

Assessing Student Satisfaction and System Usability in Industrial Robotics Education

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Resumen

Este trabajo analiza las sesiones de laboratorio de robótica industrial diseñadas para estudiantes de grado y máster de la Universidad Carlos III de Madrid. Las sesiones involucran un manejo práctico de robots CRB 15000-5 “GoFa” de ABB con herramientas personalizadas (rotulador, electroimán) para tareas de dibujo y pick-and-place, con especial énfasis en la programación manual y mediante RAPID, la simulación en RobotStudio y la sincronización con el robot real. Adicionalmente, se ha utilizado el robot TIAGo++ de PAL Robotics para ilustrar posibles aplicaciones médicas. Se realizó una encuesta de satisfacción y usabilidad a 97 estudiantes a lo largo de 2025 para evaluar la experiencia. Los cuestionarios consistieron en entre 10 y 15 elementos evaluados en una escala Likert de cinco niveles. Los resultados indican que las sesiones han tenido buena acogida, estimulan la participación y refuerzan conceptos teóricos clave. La programación en RAPID y la simulación han sido identificadas como los elementos que más dificultades han supuesto.

Palabras clave: Robótica educativa, Robótica industrial, Robótica colaborativa, Estudio de usabilidad y satisfacción.

Abstract

This work evaluates industrial robotics laboratory sessions designed for undergraduate and graduate students at Universidad Carlos III de Madrid. The sessions involved hands-on exercises using ABB CRB 15000-5 “GoFa” collaborative robots and custom tools (pen, electromagnet) for drawing and pick-and-place tasks, emphasizing manual and RAPID programming, simulation through RobotStudio and synchronization with the real robot. Additionally, the TIAGo++ robot by PAL Robotics was introduced for broader context in potential medical applications. To assess the experience, a satisfaction and usability survey was conducted with 97 students in 2025. The questionnaires consisted of 10 to 15 items rated on a five-point Likert scale. Results indicate that the sessions were well-received, boosting engagement and reinforcing key theoretical concepts. Students identified RAPID programming step and simulation as the most challenging components.

Keywords: Educational robotics, Industrial robotics, Collaborative robotics, Usability and satisfaction survey.

1. Introduction

At Universidad Carlos III de Madrid, several academic degrees offer an Industrial Robotics course based on a common theoretical framework. However, theory and problem-solving classes are best complemented with laboratory sessions, essential for effective training with professional tools. The design of these sessions must address the differences across these degrees, ensuring maximum value is provided to students with diverse academic backgrounds.

To evaluate the effectiveness of the sessions and plan future improvements, it was deemed necessary to collect student feedback regarding their impressions. Key aspects analyzed included the level of preparation prior to the sessions, the most challenging components, and the attitudes towards the proposed tasks. The study also considered whether specific groups might require a tailored approach due to curricular differences. Ultimately, these laboratory sessions aim to align with course goals and prepare students for examinations and final projects.

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The document is organized as follows. Section 2 provides background on educational robotics, while Section 3 describes the tools used. The methodology is laid out in Section 4, followed by the survey results in Section 5 and discussion in Section 6. Finally, conclusions are drawn in Section 7.

2. Background

Educational literature draws a distinction between “robotics in education” and “educational robotics”. Whereas the former encompasses a broader scope, covering any way a robot can help the student or educator, the latter refers specifically to STEM applications designed to “create meaningful experiences on robotics since an early age”. It is therefore within the context of educational robotics that learning frameworks can be established, enabling the development of pedagogical strategies that leverage robotic technologies to foster specific competencies (Scaradozzi et al., 2019).

In the specific context of higher education and industrial engineering, previous works analyze and discuss the development of hands-on robotics courses. A study conducted at the University of Louisiana, Lafayette, which introduced a fully-equipped laboratory with ScorBot-ER robots and RoboCell simulation software, revealed that student response was highly favorable. The study highlighted the enjoyment and perseverance participants showed during the completion of various projects. The engaging nature of the proposed tasks encouraged students to overcome initial difficulties regarding the subject’s complexity, allowing them to appreciate the practical challenges these sessions posed (Rawat and Massiha, 2004).

