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Development of a Multi-CartClimb for Automotive Technology Students at Vocational Colleges

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Abstract: This study focuses on the development and evaluation of an innovative product named Multi-CartClimb, a multifunctional piece of equipment that integrates the functions of a trolley and a ladder. Designed specifically for students in the Automotive Technology workshop at Kolej Vokasional Sungai Buloh, its primary aim is to enhance work efficiency, improve user safety, and optimize space utilization in limited technical workshop environments. The development process followed a user-centered design approach, incorporating needs analysis, prototype construction, and performance evaluation through hands-on testing and in-depth feedback sessions with students and instructors. Qualitative findings from expert interviews and user feedback indicate that the Multi-CartClimb effectively streamlines workshop tasks by combining two essential tools into a single unit, reducing workflow interruptions and improving workspace organization. Respondents consistently noted its suitability for vocational workshop settings, with particular appreciation for its compact, foldable design and potential as an educational tool for teaching engineering design, innovation, and problem-solving. The product was also perceived to enhance safety by reducing the risks associated with unstable ladders and the separate handling of heavy trolleys. However, several areas for improvement emerged from user experiences, including the product's weight, handle ergonomics, and stability on uneven surfaces. Recommendations include the adoption of lighter yet durable materials, the introduction of an adjustable handle for improved ergonomics, and enhancements to the wheel-locking and anti-slip features. Overall, the Multi-CartClimb demonstrates strong potential not only as a practical workshop solution but also as a valuable teaching aid that supports project-based learning and fosters technical innovation among vocational students.

Keywords: Multi-CartClimb, technical innovation, vocational education, product design, workshop safety, ergonomics

1. Introduction

Recent technological advancements have shown an increasing reliance on multifunctional equipment across various sectors, particularly in logistics, construction, and manufacturing industries. Prior studies, such as those by Anderson et al. (2019) and Oliveira & Santos (2020), have confirmed that the use of equipment like carts and ladders can significantly improve work efficiency, reduce operation time, and minimize the risk of workplace injuries. However, these studies primarily focus on industrial and commercial sectors, which have distinct operational requirements and user skill levels compared to vocational education settings.

Similarly, research from countries like the United States and Japan has emphasized the integration of multiple functionalities into single equipment units to optimize space usage and reduce long-term maintenance costs. Lee et al. (2020) and Muller & Schwarz (2021) reported that multifunctional tools can decrease storage space requirements by up to 25% and enhance overall organizational productivity. Despite these findings, the effectiveness of such tools within vocational institutions where students are still acquiring foundational technical skills—remains largely unexplored.

In South Korea, studies have highlighted that multifunctional mechanical structures, while innovative, often involve complex systems that can lead to higher repair costs when one component fails, as indicated by Kumar et al. (2021). This

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underscores the need for user-friendly, modular designs especially suited for educational settings where the users—students—require safe, intuitive, and cost-effective tools during their learning phase.

Meanwhile, Chinese research and development efforts in vocational training equipment have increasingly adopted ergonomic design principles to enhance safety and usability, particularly in high-risk training environments. The Ergonomic Research Group (2019) and PSA Research Team (2023) stressed that ergonomic considerations must be prioritized, especially in environments with repetitive interaction between users and tools. Nonetheless, these ergonomic advancements have yet to be fully translated into vocational education contexts—especially in automotive workshops—where limited space and inherent risks demand highly adaptable and secure equipment.

Recognizing this gap, the present study aims to develop the Multi-CartClimb, a multifunctional tool that integrates the functions of a cart and a ladder, specifically tailored for Automotive Technology students at Vocational Colleges. The product is designed based on a user-centered design approach**,** where feedback from the target users forms the foundation of the prototype's development and continuous refinement.

Overall, this study contributes to strengthening technical education by integrating ergonomic, safety, and economic considerations into product development. The innovation also demonstrates that industrial hardware design can be successfully adapted for educational purposes when real-world constraints and user needs are incorporated into the design process. As such, this research opens pathways for future applied and impactful studies in vocational education, in alignment with the demands of Industry 4.0**.**

2. Methodology

This section outlines the methodology used in developing the Multi-CartClimb, an innovative multifunctional tool designed for students in the Automotive Technology Program at Kolej Vokasional Sungai Buloh. The methodology is structured based on the ADDIE model, which consists of five systematic phases: Analysis, Design, Development, Implementation, and Evaluation. This model was selected to ensure that the product development process is well-organized, user-focused, and aligned with the intended educational outcomes.

