

Implementing action research in MART: a multidisciplinary educational innovation project for continuous learning and community engagement

Implementación de la investigación-acción en MART: un proyecto de innovación educativa multidisciplinar para el aprendizaje continuo y el compromiso comunitario

José María De la Varga-Salto¹, Fuensanta Galindo-Reyes², José Manuel González-Varona³, Adolfo López-Paredes⁴

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Abstract

In this study we present the implementation of Action Research (AR) within Málaga Racing Team (MART) at the University of Málaga (UMA); initially launched as a multidisciplinary project to participate in Formula Student (FS). Founded in 2016 by a small group of engineering students, MART has evolved into an innovative educational initiative, now involving eighty students from over twenty different undergraduate and graduate programs. MART's mission extends beyond vehicle development; it encompasses educational, social, and research initiatives aimed at fostering technical skills, promoting social responsibility, and encouraging interdisciplinary collaboration among students. The primary aim of the study is to show how AR has facilitated and guided MART's progress and achievements, addressing the dual objectives of experiential learning and community engagement.

AR, recognised for its iterative and participatory nature, is particularly suited for projects that integrate technical and educational objectives. This approach allows MART to systematically progress through cycles of planning, action, observation, and reflection, facilitating continuous improvement and problem-solving. Through AR, MART has achieved significant milestones, including transitioning from combustion to electric vehicle technology and developing programs such as MART Academy, MART Social, MART Academy School or MART Research. These programs provide specialised training for students, drive social impact through outreach initiatives, contribute to the local community, particularly by promoting STEAM vocations among younger audiences, and facilitates knowledge dissemination and academic contributions.

The results demonstrate the effectiveness of AR in enhancing MART's technical performance and educational impact. Structured cycles have enabled MART to improve both vehicle design and interdisciplinary skill development, leading to notable placements in FS competitions. Additionally, MART's social initiatives, supported by the AR framework, have positively impacted the community, aligning with the United Nations' Sustainable Development Goals (SDGs) in education and innovation.

The discussion addresses how AR has assisted MART in overcoming challenges related to interdisciplinary coordination and resource management. Coordination among students from various disciplines, including engineering, business, and communication, was facilitated through structured feedback mechanisms and regular team meetings, fostering a collaborative culture. Despite resource limitations, particularly during the transition to electric vehicle technology, MART managed to adapt and grow by establishing partnerships and refining its sponsorship strategies.

¹ Universidad de Málaga. Departamento de Economía y Administración de Empresas. Facultad de Marketing y Gestión. Av. Francisco Trujillo Villanueva, 1, 29071, Málaga, Spain. Email: jmdelavarga@uma.es ORCID: 0000-0002-6457-9846

² Universidad de Málaga. Departamento de Economía y Administración de Empresas. Facultad de Marketing y Gestión. Av. Francisco Trujillo Villanueva, 1, 29071, Málaga, Spain. Email: fcgr@uma.es ORCID: 0000-0003-2509-3074

³ Universidad de Málaga. Departamento de Economía y Administración de Empresas. Escuela de Ingenierías Industriales. Arquitecto Francisco Peñaolas, 6, 29071, Málaga, Spain. Email: jmgonzalezva@uma.es ORCID: 0000-0003-2231-4572

⁴ Universidad de Málaga. Departamento de Economía y Administración de Empresas. Escuela de Ingenierías Industriales. Arquitecto Francisco Peñaolas, 6, 29071, Málaga, Spain. Email: loppar@uma.es ORCID: 0000-0001-5748-8308

This study affirms the potential of AR as an approach for educational innovation in multidisciplinary settings. The iterative cycles of AR have allowed MART to balance technical success with social responsibility, setting a benchmark for other educational initiatives. The findings underscore the value of continuous reflection and adaptation in managing complex projects and suggest that AR can serve as an effective approach for projects that aim to integrate technical, educational, and social goals. Future directions include expanding MART's industry partnerships and further enhancing its training programs to address emerging technical challenges. The success of MART provides a replicable model for institutions seeking to create holistic educational experiences that prepare students for the complexities of modern engineering and social responsibility.

Keywords: Action research, higher education, formula student, MART.

Resumen

En este trabajo presentamos la implementación de Action-Research AR (“Investigación-Acción”) en el equipo Málaga Racing Team (MART) de la Universidad de Málaga (UMA), inicialmente un proyecto multidisciplinario para competir en Formula Student (FS). AR ha facilitado el desarrollo técnico y la responsabilidad social de MART, permitiendo la mejora continua en el diseño de vehículos y en la capacitación de los estudiantes. Además, iniciativas como MART Social o MART Academy School promueven el compromiso comunitario y la educación en STEAM. Los resultados subrayan el valor de AR como herramienta educativa innovadora, equilibrando el aprendizaje experiencial y el compromiso comunitario en entornos educativos complejos.

Palabras clave: Investigación acción, educación superior, formula student, MART.