Assessment of student satisfaction is key to understanding the effectiveness of the laboratory sessions. In this context, a study in 2019 evaluated the performance of young STEM students (primary and secondary school) programming an educational robot for an international competition held in Portugal. The competition challenged students to program a fully autonomous micro-robot to identify the most effective route through a maze. The complexity of the task is mitigated through the adoption of visual programming languages. Crucially, usability tests were conducted with a small group of students aged 11–17 to rate the prototype using Brooke’s System Usability Scale (SUS) (Barradas et al., 2019).

Complementing these pedagogical and assessment frameworks, recent technical research has sought to lower the barrier to entry for novice users through advanced control strategies. Specific approaches have adopted intuitive learning from demonstration (LfD) techniques combined with learning by exploration (LbE) force-based algorithms, with a focus on collaborative robotics. These methods aim to assist users with arbitrary backgrounds in handling robot manipulators during contact-rich tasks. A visual servoing algorithm complemented with a reinforcement learning policy was proposed as an alternative to standard manual operation via teach-pendant or hand guiding in gravity compensation mode (Shi et al., 2021).

Ultimately, combining pedagogical frameworks with intuitive control strategies mitigates the cognitive load of complex hardware. This reduction in technical barriers significantly improves user experience and student satisfaction, justifying the assessment methodology proposed in this work.

3. Materials

3.1. Robots

The ABB CRB 15000-5 “GoFa” industrial manipulator (Figure 1(a)) is the central element in the proposed laboratory sessions. It features six degrees of freedom (DoF) in the usual arm configuration (shoulder, elbow, wrist), to which an offset has been added between the last two axes in order to mitigate the effects of wrist singularities. Hardware and software safety mechanisms are implemented to ensure compliance with collaborative robotics safety standards, thus making it suitable for hands-on handling during the sessions. Manual teleoperation is possible through a tablet-like device with a built-in joystick. Automated tasks can be programmed by means of the proprietary RAPID language, and simulated before its execution on the real robot. Four GoFa robots are available at our facilities, each having an external computer with the RobotStudio simulator installed and assigned to it.

In addition, the mobile service bi-manipulator TIAGo++ by PAL Robotics (Figure 1(b)) is used to provide a brief introduction to robotic medical scenarios for bioengineering students.



Figure 1: Robot platforms used during laboratory sessions.

3.2. Tools

A flexible 1-DoF gripper tool (Figure 2(a)) was designed and built to be used in the first iterations of the pick-and-place task, and in various student projects (Łukawski et al., 2025a).

In order to combine grabbing and drawing capabilities, a double tool was introduced by merging a pen holder and a digitally-actuated electromagnet (Figure 2(b)). A compliant design featuring movable elements and springs allows both ends to slightly retract upon pressing against an obstacle.

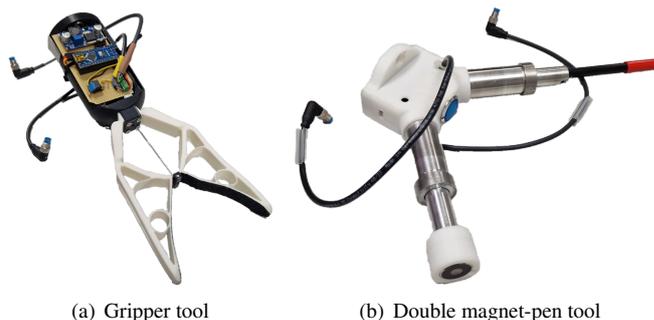


Figure 2: Tools mounted on the end-effector of the GoFa robot.

4. Methods

4.1. Targeted student groups

The statistical study presented in this work targeted a total of 97 students of four university degrees, covering the Bachelor’s and Master’s degree levels. It was conducted in 2025 at Universidad Carlos III de Madrid, during the academic years 2024–25 and 2025–26.

