PlatROB: A low-cost modular platform for teaching mobile robotics and AI to undergraduate mechatronic engineering students

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***Abstract*—This innovative practice paper describes the design, development and validation of PlatROB, an educational platform for teaching robotics and artificial intelligence (AI). The increasing demand for advanced robotic systems necessitates that engineering students enhance their system integration skills specific to robotics and AI, which requires specialized hardware and software for effective learning. PlatROB is a low-cost, modular robotic platform that fosters the development of robotic system integration abilities across key engineering disciplines including mechanics, electronics, and programming. Using PlatROB, students can perform different basic mobile movement types, such as Ackermann, differential and omnidirectional. The modular design allow students to experiment with each movement type by simply adding specific modules for control and processing, sensing, and actuation. Furthermore, the structure and mechanisms of PlatROB are 3D printable, familiarizing students with rapid prototyping technologies. Additionally, the platform is capable of being programmed with teleoperation algorithms and autonomous navigation using computer vision. To support the learning process, detailed manuals and test codes were provided to facilitate assembly and verify proper module integration. The learning effectiveness of PlatROB was evaluated in workshops with mechatronics engineering students from different program levels. A mixed-methods approach was utilized, combining quantitative (pre- and post-questionnaires) and qualitative (observation charts and surveys) tools. The results highlighted PlatROB's versatility as an educational tool for undergraduate students, enhancing their understanding of robotics systems integration. Early-stage students gained foundational knowledge in ground vehicle configurations, robotics technology, testing, and programming, while advanced students reinforced their understanding of complex robotics and AI concepts and implementation, including computer vision. The modular design enabled customized learning pathways, increasing students' technical skills and system-thinking abilities through hands-on, collaborative projects.**

***Index Terms*—Mobile Robotics, Modular Platform, Robotics & AI Education, Low-cost Robotics, Mixed-methods Approach**

I. Introduction

The widespread adoption of robotics and artificial intelligence (AI) has significantly impacted various industries. The autonomous vehicle sector, for instance, is projected to experience substantial growth, with an expected market size of $62.4 million by 2030 [1]. AI algorithms are being applied to mobile robots worldwide, across applications like agriculture, warehousing, manufacturing, and domestic tasks. The market for mobile robots with AI algorithms is forecasted to grow at 14.9% by 2028 [2], indicating increased demand for advanced robotic systems.

Engineering programs are emphasizing the fundamentals of integrated robotic systems, including kinematics, dynamics, odometry, control, and sensing, along with core AI concepts like machine learning, computer vision, and natural language processing [3]–[9]. This approach prepares engineers to design, integrate, and deploy these technologies across various applications. Curricula also expose students to real-world use cases and industry applications through case studies, industry partnerships, and hands-on projects, fostering interdisciplinary collaboration and communication skills.

Robotic educational platforms provide hands-on learning experiences, allowing students to explore robotics, programming, and engineering principles. Platforms like Limo and JET bots offer viable options for teaching autonomous navigation [10], [11]. Limo's modular design facilitates versatility, while JET bots lack this adaptability. However, the high costs of these educational kits, ranging from $400 to $2500, can limit their adoption in educational settings.

Popular alternatives like the LEGO Mindstorms kit feature motors and sensors, enabling students to learn system integration [12]. Its block-based programming makes it accessible to a wide range of users, but it is geared towards a younger audience, which can be a disadvantage for advanced robotics or AI topics. The GEARS IDS kit, similar to LEGO Mindstorms, contains mechanical and electronic components used in real-world applications [13]. However, both kits lack the specialization found in other educational robotics kits.

Despite their generalized approach, kits like LEGO Mindstorms are popular due to their accessibility and affordability. A study by Takacs et al. evaluated various educational kits, considering factors like modularity, community support, and pricing, and found LEGO Mindstorms to be a viable option for educational institutions [14]. This underscores the importance of balancing accessibility and depth in educational robotics.

Low-cost robotic platforms have been developed to provide affordable tools for learning robotics and AI. The AutoAuto platform includes a simulator for students lacking hardware [15]. The TurtleBot Waffle and Burger is another popular platform for teaching mobile robotics and autonomous navigation [16]. However, these platforms' differential drive configuration restricts adaptability to other locomotion mechanisms. Intuitive usability, as seen with the URA 4.0 modular robot, is crucial to reduce errors during assembly or programming [17].

Universities have also developed their own low-cost solutions. The E-Puck, developed by the Swiss Federal Institute of Technology in Lausanne (EPFL) in 2004, enhances student learning in embedded systems and robotics [18]. The University of Michigan's robot focuses on teaching AI, embedded systems programming, 3D modeling, and electronic circuit design [4].

