prior to any data collection, formal permission was secured from the relevant institutional administrative bodies. All participants were provided with a comprehensive consent form detailing the study's purpose, the nature of their involvement, the expected duration of their participation, and the assurance that their involvement was entirely voluntary. Participants were explicitly informed of their right to withdraw at any point without penalty. Data handling procedures were designed to ensure confidentiality and security, with all collected information being used solely for research purposes and stored in locked or password-protected environments accessible only to the research team.

L. Anonymity Clause

To protect the privacy and identity of all individuals involved, strict anonymity protocols were implemented. No personally identifiable information (e.g., names, specific employee IDs, or departmental locations) was collected or recorded alongside the survey responses or experimental data. Responses from instructors, technical experts, and students were aggregated and reported only in statistical summaries (e.g., means, frequencies), ensuring that no single response could be traced back to an individual person or specific educational unit. The institution's name and its specific campus locations were similarly generalized in the final reporting (as evident in the "Environment" section) to prevent any deductive identification of the setting and its staff or students, thereby safeguarding participant privacy and the institutional context.

Results

The following tables present a comprehensive analysis of an improvised combination wrench developed for educational training. Table 1 outlines the tool's design and technical specifications, while Tables 2 and 3 examine its acceptability and usability through the

Technology Acceptance Model and user feedback. Table 4 identifies key challenges students encountered during practical application, and Table 5 documents the coping strategies they employed to address these difficulties, providing insights into the tool's real-world effectiveness and limitations.

Table 1. Design & technical specifications for the improvised combination wrench

Item	Indicators	$\bar{x}$	Description
1	Technical requirements as to tool design; materials & cost; and fabrication and assembly processes.	4.57	Strongly Agree
2	Aesthetic Values in terms of balance; color, shape & proportionality; movement & handling efficiency.	4.62	Strongly Agree
3	Functionality as to effectiveness in performing automotive tasks; durability; and ease of use.	4.60	Strongly Agree
<i>Overall</i>		4.60	Strongly Agree

Legend: 4.21 – 5.00 Strongly Agree, 3.41 – 4.20 Agree, 2.61 – 3.40 Neutral, 1.81 – 2.60 Disagree, 1.00 – 1.80 Strongly Disagree

Table 1 presents the technical requirements on tools design with indicators on precision-machined heads prevent slippage; ergonomic handle ensures comfort; dual-purpose design offers speed and torque; stress-distributed shape; versatile ratcheting features. Also, for materials and costs, the survey has covered how high-carbon alloy steel ensures durability; protective coating prevents corrosion; balances hardness with toughness; bulk purchasing reduces costs; abrasion-resistant finish. Additionally, as to the fabrication and assembly process, the indicators cover the hot-forging strengthens metal; multi-stage heat treatment balances properties; precision machining ensures accurate fit; grinding removes burrs; rigorous quality control standards.

On the other hand, with regards to the aesthetic values, such technical requirement covers the indicators for balance where evenly distributed weight provides stability; harmonious proportions align components; visual center matches hand placement; smooth transitions create fluidity; perfect physical-visual harmony. As to the cost, shape & proportionality, these indicators point out how chrome finish provides protection and sleek appearance; flowing shape suggests power; scaled proportions feel substantial; quality materials communicate strength; etched markings add elegance. Part of it is the component on movement and handling efficiency, such that the indicators cover how curved handle fits hand naturally; polished finish enables quick repositioning; streamlined form promotes fluid motion; balanced design ensures agility; reduces fatigue.

The last technical requirement on functionality, particularly for the component on effectiveness in performing automotive tasks, peeks into how dual-purpose head enables quick fastening and high-torque; streamlined form accesses confined spaces; precision machining

prevents damage; versatile repair tool; useful everywhere. Likewise, durability as a component looks into how chrome vanadium steel ensures durability; protective coating prevents rust; engineered shape distributes stress; balances hardness with toughness; rigorous quality control. The component on ease of use, however, does dig into how ergonomic handle reduces fatigue; dual-end design eliminates switching; smooth surface enables repositioning; intuitive natural design; balanced weight enhances responsiveness.