The groups were selected due to the inclusion of a course on Industrial Robotics in their academic plan, to be detailed below (in chronological order regarding the time of the year the sessions had been carried out):

- Bachelor in Robotics Engineering (later labeled as “Rob (B)”): second-year required course. A second session was added to expand on the programming aspects of ABB robots with RAPID and RobotStudio.
- Bachelor in Industrial Technologies Engineering (“Ind (B)”): fourth-year elective course included in the Automation and Electronics specialization.
- Master in Robotics and Automation (“Rob (M)”): first-year elective course. An introductory pick-and-place task through interactive block programming is conducted before the main drawing task session.
- Bachelor in Biomedical Engineering (“Bio (B)”): required course on Robotics that transitioned from the fourth to the third year during this study due to a revision of the degree plan. Students from both old and new plans were targeted and treated indistinguishably.

Prior to the execution of the sessions, our students were familiarized with the morphology of industrial robots (including sensors and actuators), basic mathematical tools (such as homogeneous transformation matrices and quaternions), and RAPID programming, in theory and problem-solving classes. Shortly before, they must have completed two sessions in a computer room for an introduction to RobotStudio and simulated robots.

4.2. Proposed tasks

The laboratory sessions evolved from previous iterations using a legacy dual-pen tool (for drawing) and a separate flexible gripper (for pick-and-place). Since the deformation of the flexible material hindered object grasping, different designs were explored. Figure 3(a) depicts a visual servoing application featuring this tool (Łukawski et al., 2025b).

In 2025, a new magnet-pen tool was introduced to eliminate tool changes and improve performance in pick-and-place tasks. For the latter, simple 3D-printed geometric shapes (40×40×40 mm cubes and cylinders) were fitted with metal screws to facilitate electromagnetic lifting.

The drawing task is mandatory for all students to review basic concepts. Additionally, the pick-and-place task was added to the specialized Rob (B) and Rob (M) degrees to provide deeper programming insight.

These two-hour sessions were held near the midterm period. The infrastructure consisted of four workstations equipped with a GoFa robot and an external computer with a RobotStudio installation, intended for groups of 4–6 participants.

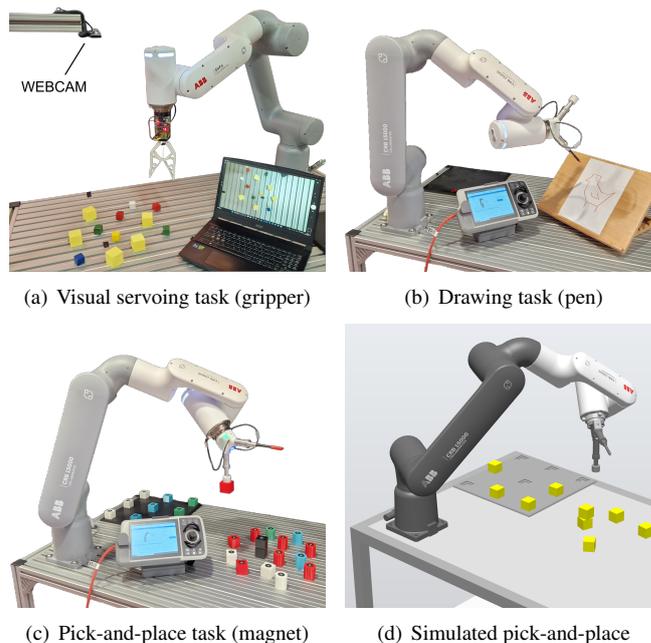


Figure 3: Various real and simulated didactic use cases.

4.2.1. Drawing task

Figure 3(b) depicts the setup: a standard paper sheet is attached to a flat surface, on which a drawing must be made using the pen tool connected to the robot. The robot and the paper are fixed on a table. The drawing should be reasonably simple and attained through the connection of several points. Points are defined manually, while the paths between them are drawn by the robot through motion instructions programmed in RAPID.