In the analysis phase, the researchers identified the system requirements using two main methods: questionnaires and interviews. Online questionnaires were distributed via Google Forms to lecturers and program coordinators who were directly involved in the bus booking process. Additionally, interview sessions were conducted with the bus booking coordinator to gain deeper insights into the existing process, challenges faced, and specific system requirements. The design phase focused on developing the user interface, system navigation structure, and database schema. The application was built using the Flutter framework and supported by Firebase as the real-time database. All components were developed based on the initial analysis to ensure that the system met the actual needs of the target users.

2.1. ADDIE Model of Product Development

The development of the *Multi-CartClimb* was guided by the ADDIE model, which provided a structured framework for its creation. In the analysis phase, a needs assessment was conducted to identify user requirements through observations of the workshop environment, common student tasks, and existing challenges related to the use of separate workshop tools such as trolleys and ladders. This phase aimed to understand the practical issues students faced in managing multiple pieces of equipment.

In the design phase, initial sketches were produced using computer-aided design (CAD) software to conceptualize an integrated trolley-ladder unit that was safe, efficient, and user-friendly. Key design considerations included functionality, safety, space efficiency, and ease of use. The development phase involved constructing a working prototype using durable materials such as stainless steel and anti-slip padding, with ergonomics and mechanical strength prioritized to ensure suitability for actual workshop use.

During the implementation phase, the prototype was introduced into a real workshop environment to assess its performance under authentic conditions typical for automotive students. Finally, in the evaluation phase, feedback on the product's effectiveness, usability, and design was gathered from three workshop instructors with expertise in vehicle maintenance and workshop equipment, providing valuable insights for further refinement.

2.2 Research Instruments

The instruments used in the evaluation phase were developed specifically for this study to ensure alignment with the research objectives. These included an observation checklist, which was used by the researcher to document user behavior, time efficiency, and product performance during testing sessions, and an interview guide, designed to collect open-ended feedback from selected respondents regarding their experiences using the product and suggestions for improvement. The interviews were conducted face-to-face, each lasting approximately 45 minutes, and all sessions were audio-recorded to allow the data to be revisited and validated during the analysis stage. All instruments underwent expert review to ensure content validity. The feedback gathered during the evaluation phase contributed to the final refinement of the prototype and confirmed the practical value of the Multi-CartClimb within a vocational education setting.

2.3 Data Analysis Technique

Qualitative data collected from interviews and observations were analyzed using a thematic analysis approach. This allowed the researcher to identify recurring patterns, categories, and key themes related to the usage and potential improvements of the Multi-CartClimb. The combination of these analyses provided a comprehensive understanding of the product's effectiveness from the users' perspective.

3. Results

This section presents the findings from the development and evaluation of the Multi-CartClimb product and the drawing product as presented in Figure 1. The results include assessments of product functionality, user evaluation, and feedback on design and usability. Data were collected through observations, user testing, questionnaires, and interviews with target users at the Automotive Technology Workshop, Kolej Vokasional Sungai Buloh. Descriptive analysis was conducted to assess how well the research objectives were met and to identify the product's strengths and areas for improvement.

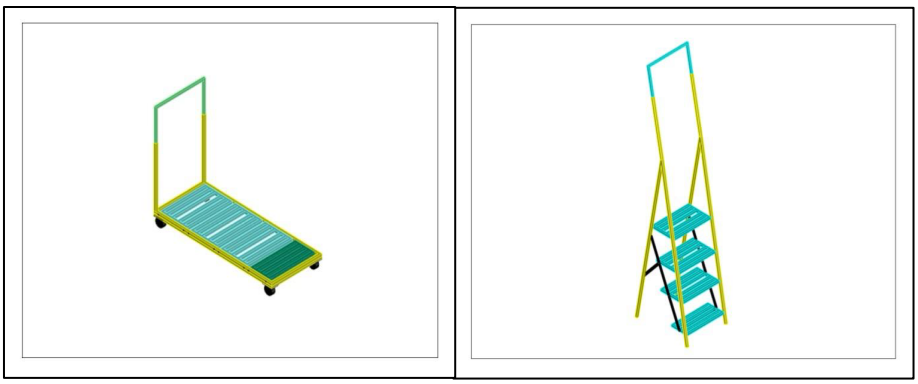


Figure 1. Multi-CartClimb

3.1 Product Functionality and Usability

Most users reported that the *Multi-CartClimb* was easy to operate and highly effective for tasks involving transportation and accessing elevated components—particularly during maintenance work on the upper parts of vehicles, such as roofs and suspension systems. Positive feedback was given on the product's dual function, as it eliminated the need to switch between a separate cart and ladder, thereby saving time and reducing workflow interruptions.