This article presents the design, development, and evaluation of the low-cost PlatROB platform for teaching mobile robotics and autonomous navigation, shown in Fig. 1 . The platform balances accessibility, adaptability, and depth in educational robotics and AI. Section 1 describes the modular design of the PlatROB platform and the functionality of each module, highlighting its ability to encompass commonly used ground vehicle configurations. Section 2 reviews the platform's suitability for educational purposes through validation tests in workshops. Section 3 discusses the outcomes of the validation tests, evaluating the platform's performance and key insights. Section 4 identifies the platform's contributions to enhancing practical learning experiences and suggests potential future directions for further development.

II. Design and Implementation of PlatROB

A. Design Requirements

The development of the PlatROB platform was driven by the need to create a durable and versatile educational tool for teaching both mobile robotics and AI. Key considerations included: i) Ease of replication and affordability, modular and 3D-printable design which enables more institutions to adopt and integrate the platform into their curricula; ii) Versatility of movement, modular design to encompass most commonly used ground vehicle configurations, ensuring familiarity with diverse mobility mechanisms; iii) Cost-effectiveness, design that minimizes costs without compromising performance; and

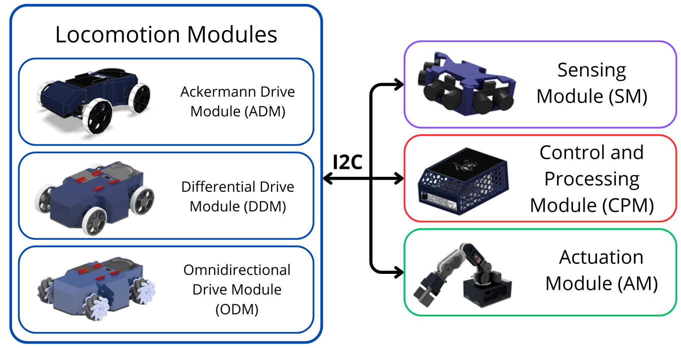


Fig. 1: PlatROB: Modular Robotic Educational Platform.

iv) Compact size: small modules facilitate the transport and storage, the maximum size for the platform was set at 30 cm x 30 cm x 15 cm. The modular and 3D-printable approach aims to strike a balance between accessibility, adaptability, and depth of learning, making PlatROB well-suited for educational applications in mobile robotics and AI.

B. Modular Design

The modular design of the PlatROB platform was intentionally engineered to encompass the most common types of movement used in mobile robots: Ackermann, omnidirectional, and differential motion. This comprehensive approach allows students to gain familiarity with a diverse range of ground vehicle configurations. To further enhance the platform's educational value, the entire structure is manufactured using 3D printing. This not only enables students to become acquainted with rapid prototyping methods but also empowers them to apply modifications and customizations as needed. The 3D-printed design also facilitates immediate replacement of parts without relying on supplier availability, making the platform cost-effective to fabricate.

The PlatROB platform is composed of six distinct modules, each providing specific features and functionalities: the Ackermann Drive Module, the Differential Drive Module, the Omnidirectional Drive Module, the Sensing Module, the Control and Processing Module, and the Actuation Module, see Fig. 1. The following subsections will detail the operation and capabilities of each module.

1) Ackermann Drive Module (ADM): The ADM is designed to emulate a scaled-down car with an Ackermann steering mechanism. Key features of the module are: a turning radius of 10 cm, allowing for nimble and responsive maneuvering; a maximum speed of 1.5 m/s, providing a good balance of speed and control; and a maximum payload capacity of 10 kg, enabling experimentation with various loads. The module receives direct instructions from the Control and Processing Module, allowing students to program and control the Ackermann-style locomotion. The internal design of the ADM features several mechanisms to optimize performance. As shown in Fig. 2 the module has a single motor that transmits power to the front wheels using bevel gears and universal joints. This compact design enables continuous wheel move-