1. Introduction

Educational innovation has evolved to emphasise interdisciplinary, collaborative and applied approaches that prioritise real-world problem-solving and skill acquisition across technical and social domains. Formula Student (FS) is a prime example of this paradigm, offering university students a unique opportunity to design, build, and race a Formula-style single-seater vehicle. This competition, which is held globally in countries like Spain, Germany, and the United States, judges not only the speed and performance of the vehicles but also assesses the design, cost, and commercial viability of each team's project (FSG, 2024). FS thus requires participants to engage in a broad spectrum of skills, from engineering and project management to teamwork and communication, making it an ideal environment for experiential and applied learning (Davies, 2013).

In response to this educational context, Málaga Racing Team (MART) was founded in 2016 at the University of Málaga (UMA). MART is structured around two main areas: the Technical Area, responsible for the vehicle's design, development, and construction, and the Business Area, which manages economic, communication, and sponsorship tasks. This dual approach not only prepares students for the technical demands of FS but also involves them in broader social and educational initiatives. MART's operational framework is organised into four foundational pillars: MART Academy (skill development), MART Social (social responsibility projects), MART Academy School

(promotion of STEAM vocations among pre-university students) and MART Research (knowledge dissemination and research). Through these pillars, MART extends its impact beyond the competition, fostering students' academic, social, and professional growth.

The present study employs Action Research (AR) as its guiding methodology, chosen for its suitability in educational contexts that demand iterative learning and adaptation. Originating from the social sciences, AR is a participatory approach characterised by cyclical phases of planning, action, observation and reflection (Lewin, 1946; Kemmis & McTaggart, 1988). Unlike traditional research approaches, AR facilitates continuous improvement by directly involving participants in addressing project-related challenges, making it particularly well-suited for complex and evolving projects like MART. The flexibility of AR allows the team to refine technical processes and organisational structures continuously, as well as to adapt their strategies in response to feedback from real-world application (Reason & Bradbury, 2008).

This paper aims to examine the effectiveness of AR in guiding the development of a multidisciplinary and holistic project like MART. Specifically, it explores how AR contributes to the achievement of MART's technical objectives, enhances the acquisition of interdisciplinary skills among students, and supports the implementation of educational and social initiatives. By presenting a comprehensive AR-based approach to managing a FS team, this study contributes insights into how educational institutions

can leverage experiential learning methodologies to foster innovation, collaboration and social responsibility, aligning with the United Nations' Sustainable Development Goals (SDGs).

2. Theoretical Framework

AR is a participatory and iterative approach rooted in pragmatist philosophy, designed to integrate research with practical problem-solving in specific contexts (Lewin, 1946; Kemmis & McTaggart, 1988). Through cycles of planning, action, observation, and reflection, AR encourages continuous improvement and adaptation, empowering participants to address real-world challenges effectively (Reason & Bradbury, 2008).

This approach is considered to be a widely used tool in different fields of knowledge. For instance, Fernández Vázquez-Noguerol et al. (2018) developed an AR methodology to implement lean construction techniques in the management processes of a construction company, while others researchers implemented this approach in areas such as health (Zøylner et al., 2020), business models (Huang and Chen, 2022) or occupational health (Chen et al., 2024) among others. The combination of action and research has indeed attracted researchers and the wider academic and educational community. In higher education, for instance, AR serves as a powerful tool for transformative learning and institutional improvement. According to Cohen et al. (2017), scholars have leveraged this approach to tackle complex educational issues, such as curriculum development (Cebrián et al., 2015), teaching methods (Colombari & Neirotti, 2022), and evaluation procedures (Pittman et al., 2021), providing evidence of its versatility in enhancing educational practices. Moreover, Miño-Puigcercós et al. (2019) emphasise AR's capacity to cultivate student values and attitudes, particularly in collaborative and interdisciplinary learning environments.

In the context of Industrial Engineering and Industrial Management, AR has proven particularly beneficial for advancing teaching and learning processes. Several studies underscore the role of AR in promoting interdisciplinary collaboration (Fernández Vázquez-Noguerol et al. (2018) and applying knowledge practically (Smeds et al., 2018; Teixeira et al., 2020), while Gutiérrez-Ujaque (2023) highlights its relevance in aligning educational outcomes with industry requirements. Mackeogh & Fox (2009) add that AR's iterative structure is especially effective in adapting learning strategies to meet evolving educational demands. These studies collectively underscore AR's capacity to foster real-world skills, making it an ideal approach for complex, interdisciplinary initiatives like FS, where the demands on students go beyond technical knowledge to include project management, leadership, and social engagement.

Project-Based Learning (PBL) models are increasingly valued in engineering and technical education, as they encourage active, experiential learning that fosters both technical and interpersonal skills (Lavado-Anguera, et al., 2024). This approach aligns with the requirements of FS, an international competition in which university teams design, build, and race Formula-style cars. FS challenges students to develop a range of competencies, from technical design and cost management to business strategy and communication, making it an ideal platform for the practical application of AR. The competition not only assesses vehicle performance but also evaluates factors such as design innovation, cost-effectiveness and commercial viability (Davies, 2013).