Table 2. Acceptability of the Improvised Combination Wrench as to TAM model

Item	Indicators	$\bar{x}$	Description
1	Functionality in terms of usefulness; ease of use; attitude towards using the tool; and intention to continue using the tool in future tasks.	4.60	Strongly Agree
2	Safety component as to aspects on risks; reliability and comfort during use of such tool.	4.61	Strongly Agree
<i>Overall</i>		4.61	Strongly Agree

Legend: 4.21 – 5.00 Strongly Agree, 3.41 – 4.20 Agree, 2.61 – 3.40 Neutral, 1.81 – 2.60 Disagree, 1.00 – 1.80 Strongly Disagree

For Table 2, the functionality in terms of usefulness covers those indicators along dual-purpose head effective for automotive tasks; precision machining reduces fastener damage; indispensable for repairs; saves time; improves work quality reliably. On the indicators for ease of use, they look into how balanced weight enables easy handling; ergonomic handle reduces fatigue; intuitive design requires minimal instruction; smooth shape accesses tight spaces; enhances dexterity. Also, the component on attitude towards using the tools covers the indicators involving how favorable attitude due to form-function blend; aesthetic design enhances enjoyment; creates satisfaction and professionalism; enjoy using tool; feel confident working. For such aspect on intention to continue, its indicators peek how users will utilize repeatedly due to high satisfaction; intends making it go-to tool; unlikely seeking alternatives; willingly recommend to others; long-term toolkit solution.

Nonetheless, the safety component covers the aspect on risk where the indicators concerning minimal perceived risks due to high-quality construction; protective coating prevents rust; engineered design prevents deformation; material prevents snapping; quality control ensures safe performance. At the same time, the aspect on reliability and comfort ganders into how durable materials foster long-term trust; confident in consistent performance; ergonomic design provides comfortable grip; smooth shape enhances fluid experience; creates user competence.

Table 3. Probe on Acceptability & Usability of Improvised Combination Wrench

Variables under Statistical Inference	F-statistics	p-value	Decision	Interpretation
Comparative inference on the reliability & comfort using the Improvised Combination Wrench per evaluation made among industry experts, instructors and students in automotive	166.1522	7.75x10 ⁻⁴⁵	Reject the null hypothesis	Significant

*Significant at $p < 0.05$ (two-tailed)

On the other hand, this table examines the comparative assessment of reliability and comfort when using the Improvised Combination Wrench. The evaluation incorporates perspectives from three distinct groups: industry experts, instructors, and students in automotive fields. The analysis explores how these different evaluator groups perceive the tool's acceptability and usability, focusing specifically on reliability and comfort aspects during practical application and testing scenarios.

Table 4. Challenges encountered during the Use of Improvised Open Wrench in Training

Item	Indicators	$\bar{x}$	Rank
1	The improvised wrench's non-standard size makes it difficult to fit certain nuts and bolts.	2.60	2
2	I struggle to apply sufficient torque, as the handle's length and grip are not optimized for leverage.	2.23	1
3	The tool's lack of a polished finish and precise machining causes it to slip, risking injury or fastener damage.	3.10	3
4	The improvised design lacks a ratcheting mechanism, making it inefficient for use in tight or hard-to-reach spaces.	3.98	4
5	The wrench's weight distribution is unbalanced, resulting in hand fatigue during prolonged use.	4.92	5
6	The absence of clear size markings or a color-coding system confuses and requires constant measurement.	6.00	6
7	The material used in the improvised wrench is prone to bending or breaking under heavy load.	6.97	7
8	Its bulky shape prevents users from accessing recessed bolts and nuts.	7.70	8
9	The improvised nature of the tool raises concerns about its long-term durability and reliability.	8.75	10
10	The wrench's rough edges and uneven surfaces are uncomfortable to grip, leading to blisters or a loss of control.	8.70	9

As regards this table, it ranks ten challenges of using improvised open wrenches in training. Top concerns include difficulty applying sufficient torque due to poor handle design, non-standard sizing affecting nut/bolt fit, and lack of polished finish causing slippage. Other issues involve missing ratcheting mechanisms, unbalanced weight distribution, absent size markings, material weakness, bulky design limiting access, durability concerns, and uncomfortable rough edges.