The session is organized as follows:

1. Introductory talk to provide context on industrial robotics. A classical industrial ABB robot is placed nearby the GoFa models. Differences between factory-constrained environments and modern human-robot collaborative workspaces are highlighted.
2. Hardware and software description. The main components are pointed out: robot links and joints, the controller cabinet, inherent safety mechanisms (internal sensors, safety controller), the FlexPendant tablet as a human-robot interface (HRI).
3. Joystick control via tablet and kinesthetic guidance in gravity compensation mode. The students are instructed on the presence of singularities with a practical example in which the fourth and sixth axes are aligned during linear mode in joystick operation.
4. Tool definition and calibration. The tip of the pen tool is determined using the built-in four-point procedure.
5. Work object definition and calibration. A user frame is defined along the sides of the paper sheet.
6. Point definition. Using the kinesthetic mode, several points are defined on the paper’s surface, in addition to an initial position above it.
7. Synchronization with RobotStudio, offline programming. Motion instructions are created and tested in simulation.
8. Synchronization with the robot. The code has been verified by the instructor and the instructions are performed by the real robot. Adjustments are made if necessary.

Throughout the session, the instructor reviewed several basic concepts, reinforcing the fundamentals taught in theoretical lectures while providing a practical approach to robot control, RAPID programming, data synchronization and task execution on a real robot. Particular emphasis was placed on the correct motion sequence applied during the execution of the task: the definition of an initial resting point, speed reduction during approach, introduction of “fine” points and linear paths where applicable, and the use of offsets to minimize unnecessary targets. Furthermore, students were guided through the simulation-to-reality transfer process, adapting code prepared in RobotStudio for execution on the real robot.

4.2.2. Pick-and-place task

An additional session was added in the Rob (B) and Rob (M) groups to expand the hands-on experience with robots on these specialized degrees. Stemming from the drawing scenario and layout, Figure 3(c) depicts a similar setup in which several 3D-printed elements (cubes and cylinders) are scattered over the table. The goal of the proposed task is to pick them from a storage area using the electromagnet end of the dual tool, and build a stack afterwards.

Rob (B) students are provided with a code template filled with basic instructions that must be completed in the RobotStudio editor with a simulated robot. Basic RAPID programming concepts are reviewed, with a focus on control flow loops and variable handling. Once the task has been fulfilled, the program is transferred and tested on the real robot. Adjustments are made if necessary. A reverse, unstacking operation is proposed if the main task was completed successfully.

Rob (M) students, on the other hand, receive this session before the drawing one. In contrast, it is aimed to be an introductory practice class on block programming through a built-in wizard in the robot’s tablet device.

4.3. TIAGo++

Exceptionally, Bio (B) students receive a preceding ten-minute talk and presentation of robot TIAGo++ to establish a tighter connection between the mainly industrial-focused theme of the session and the biomedical context of their degree. The robot is introduced by the instructor and real use cases are presented such as an assistive robotic task executed in a rehabilitation center in Madrid (Naranjo-Campos et al., 2024). A demo application is launched afterwards during which the robot describes itself using predefined motion sequences and dialogue lines synthesized using a built-in text-to-speech engine.

4.4. Survey

The students were requested to fill out a questionnaire composed of 10 to 15 items, depending on the degree and number of sessions. The form was shaped after the system usability scale (SUS), expanding on the original 10 items to account for satisfaction-related questions (Brooke et al., 1996). Similarly to the SUS, a five-level Likert scale was adopted to qualitatively assess the attitude of the students towards the session, with the following allowed responses: strongly disagree, mildly disagree, neutral, mildly agree, and strongly agree.

5. Results

The R programming language was used to plot the resulting graphs. The “HH” package was selected for its effectiveness and suitability in correctly representing the Likert scale (Heiberger and Robbins, 2014). Original survey items, collected anonymous responses and R scripts have been uploaded to a public GitHub repository.¹

In the following figures, survey items have been categorized according to the topic they relate to, ranging a different number of targeted student groups:

- The drawing task (Figure 4) using the pen tool was performed by all groups.
- Only specialized Rob (B) and Rob (M) groups completed the pick-and-place task (Figure 5) with the magnet tool.
- A subset of items unrelated to a specific task was included in the survey for all groups (Figure 6).
- Individual miscellaneous items were directed at the Rob (M) and Bio (B) groups (Figure 7).

6. Discussion

Students across all groups found the laboratory sessions engaging and illustrative of theoretical concepts. Similar satisfaction and success rates were observed in both the drawing and pick-and-place tasks. These were completed with minimal supervision, despite occasional difficulties in executing programmed trajectories in the simulator and on the real robot.