Respondents agreed that the design was well-suited to a vocational workshop environment and appreciated its compact, foldable structure, which optimized storage space. These findings were supported by R1, a senior workshop instructor with over 15 years of automotive repair experience, who remarked,

"This kind of tool saves time and reduces fatigue. We no longer need to fetch separate equipment just to reach the top or move heavy parts it really streamlines operations."

R3, a technician with more than 10 years of hands-on experience, also highlighted that combining both tools into one unit improved work efficiency and reduced safety risks.

3.2 Safety and Ergonomic Aspects

From a safety standpoint, users indicated that the *Multi-CartClimb* was stable during use, particularly when the ladder was fully extended and weight was evenly distributed. However, some

respondents raised concerns about stability on uneven workshop floors, pointing to the need for enhancements in the wheel-locking mechanism and anti-slip features.

Ergonomic feedback revealed that the handle design could be improved for greater comfort during pushing and pulling. Several students noted that the handle height did not accommodate all body sizes, suggesting an adjustable handle as a more inclusive design feature. **R3** reinforced this point, stating,

"The handle feels a bit high for shorter users if it could be adjusted, it would suit everyone better."

These observations align with survey findings, where users highlighted ergonomic issues, especially related to handle comfort and height.

3.3 Durability and Material Construction

Load testing was conducted to assess the structural durability of the prototype. The results showed that the product could withstand a maximum weight of up to 90 kilograms without any structural damage. However, it was noted that the use of galvanized steel made the product relatively heavy, making it more difficult to maneuver, especially for students with smaller builds or lower physical strength.

Respondents recommended replacing the current material with a lighter alternative, such as aluminum or stainless alloy, without compromising strength. This reflects user awareness of the need to balance durability and usability in real-world applications.

3.4 User Satisfaction and Suitability

Overall the experts view on the functionality, usability, and suitability in an automotive workshop is good. Users reported that the integrated tool streamlined workflows, reduced dependence on multiple separate tools, and minimized workspace congestion.

R2, a curriculum coordinator with 12 years of vocational training experience, emphasized the educational potential of the *Multi-CartClimb*:

"The Multi-CartClimb reflects real-world problem-solving. It can be a powerful project-based learning tool where students apply theory in practical contexts. Its compact design is suitable for training environments with limited space. It teaches students how design thinking can lead to practical innovation."

The space-saving design, and many students expressed interest in the product's development process—particularly in aspects such as user-centered design, material selection, and functional testing.

Figure 1 presents the qualitative analysis results from three (3) experterts. The findings indicated strong support for the need for an integrated cart-ladder innovation. The Multi-CartClimb aligns with the current needs of technical workshop environments and supports the broader innovation agenda in vocational education. This product not only fulfills operational requirements but also creates opportunities for project-based learning, where students can apply engineering theory to real-life situations.