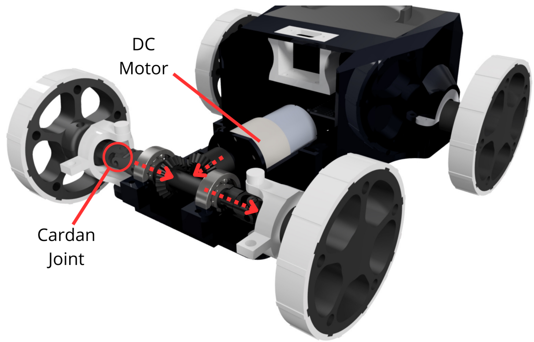


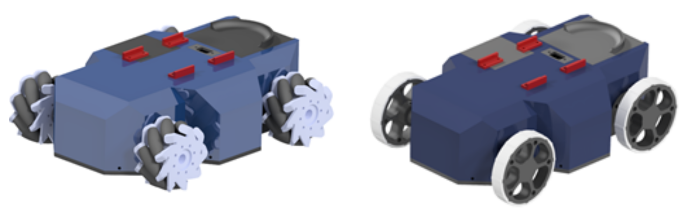
Fig. 2: Ackermann Drive Module (ADM): Front transmission

ment while maintaining a small footprint. Extensive testing was carried out to determine the optimal wheel type, with silicone rubber wheels selected for their superior traction and slip prevention.

For locomotion actuation, the ADM has two key components: a 12V DC motor that powers the platform's acceleration and movement; and a servo motor that controls the steering of the front wheels, enabling distinctive Ackermann steering pattern. A printed circuit board (PCB) was designed to distribute power and streamline connections between components. Additionally, a safety system was incorporated for platform startup and shutdown, using a VNH5019 driver to control the DC motor. Communication with other modules is achieved using the I2C protocol, enabling high-speed data exchange and seamless connectivity between multiple devices. The ADM includes an Arduino UNO microcontroller to receive instructions via I2C and execute them accordingly.

2) Omnidirectional/Differential Drive Module (ODD/DDM): The O/DDM is designed to provide two distinct mobility configurations: omnidirectional and differential. At the core of this module, the same fundamental design and components are used, but the mobility mode can be changed by simply replacing the conventional wheels with specialized "mecanum" wheels shown in Fig. 3. In the differential drive configuration, the platform can move forward, backward, and turn by independently controlling the left and right wheels. This is a common and well-understood form of mobile robot locomotion. In the omnidirectional configuration, enabled by the mecanum wheels, the platform can move in more ways of direction, including sideways and diagonally. This increased maneuverability can be particularly useful in tight spaces or for complex navigation tasks. To ensure precise control of the platform's movement in both configurations, the O/DDM features independent PID control for each of its motors. This allows the module to fine-tune the speed and direction of each wheel, resulting in smooth and accurate platform movements. Maintaining a consistent design approach, the hardware components used in this module, such as the DC motors, are standardized across the entire PlatROB platform. This allows for interchangeability and simplifies the overall system integration. Like the ADM, the O/DDM also utilizes an Arduino UNO as its platform controller.

3) Control and Processing Module (CPM): The CPM serves as the central hub that coordinates the operations of the various PlatROB modules. Its primary responsibility is to send instructions and commands to the other modules, including the ADM, O/DDM and Actuation Module. At the core of the CPM is a Single Board Computer (SBC) - the NVIDIA Jetson Nano. This powerful and versatile embedded computer is well-suited for educational applications, enabling the PlatROB platform to execute advanced computer vision algorithms, neural networks, and even facilitate teleoperation capabilities. The integration of the Jetson Nano SBC within the CPM allows students to explore and implement a wide range of robotic and artificial intelligence-based functionalities on the PlatROB. The CPM provides four available USB ports, which can be utilized to connect various sensors and peripherals to the platform, opening up a world of possibilities for students to integrate and experiment with diverse sensor technologies, such as cameras, GPS modules, 2D LiDAR (Light Detection and Ranging) units, and more. The centralized role of the CPM, combined with the diverse sensor connectivity options, enable students to explore a wide range of robotic applications and gain hands-on experience in integrating systems.



(a) (b)

Fig. 3: (a) Omnidirectional Configuration (ODM) (b) Differential Configuration (DDM)

4) Actuation Module (AM): The AM is a key component of the PlatROB that allows to explore the fundamentals of robotic manipulators and their associated kinematics and control algorithms. At the heart of the AM is a 4-degree-of-freedom (4-DOF) robotic arm, see Fig. 4 . This 4-DOF configuration is widely used in real-world robotic applications, making it an ideal choice for educational purposes. The AM is designed to handle a maximum weight of 200 grams, which is suitable for lifting and manipulating lightweight objects or "dummy" items commonly used in educational settings. To achieve the 4-DOF movement, the AM is equipped with five servo motors - four dedicated to controlling the individual joints of the robotic arm, and one operating the gripper, allowing students to practice grasping and handling objects. Similar to the ADM and O/DDM modules, the AM incorporates its own microcontroller, which enables independent programming and control of the robotic arm. This allows students to develop and test their own algorithms and control strategies, further enhancing their understanding of robotic manipulator kinematics and control. Furthermore, the AM is designed to communicate with the rest of the PlatROB platform using the I2C protocol. This enables seamless integration with the CPM module, allowing students to explore the coordination and integration of robotic manipulators with other mobile robot components, such as the ADM or the O/DDM.