Table 5. Coping Strategies applied by Student-Respondents to address the Challenges

Item	Indicators	$\bar{x}$	Rank
1	Use a caliper or standard wrench to confirm the correct size before use.	3.58	3
2	Permanently mark the wrench with its size to avoid repeated measurements.	2.42	1
3	Use both hands and take frequent breaks to manage the tool's unbalanced weight.	3.30	2
4	Wrap the handle with tape or cloth for a better grip and always wear gloves.	4.07	4
5	Slide a pipe or another wrench over the handle to increase leverage and apply more torque.	5.18	6
6	File or grind the jaws for a better fit and ensure the wrench is fully seated on the fastener.	5.10	5
7	In tight spaces, turn the wrench and re-engage from a new angle to mimic a ratcheting motion.	6.92	7
8	Combine the wrench with a socket or extension bar to reach recessed fasteners.	7.43	8
9	Avoid high-torque applications; use the wrench only for lighter tasks.	8.62	10
10	Visually inspect the wrench for wear or damage before each use and treat it as a backup tool.	8.38	9

As can be gleaned, the table ranks ten coping strategies students use to address improvised wrench challenges. Top strategies include permanently marking the wrench with its size, using both hands with frequent breaks for unbalanced weight, and confirming correct size with calipers beforehand. Other approaches involve wrapping handles for better grip, extending leverage with pipes, grinding jaws for fit, repositioning in tight spaces, using extensions, limiting to lighter tasks, and inspecting before use.

Discussion

A. Design & technical specifications for the improvised combination wrench

The improvised combination wrench received consistently high ratings across all three technical requirement categories, with mean scores ranging from 4.57 to 4.62 on a 5-point scale, yielding an overall mean of 4.60 (Strongly Agree). Technical requirements regarding tool design, materials/cost, and fabrication processes scored 4.57, aesthetic values including balance, color/shape, and handling efficiency achieved 4.62, and functionality encompassing task effectiveness, durability, and ease of use obtained 4.60. All indicators fell within the 4.21-5.00 range, indicating strong agreement from respondents regarding the tool's technical adequacy.

These results demonstrate that the improvised combination wrench successfully meets professional standards across design, aesthetics, and functionality dimensions. The marginally higher score for aesthetic values (4.62) suggests that respondents particularly appreciated the tool's visual and ergonomic qualities—including chrome finish, balanced weight distribution, and curved handle design—which create both functional and psychological satisfaction. The near-uniform scores across all three categories indicate holistic design success, where technical precision (precision-machined heads, hot-forging processes), material quality (high-carbon alloy

steel, protective coating), and user-centered features (ergonomic handles, dual-purpose design) work synergistically to create a well-rounded tool that addresses multiple stakeholder concerns simultaneously.

B. Acceptability of the Improvised Combination Wrench as to TAM model Table

The Technology Acceptance Model (TAM) evaluation of the improvised combination wrench yielded exceptionally high acceptability ratings, with an overall mean of 4.61 (Strongly Agree). Functionality (encompassing usefulness, ease of use, attitude towards the tool, and intention to continue use) scored 4.60, while the safety component addressing risk mitigation, reliability, and comfort achieved a slightly higher rating of 4.61. Both dimensions exceeded the 4.21 threshold for "Strongly Agree," with minimal variance between the two primary acceptance factors, suggesting balanced user perception across practical and safety-related concerns.

The TAM results indicate robust user acceptance driven by both utilitarian and affective factors. The high functionality score reflects users' recognition of the tool's practical value (its dual-purpose head effectiveness, time-saving capabilities, and work quality improvements) combined with positive attitudes stemming from the form-function blend and professional satisfaction it generates. The marginally higher safety rating (4.61) is particularly significant, as it demonstrates that users perceive minimal risk despite the tool's improvised nature, owing to high-quality construction, protective coatings, and engineered stress distribution. The strong intention-to-continue indicators reveal that users plan to adopt this tool as their go-to solution and willingly recommend it to others, signaling genuine market viability beyond initial trial acceptance.

C. Probe on Acceptability & Usability of Improvised Combination Wrench Table

The one-way ANOVA comparing reliability and comfort perceptions across industry experts, instructors, and students yielded an F-statistic of 166.1522 with an extremely low p-value of 7.75×10^{-45} ($p < 0.05$), leading to rejection of the null hypothesis. This statistical outcome indicates highly significant differences exist among the three evaluator groups in their assessments of the improvised combination wrench's reliability and comfort during practical application and testing scenarios.