Notably, the slightly superior results in the Rob (M) group regarding the drawing session can be attributed to their prior introductory pick-and-place session. Conversely, these students found the simulation and robot synchronization more challenging, a result that might be counterintuitive for a Master’s in Robotics. However, it must be noted that incoming students do not necessarily possess a robotics background; in fact, many entrants lack specialized prior training.

Bio (B) students required more instructor assistance, likely due to the reduced course load compared to other groups. Specifically, the credit load is half that of the other cases, there is no final assignment to be delivered at the end of the semester (consisting of a RAPID programming project), and the introductory computer lab sessions were omitted due to time constraints.

Finally, the Ind (B) group achieved slightly better results in simulation-to-reality code transfer. As with other metrics, this could be linked to the lower student-to-workstation ratio in this group, which allowed for more personalized assistance from the instructor.

Prior preparation helped students feel confident and competent using available tools, while the sessions also provided the instructor an opportunity to review key concepts prior to assessments and final class projects. The drawing task boosted engagement and motivated more complex designs. New elements introduced in 2025, such as the introductory talk on TIAGo++, were well-received.

¹<https://github.com/roboticslab-uc3m/gofa-lab-surveys>

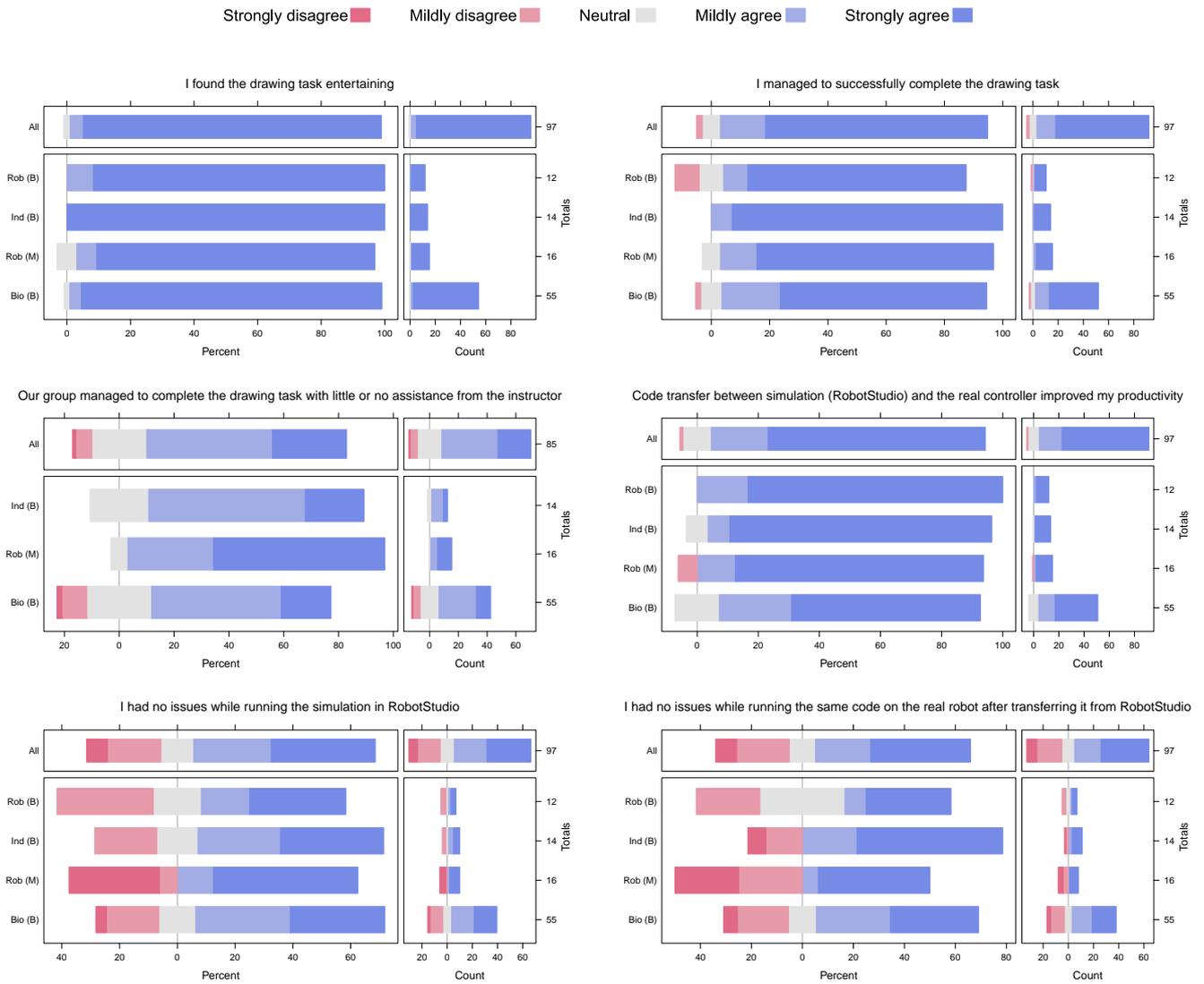


Figure 4: Survey results: items related to the drawing task. Responses are aligned with a five-level Likert scale in which negative feedback corresponds to red tones and positive feedback to blue tones, distributed on the left and right sides of the central neutral gray tone, respectively. More intense tones reflect a stronger feedback. A dual diagram is shown reflecting percentages (left graph) and response count (right graph). Targeted group names are abbreviated: “Rob (B)” for the Bachelor in Robotics Engineering, “Ind (B)” for the Bachelor in Industrial Technologies Engineering, “Rob (M)” for the Master in Robotics and Automation, and “Bio (B)” for the Bachelor in Biomedical Engineering. Certain items did not target all groups. An additional row is added to measure the overall response of all surveyed students. These graphical results have been produced with the “HH” package for the R programming language.

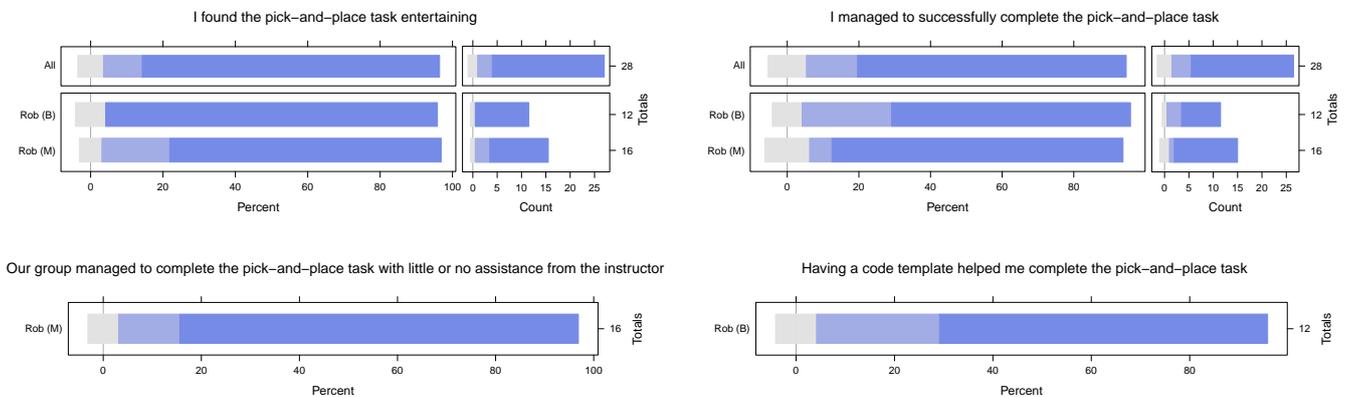


Figure 5: Survey results: items related to the pick-and-place task. See Figure 4 for description.