5) Sensing Module (SM): The SM provides the platform with the ability to gather data from the external environment. This module consists of distance measurement sensors, including ultrasonic and infrared sensors. This sensor setup allows for the implementation of obstacle avoidance algorithms on the PlatROB, as well as the opportunity to practice sensor fusion and noise management techniques. While the CPM has USB ports to add other types of sensors, the SM simplifies the integration of sensors that lack USB connectivity. This ensures that the platform can still be equipped with essential sensing capabilities for robotics applications, even when working with sensors that do not have a direct USB interface.

C. Implementation Process

The PlatROB platform was designed with a modular approach to facilitate the assembly process for students. The building and assembly steps, as well as the thorough verification process, are detailed in the following sections. The verification process involved both internal validations with the development team and evaluations with undergraduate mechatronics engineering students to validate the functionality and performance of the PlatROB.

1) PlatROB Integration: The PlatROB modules communicate via I2C, a communication protocol chosen for its ability to connect multiple devices using a minimal number of pins. Additionally, I2C offers higher communication speeds compared to other protocols, enabling faster response times and more seamless coordination between the different modules. Each module is equipped with its own independent power system, including a dedicated battery. This design choice ensures that the modules can be used separately if needed, providing flexibility and autonomy for the students. The independent power system also allows the modules to be easily integrated and disconnected without concerns about shared power sources. In terms of the physical integration of the modules, the PlatROB features both mechanical and electronic couplings. This allows the modules to be connected and disconnected seamlessly, enabling students to reconfigure the platform as per their learning objectives. Figure 4 illustrates the integration of the ODM, the AM, and the CPM. Each of these modules contributes unique capabilities to the overall PlatROB platform. The ODM provides the platform with the ability to move in multiple directions enhancing the PlatROB maneuverability for navigating complex environments and perform intricate tasks. The AM introduces a 4-DOF robotic arm to the platform. This manipulator enables the platform to pick up and manipulate objects. The AM serves as the central hub, housing the powerful NVIDIA Jetson Nano SBC. This SBC empowers the platform to execute computer vision algorithms, implement neural networks, and facilitate teleoperation capabilities.

2) Prototype Verification: The functionality verification of the PlatROB platform focused on the integration between

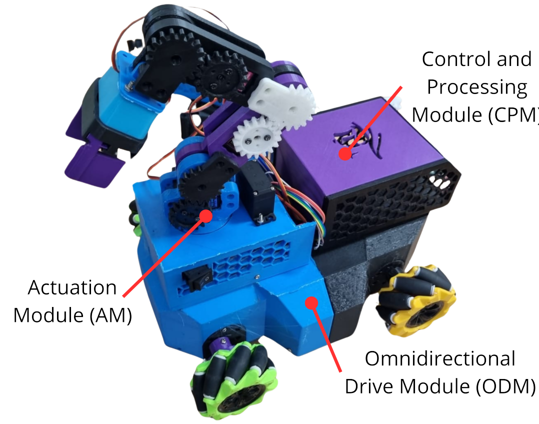


Fig. 4: ODM-PlatROB: Integration of the Omnidirectional Drive (ODM), Actuation (AM), and Control and Processing (CPM) Modules

CPM and ADM modules. The development team conducted extensive tests to ensure seamless coordination between these core components. To assess the platform's capabilities, a series of tests were performed. First, maximum speed trials were conducted to verify the PlatROB could achieve at least 1 m/s. This was measured by timing how quickly the platform could reach a distance of 1 meter. Additionally, load tests were carried out using 1 kg weights while measuring the maximum speed. The results demonstrated that the PlatROB module could successfully move a load of up to 10 kg at a speed of 0.5 m/s. The verification tests were crucial for ensuring that PlatROB provide a robust and reliable educational experience for the students.

3) Manuals, Guides and Test Codes: Educational material was prepared for guiding the students and teachers use of the PlatROB platform: i) Assembly Manuals: Detailed manuals were prepared highlighting key assembly points for each module to guide students through the assembly process; ii) Functionality Guides: Students were provided guides to fill out after completing certain assembly steps, answering questions about the functionality of the components; iii) Test Codes: Sample test codes were provided to students to verify the proper functioning of the module integration and ensure the platform is operating as intended.