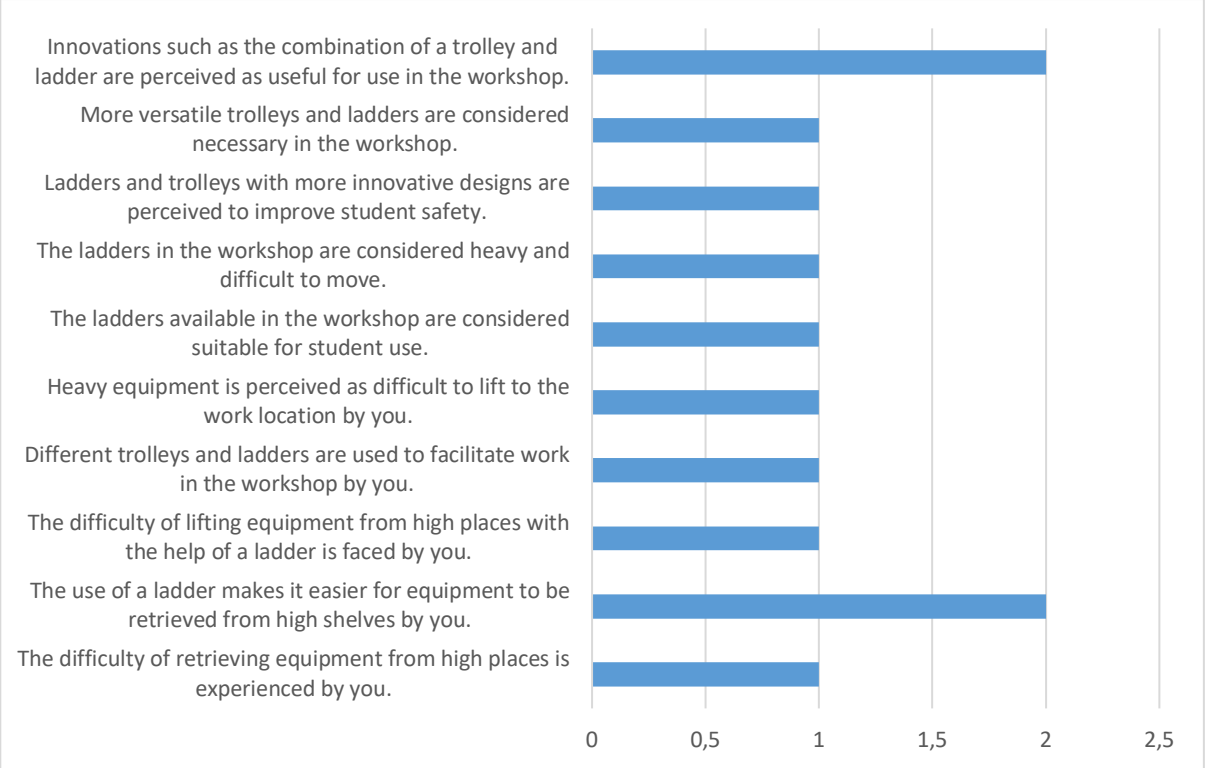


Fig. 1: Product Assessment

Discussion

Based on the findings and testing conducted, several areas for improvement have been identified to enhance the efficiency, safety, and durability of the Multi-CartClimb. One key suggestion involves improving the ladder folding mechanism. The addition of high-quality hinges and an automatic locking system could provide better stability and user safety during use. This aligns with research in Japan, where Koyama et al. (2020) highlighted the effectiveness of using precision-engineered joints and locking systems in multifunctional industrial tools to prevent workplace injuries.

Furthermore, the handle design can be refined to offer better ergonomics and user comfort. In a U.S.-based study, Johnson and Turner (2019) found that ergonomic redesigns in tools used in automotive training centers significantly reduced operator fatigue and improved learning efficiency. Applying these principles to the Multi-CartClimb can help meet users' physical needs more effectively.

Regarding materials, while the current prototype uses heavy-duty metal for durability, it results in limited portability. It is recommended that the frame be reconstructed using high-quality aluminum or lightweight alloy, which offers strength while easing mobility. This recommendation is supported by Korean research (Lee & Park, 2018), which demonstrated that lightweight composite metals in tool carts not only reduce user strain but also enhance usability in tight industrial environments.

Safety can be further increased through features such as thicker anti-slip rubber pads at the ladder base and on handles, reducing the risk of injury. The inclusion of an automatic wheel-brake system is also proposed to prevent movement during ladder use—an approach consistent with Chinese research by Zhang et al. (2021), which emphasized the need for auto-locking wheels in mobile equipment to improve user stability and prevent operational hazards.

In terms of functionality, the integration of reflective stickers or LED lighting systems can improve product visibility in low-light conditions, a common challenge in vocational workshops. This is in line with a U.S. Occupational Safety and Health Administration (OSHA) recommendation that highlights the importance of visual aids in preventing trip-and-fall incidents in poorly lit spaces.

Additionally, the product should undergo further stress and stability testing under various real-world conditions, including uneven surfaces and full-load operation. Studies from Japan and Korea have consistently emphasized the importance of real-condition simulations to validate tool reliability before industry deployment (Kobayashi et al., 2020; Choi & Kim, 2017).

Overall, these proposed improvements will enhance the durability, stability, and ease of use of the Multi-CartClimb. With thoughtful adjustments in design, construction materials, and safety features, the Multi-CartClimb can become a more practical and reliable solution, not only for vocational automotive workshops but also for broader industrial applications. The project has demonstrated its potential to reduce physical strain, save storage space, and

improve workshop safety. The integration of the trolley and ladder into a single unit has shown multiple benefits, including streamlined workflow and optimized spatial usage.

Conclusion

In conclusion, the Multi-CartClimb project demonstrates significant potential for further development, not only within educational institutions but also in the automotive industry and other sectors that require versatile and multifunctional equipment. With continuous improvements and extended research, this product has the capacity to evolve into a meaningful innovation that benefits end-users, enhances work productivity, and contributes to technological advancement in the fields of engineering and automotive technology.

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Conflict of Interest

The authors declare no conflicts of interest.

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