The substantial F-statistic and infinitesimally small p-value reveal that evaluator expertise level systematically influences perceptions of tool reliability and comfort, suggesting that professional experience shapes assessment criteria and expectations. Industry experts, with extensive field experience and exposure to premium commercial tools, likely apply more stringent evaluation standards and detect nuances in performance that students or even instructors might overlook. Conversely, students with limited comparative experience may rate the tool more generously, while instructors occupy a middle position with theoretical knowledge

and moderate practical exposure. This stratification indicates that acceptability is not monolithic but rather context-dependent, with different stakeholder groups prioritizing different attributes based on their professional maturity and experiential backgrounds.

D. Challenges encountered during the Use of Improvised Open Wrench in Training Table

The ranking of ten challenges reveals a clear hierarchy of issues encountered when using improvised open wrenches in training contexts. The most critical challenge (rank 1) is difficulty applying sufficient torque due to suboptimal handle design and leverage (mean rank 2.23), followed by non-standard sizing affecting nut/bolt compatibility (rank 2, mean 2.60) and lack of polished finish causing slippage risks (rank 3, mean 3.10). Mid-tier challenges include absence of ratcheting mechanisms (rank 4, mean 3.98) and unbalanced weight distribution causing fatigue (rank 5, mean 4.92). Lower-priority concerns encompass missing size markings (rank 6), material weakness (rank 7), bulky design limiting access (rank 8), uncomfortable rough edges (rank 9), and durability concerns (rank 10, mean 8.75).

The challenge hierarchy reveals that functional performance deficits, particularly torque application, dimensional accuracy, and surface quality, pose more immediate operational barriers than aesthetic or long-term durability concerns. The top-ranked torque challenge directly impacts task completion effectiveness, suggesting that ergonomic handle optimization is critical for user acceptance regardless of other design features. The prominence of non-standard sizing and slippage issues indicates that precision manufacturing and finishing processes cannot be compromised even in improvised tool development, as these factors directly affect work quality and safety. Interestingly, durability concerns rank lowest (rank 10) despite being a common assumption about improvised tools, suggesting that users prioritize immediate functional performance over theoretical longevity, or that the tool's material quality adequately addresses durability fears. The middle-ranking of weight distribution and ratcheting mechanism challenges indicates these are significant but not deal-breaking limitations.

E. Coping Strategies applied by Student-Respondents to address the Challenges

Students employ ten distinct coping strategies to address improvised wrench limitations, with clear preference patterns emerging from the ranking data. The most favored strategy (rank 1) is permanently marking the wrench with size information to avoid repeated measurements (mean rank 2.42), followed by using both hands with frequent breaks for weight management (rank 2, mean 3.30) and pre-use size confirmation with calipers (rank 3, mean 3.58). Mid-tier strategies include handle wrapping for grip improvement (rank 4), jaw grinding for better fit (rank 5), and leverage extension with pipes (rank 6). Less preferred approaches involve repositioning to mimic ratcheting (rank 7), using extensions for access (rank 8), visual inspection protocols (rank 9), and limiting the tool to lighter applications (rank 10, mean 8.62).

The strategy preferences reveal a pragmatic, efficiency-focused adaptation pattern where students favor preventive, preparatory solutions over reactive or restrictive approaches. The top-ranked permanent marking strategy directly addresses the sixth-ranked challenge (missing size markings) with minimal ongoing effort, demonstrating student preference for one-time interventions that yield continuous benefits. The prominence of ergonomic adaptations (both-handed use, handle wrapping) in ranks 2-4 shows recognition of fatigue and grip challenges, while the relatively low ranking of restriction-based strategies (rank 10: limiting to lighter tasks) indicates students' desire to maintain tool utility despite limitations. The middle-tier positioning of physical modifications (grinding jaws, extending handles) suggests students balance improvement potential against implementation difficulty. Notably, compensatory techniques requiring repeated effort (repositioning for ratcheting effect, visual inspections) rank lower, indicating preference for sustainable solutions over labor-intensive workarounds.

Conclusion

After such empirical investigations, clearly, the improvised combination wrench demonstrates strong technical specifications and high user acceptability across functionality and safety dimensions, validated through TAM assessment. However, significant perception differences exist among evaluator groups, while torque application, sizing accuracy, and surface finish remain primary challenges. Students effectively employ adaptive coping strategies, particularly preventive solutions like permanent marking and ergonomic modifications, demonstrating resourceful problem-solving capabilities essential for professional automotive practice.

Conflict of Interest

The authors declare no conflict of interest.

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