III. Educational Evaluation

The PlatROB platform's effectiveness as a learning tool for undergraduate mechatronic engineering students was evaluated using a mixed-methods approach [19]. This involved a pilot study and a validation workshop to collect both quantitative and qualitative data. The pilot study assessed the workshop structure and data collection instruments, allowing for necessary refinements before the full validation workshop. During the validation workshop, students engaged with the PlatROB platform, and the evaluation team gathered feedback on its suitability for educational purposes.

A. Data collection instruments

The quantitative data consisted of pre- and post-test questionnaires that assessed the students' technical knowledge related to mobile robotics and the configuration of the PlatROB modules. The topics evaluated included mechanics, electronics, and programming. The qualitative evaluation involved observational notes from assistants who monitored the performance of each student group. This included tracking the types of questions students asked and the time they took to complete the activities. Additionally, satisfaction surveys were conducted to gather student feedback on the workshop experience, the content of the activity guides and assembly manuals, and the perceived difficulty of module assembly.

This multi-faceted approach allowed for a comprehensive evaluation of the effectiveness of the PlatROB platform as an educational tool. The quantitative tests provided objective data on knowledge improvement, while the qualitative observations and surveys offered insights into the students' perceptions and learning process.

B. Participant selection

To standardize the group of students for testing the PlatROB in the workshops and pilot study, participants were carefully selected. Prior to the workshop, a survey was sent to potential participants, asking about their current advancement on the academic program and the courses they had completed. Additionally, they were asked about their involvement in extracurricular activities. Students who were exclusively following the curriculum and had not participated in any robotics-related extracurricular activities or were part of research groups were selected to ensure that all participants were as similar as possible.

The students were divided into three groups according to their academic level. In Group 1, the students from 1st to 4th semester; Group 2 congregates students from 5th to 7th semester; and for Group 3, students from 8th to 10th semester were selected. Taking into account that in the university of study the career has a duration of 10 semesters.

In the pilot study, 23 students from different academic levels were selected. On the other hand, in the validation workshop, 51 students participated, but only 48 were included for analysis because 3 students did not complete the post-test questionnaire and satisfaction survey. Figure 5 shows the distribution of students in the validation workshop based on the semester they are in.

C. Pilot Study

This first study was a simplified version of the workshop. The aim was to test the materials used, measure the time students took for each section, and gather feedback on the assembly manuals and educational guides. The pilot study included tasks related to mechanical integration, electronic integration, and programming of the platform; the time distribution is presented in Table I. The pilot study included both a pre- and a post-test to measure the students' learning levels. After analyzing the test results using Cohen's d [20] and Analysis of Variance (ANOVA), the contribution of PlatROB to student learning remained inconclusive, mainly due to the small sample size and the limited time given to students. Nevertheless, this first trial provided valuable insights that helped improve important aspects of workshop planning, guide updates, and more.

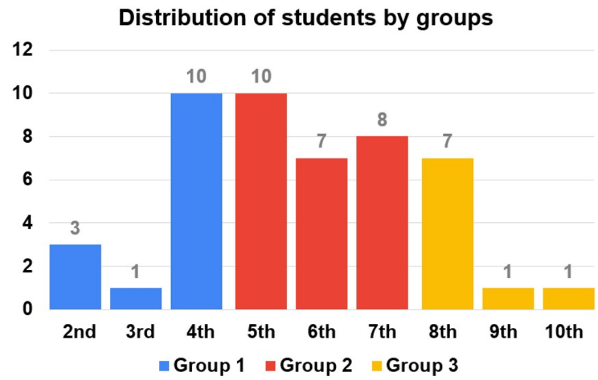


Fig. 5: Validation workshop: students distribution by groups

D. Validation Workshop

Workshops were conducted with students who are part of the 3 groups mentioned above.. The workshops incorporated the Project-Based Learning (PBL) approach, which has proven to have a greater impact on student learning, especially in laboratory sessions and small groups [21].

1) Workshop Structure: The validation process involved four separate 6-hour workshops, each targeting a different group of mechatronics engineering students. The structure presented in Table I was followed for the development of the workshops. The details of each section are provided below:

- **Individual pre-test:** Evaluation of theoretical concepts of robotics.
- **Theoretical concepts:** The assistants gave a short presentation on the theoretical concepts of mobile robotics and an explanation of the PlatROB modules.
- **Practical assembly:** In subgroups of 3 to 4, students assembled the CPM and ADM modules using provided parts, manuals, and tools; an activity guide also had to be completed.
- **Code integration and testing:** Students programmed and tested teleoperation algorithms.
- **Individual post-test:** An identical questionnaire to the pre-test was administered in order to evaluate the knowledge gain.
- **Satisfaction survey:** Students provided feedback on the workshop and PlatROB.