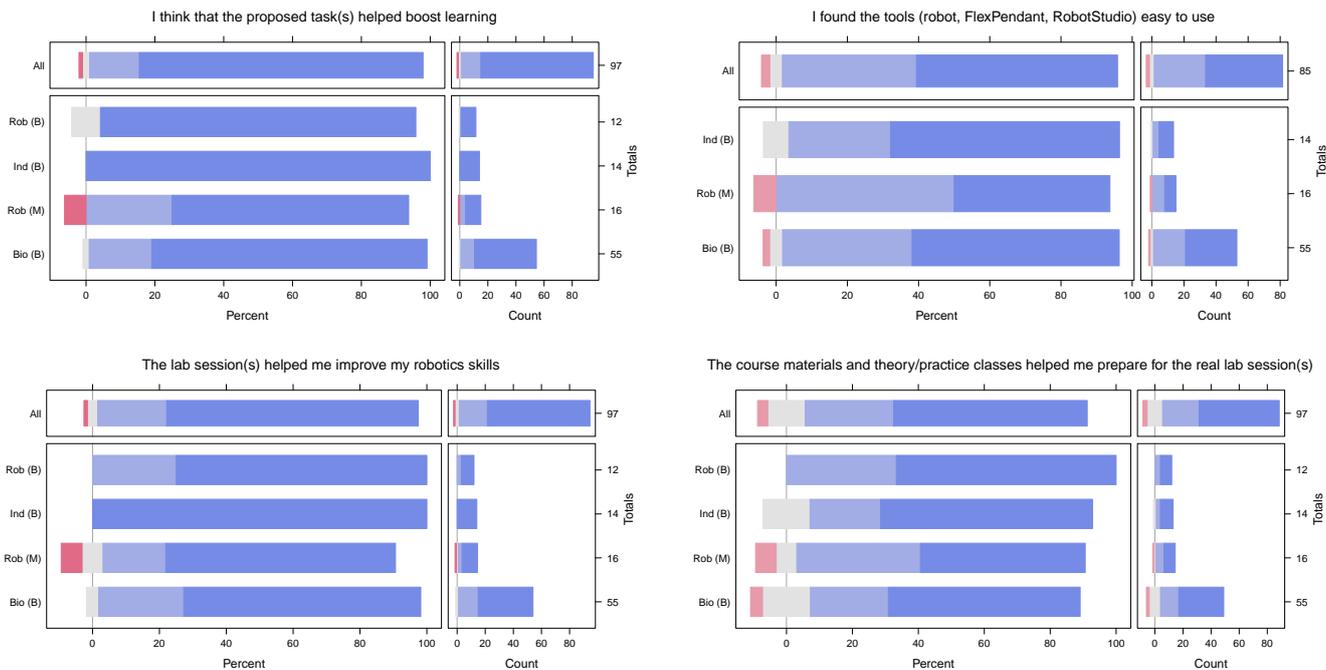


Figure 6: Survey results: common items. See Figure 4 for description.

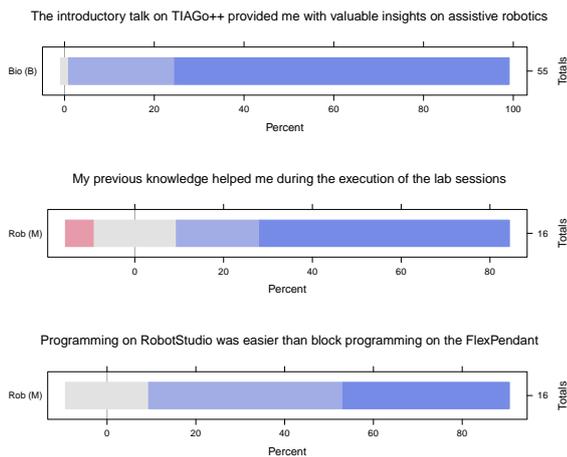


Figure 7: Survey results: miscellaneous items. See Figure 4 for description.

7. Conclusions

While academic performance has remained consistently high in recent years, quantitative grades alone do not fully capture the student experience. Consequently, this study aimed to evaluate student perception of the laboratory sessions, introducing an assessment tool based on established metrics.

In conclusion, the dual focus on system usability and student satisfaction provides a robust framework for evaluating educational robotics. Students welcomed this practice-oriented method, which allows them to simulate and deploy applications in a real setup using custom, easily simulated 3D-printed tools.

Regarding future iterations, instructors should allocate more time for the RAPID programming and simulation steps. Furthermore, future work will aim to analyze the correlation between academic results (grades and pass rates) and student's subjective self-assessment of their performance.

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