Throughout the practical sessions, each student group was assigned an assistant to observe performance, answer questions, and provide assembly support as needed.

TABLE I: Pilot study and workshop schedules

Activity	**Individual pre-test**	**Theoretical concepts**	**Practical assembly**	**Code integr. and testing**	**Break**	**Individual post-test**	**Satisfaction survey**
Pilot Study (3 hours)	15 min	0 min	60 min	75 min	0 min	15 min	15 min
Workshop (6 hours)	15 min	20 min	160 min	105 min	30 min	15 min	15 min

IV. Results and Discussion

A. Quantitative Data

1) Pre- and post-tests: The results of the pre- and post-session technical knowledge tests were analyzed. The test scores ranged from 0 to 20, with a passing grade of 11, according to our grade system in Perú. The analysis of the test score distributions, by group, as seen in Figure 6 revealed the following:

- Group 1 students had a pre-test average of 6.57 (failing) and post-test average of 10.67 (still failing). This indicates that fist and second-year students (1st to 4th semester), who lack the necessary theoretical foundation, benefited from the hands-on module use but not enough to reach passing grades.
- Group 2 students had a pre-test average of 10.17 (failing) and a post-test average of 13.51 (passing). The workshop helped students from 5th to 7th semester reach a passing average, demonstrating that the platform effectiveness in improving their knowledge.
- Group 3 students had a pre-test average of 14.15 and a post-test average of 16.49. The increase in average scores was less than the other groups, suggesting that Group 3 students, having already taken system integration courses, had already developed some of the relevant skills and knowledge before the workshop.

These results indicate that the PlatROB platform was most effective in improving the knowledge of Group 1 and Group 2 students, who were able to apply the hands-on experience to enhance their understanding. The needs of Group 3 students may require further tailoring of the educational approach.

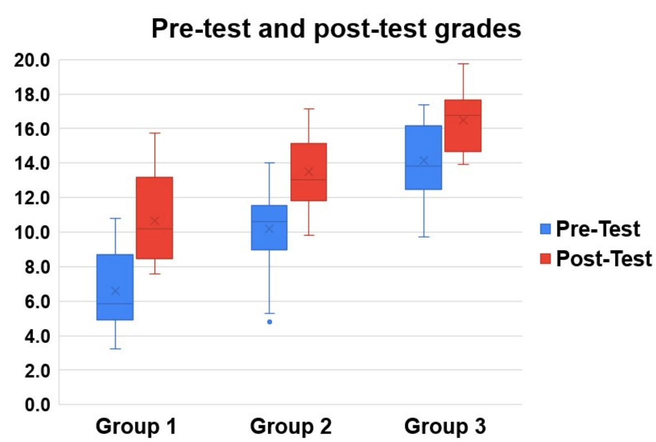


Fig. 6: Workshop: Pre-test and post-test results

To further analyze the test score results, an ANOVA was conducted on the pre-test and post-test data. Table II shows that the p-values associated with each student group were found to be statistically significant ($p < 0.05$). These results suggest that a 6-hour workshop time frame may have been sufficient for students to gain new knowledge (Group 1) or solidify their previous knowledge of robotics by focusing on practical skill (Group 2 and Group 3).

In addition, the effect size metric, Cohen's d, was calculated. This metric allows us to assess the impact that the workshops conducted with the educational platform had on the learning of the topics covered [20]. Teaching methods vary in their impact on student learning, and the analysis revealed a Cohen's d score greater than 1.0 for all the groups, with the greatest impact on Group 1, as shown in Table II. This is consistent with the 4-point increase in their grades. The ongoing mechatronics engineering program courses are predominantly theoretical during initial years, so this practical experience, integrated with their existing theoretical knowledge, has helped reinforce the concepts they have been studying at the university. Conversely, the group with the least impact comprised students in the higher semesters. These students already have substantial knowledge of the topics due to their coursework, so the workshop had a less significant impact on their learning.

B. Qualitative Data

1) Observation insights from skill performance: During the pilot study, it was observed that most subgroups were able to complete the assembly of only the ADM or only the CPM. Only one subgroup composed of senior students was able to complete the assembly of the two modules and the validation tests. This was presumably due to the short time period allocated for the practical part of the study. To address this, the workshop duration was increased to 6 hours and better results were achieved as shown in Table III. All participating subgroups were able to complete the assembly of the ADM and CPM modules. Additionally, there were only 3 subgroups that did not complete the validation test tasks and more than half of the workshop subgroups were able to complete all the

TABLE II: Workshop: ANOVA and Cohen's d for pre- and post-test technical knowledge data

Group	**p-value**	**Cohen's d**
Group 1	2.11×10^{-4}	1.63
Group 2	4.91×10^{-6}	1.46
Group 3	0.04	1.09

TABLE III: Workshop skills performance by program academic level

Groups	ADM Assembly Task		CPM Assembly Task		Testing Task		Programming Task		Avg. Tasks completed	
	Quantity*	Avg. time (min)	Quantity	Avg. time (min)	Quantity	Avg. time (min)	Quantity	Avg. time (min)	Quantity	Avg. time (min)
Group 1	8/8	90.5	8/8	58	3/4	63.67	3/4	55.33	5.5/6	267.5
Group 2	12/12	84.5	12/12	57.67	5/6	38	3/6	40.33	5.33/6	220.5
Group 3	6/6	74	6/6	58.67	2/3	27.5	2/3	42	5.33/6	202.17

* Total quantities in all the cases are related to the number of subgroups.

tasks. It is important to note that the assembly time of the ADM decreased with each higher year of university, while there is no substantial change in the assembly time of the CPM. This is because the CPM is easier to assemble, as it does not require the development of practical experience, unlike the other module. As an additional note, most student subgroups in the workshop comprised 4-5 people. However, due to an absence in one of the sessions, a subgroup from Group 3 consisted of only 2 members. This discrepancy may account for the increased time dedicated to programming activities.

2) Observation insights from type of questions and assistant intervention: The results of the questions asked by each subgroup during the workshop were also analyzed. Figure 7 shows the number of questions each group asked and whether the intervention of the assistant in charge was necessary - this means that the assistant had to manipulate the platform. It is important to note that the students from Group 1 and 2 asked the most questions, with almost a third of these requiring assistant intervention for Group 1 and half for Group 2. Similarly, an analysis of the types of questions asked revealed that Group 1 and Group 2 primarily had questions about mechanics, electronics, and assembly. This can be attributed to their lack of practical experience due to their program advancement, unlike the Group 3 students. These results highlight the importance of using the PlatROB modules to help students develop practical skills earlier in their academic careers.

Fewer questions asked by Group 3 (per person) may indicate why they took more time to complete programming tasks, as detailed in Table III.

Furthermore, Fig. 8 illustrates the distribution of queries posed to the evaluators during the workshops. This distribution is categorized by the type of question and by the student groups. Given the varying sample sizes in each group, the values were standardized for comparative evaluation. From this analysis, it is evident that students in Group 3 (G3) asked more questions related to the mechanical aspects. In contrast, most inquiries from students in Group 1 (G1) were theoretical, unlike the other groups, which had fewer theoretical questions. Lastly, it is clear across all groups that the majority of questions concerned the assembly of the platform, likely reflecting the clarity of the assembly manuals.

3) Satisfaction survey: For the satisfaction surveys, responses were recorded on a scale of 1 to 5, 5 meaning very satisfactory. The questions asked were as follows:

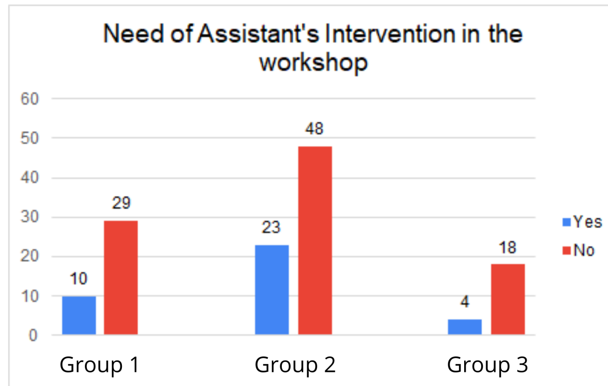


Fig. 7: Workshop Study: Number of questions and need of assistant intervention by group

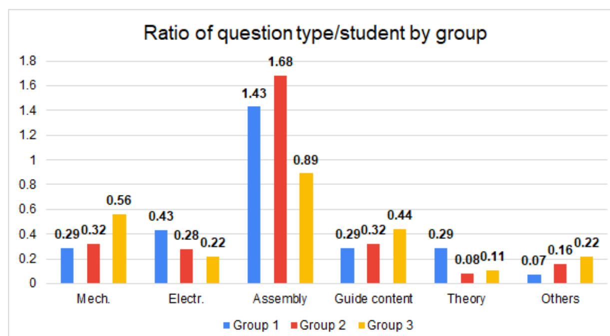


Fig. 8: Workshop Study: Type of Questions by groups

- Q1. Overall, how would you describe the workshop?
- Q2. Overall, how would you rate the content of the workshop guide?
- Q3. At a mechatronics level, how would you describe the assembly process of the Ackerman Drive Module?
- Q4. For the workshop material, how understandable is the assembly manual for the Ackermann Drive Module?
- Q5. At a mechatronics level, how would you describe the assembly process of the Control and Processing Module?
- Q6. For the workshop material, how understandable is the assembly manual for the Control and Processing Module?

The results of this survey per question are shown in Figure 9. Based on the results of this survey, it can be determined that both the workshop and the platform material received excellent feedback from the students (Q1 y Q2), with the majority assigning the maximum score to both questions. Hence, students perceived that the content developed in the workshop and the guiding material were adequate. The main areas for improvement are related to Q3 and Q5, which correspond to the assembly experience of the Ackermann Drive Module and the Control and Processing Module. For Q4 and Q6, students indicate that they could work with the workshop material provided. Overall, the satisfaction survey results demonstrate that the students were highly satisfied with the workshop and the platform material, with the exception of the assembly process for the specific modules, which could be further refined to improve the student experience.

Additionally, the students and assistants were able to share their perspectives regarding their experience with the educational platform, considering both the hardware and the educational material provided. The most relevant comments are listed below:

- **Student 1:** ”It (PlatROB) is well designed, I would add a bluetooth module”.
- **Student 2:** ”There are parts of the worshop guide that need a more general image to provide the full ‘context’ of the assembly”.
- **Student 3:** ”It is required a better explanation about how to place the electronic components”.
- **Student 4:** ”The servo motor mount needs to be improved to support greater torque”.
- **Assistant 1:** ”Students found the PlatROB platform to be innovative and engaging, leading some of them to voluntarily extend their time with the it”.
- **Assistant 2:** ”Some students were taking pictures of the assembly process, they were really interested in the educational kit.”.

These student and assistants comments highlight the strengths of the PlatROB platform, such as its modular design, clear assembly manuals, and the balance between theory and practice. Students also identify areas for improvement, such as providing more detailed guidance on specific module assembly and the electronics/programming aspects.

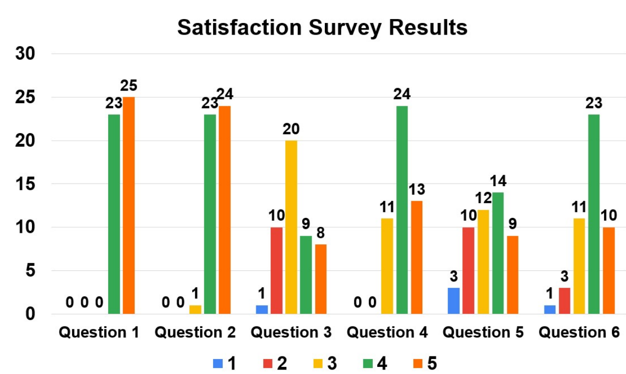


Fig. 9: Workshop satisfaction survey

V. Conclusions

This article presents the design, implementation and validation of PlatROB, an innovative educational platform for teaching robotics and AI. PlatROB features a modular design with six distinct modules: Ackermann Drive, Omnidirectional/Differential Drive, Control and Processing, Sensing, and Actuation. This modular architecture allows for customized learning pathways and the development of students’ technical skills and system-thinking abilities. The validation process utilized a mixed-methods approach within workshops with undergraduate mechatronics engineering students. Quantitative data was collected through pre- and post-session technical knowledge tests, with analysis of test score improvements using statistical metrics like p-value and Cohen’s d. Qualitative feedback was gathered through observational notes from workshop assistants and satisfaction surveys on the student experience. The results demonstrated that the PlatROB platform was effective in reinforcing students learning in robotics and related subjects at all program levels. Particularly, students in the 5th to 7th semesters were able to achieve passing averages on the knowledge tests and complete many workshop practical tasks. Students from 8th to 10th semester were able to reinforce and expand their existing knowledge of robotics and AI concepts. On the other hand, the group of students that experienced the least impact from platROB was the 1st to 4th semester students. The main reason is the low theoretical knowledge typical of their early stage in the program. To address this, it is proposed to increase the theoretical content in the workshops conducted for this group. This change will be implemented in future editions to enhance their understanding and utilization of the provided material. In addition to the platform itself, comprehensive educational materials, including assembly manuals and test codes, were also developed to support the learning process. Future objectives include addressing hardware and software improvements based on feedback, conducting larger-scale validation within program courses, and exploring expansion to other educational applications. Overall, the PlatROB platform provides a versatile, affordable, and modular tool to enable hands-on learning of robotics and AI concepts for mechatronics engineering students.

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