Research has highlighted the positive impact of FS on student development, particularly in enhancing technical expertise, teamwork and leadership skills, as well as fostering stronger connections between academia and industry (Oygarden et al., 2016; Lai et al., 2021). However, there is a notable gap in research that comprehensively applies AR to FS projects, as existing studies have focused on specific aspects. For instance, Ebner et al. (2008) employed AR to address isolated components of FS projects, while Mogles et al. (2022) utilised AR to evaluate digital footprint visualisation for project management, and Kolossváry et al. (2023) explored AR's role in promoting systems engineering acceptance. MART at the UMA provides a unique case to explore a more holistic application of AR across multiple dimensions of an FS project, from vehicle design and manufacturing to business strategy and community outreach.

The MART project exemplifies the application of AR in a multidisciplinary and socially responsible educational initiative. Since its founding, MART has grown to include students from over twenty undergraduate and master's programs, organised into a Technical Area (focused on vehicle design and manufacturing) and a Business Area (responsible for sponsorship, communication and strategic planning). This structure fosters collaboration among students from diverse academic backgrounds, enabling them to apply their disciplinary knowledge to real-world challenges and prepare for complex, interdisciplinary careers.

MART also aligns with the SDGs, particularly SDG 4 (Quality Education) and SDG 9 (Industry, Innovation, and Infrastructure). Through its foundational pillars—MART Academy, MART Social, MART Academy School and MART Research—the project extends its impact beyond technical accomplishments, promoting both academic growth and social responsibility. Miño-Puigcercós et al. (2019) argue that such initiatives are vital for fostering attitudes and values aligned with social responsibility, further justifying MART's approach.

In sum, AR offers an effective framework for managing the complexities of multidisciplinary projects like MART. By promoting cycles of reflection and improvement, AR not

Image 1. Initial team in 2016.



only drives technical advancements in the FS team but also contributes to holistic student development, equipping participants with the skills and values necessary to address both professional and societal challenges.

3. Methodology

This section outlines the methodological approach applied within MART, highlighting the structured implementation of AR since the 2019/20 academic year. Through AR, MART has progressively advanced in technical development, team organisation, and educational outcomes, establishing a framework that supports adaptive learning and problem-solving in response to real-world challenges.

3.1. Action research approach

AR, a participatory and cyclical approach, integrates planning, action, observation, and reflection, facilitating continuous learning and improvement in dynamic environments (Lewin, 1946; Kemmis & McTaggart, 1988). AR's iterative structure is particularly well-suited to MART, where students engage in a multidisciplinary and evolving project requiring both technical expertise and effective project management skills. By embedding AR within MART, the team established a responsive framework that allows for refinements in both technical and educational aspects. This methodological choice aligns with MART's goals of achieving technical excellence while fostering a meaningful educational and social impact, making AR ideal for managing the complexities of vehicle development and broader educational objectives.

3.2. Participants

The MART project involves a diverse group of participants, including students from various disciplines and faculty mentors who provide guidance throughout the AR cycles.

This section describes the team composition, their roles, and how AR has influenced their participation.

- **Team Composition.** Founded in 2016 by a small group of engineering students focused on developing a FS competition vehicle, MART has undergone significant expansion since adopting AR in 2019. Today, MART is a multidisciplinary team of over eighty students from more than twenty undergraduate and postgraduate programs, including engineering, business administration, marketing, and social sciences. This transformation from a specialised group of engineers to a diverse, multidisciplinary team illustrates the impact of AR on team growth and diversification. The evolution of MART is visually represented by comparing the initial team (Image 1), primarily focused on technical aspects, with the current team (Image 2), which showcases members from various academic backgrounds, enhanced gender diversity, and distributed leadership roles. This growth reflects MART's commitment to interdisciplinary collaboration and continuous improvement, fostered by the AR framework.
- **Faculty Involvement.** The team initially operated under the guidance of a single director specialising in engineering. Today, however, MART is directed by two co-directors—one with a background in engineering and the other in business—supported by an interdisciplinary team of faculty members from diverse fields, including education, communication, labor relations, and physical therapy, among others. Their involvement has been critical in guiding the team through each phase of the AR cycles, offering the technical and management expertise essential to the project's success.
- **Multidisciplinary and Role Distribution.** The team is organised into two primary areas:
 - **Technical Area.** This area, composed mainly of engineering students, is responsible for the design, construction, and testing of the vehicles. The team

Image 2. Current team in 2024.



works across several technical disciplines, including mechanical engineering, aerodynamics, materials science, and vehicle dynamics.

- **Business Area.** This area, including students from business, marketing, and communication, manages sponsorships, budgeting, public relations, and competition logistics, including passing highly competitive online exams to secure FS competition slots.

The application of AR has facilitated more efficient role distribution within the team, promoting collaboration among students from diverse academic backgrounds. Additionally, MART has prioritised gender diversity, with women holding 37.88% of the positions and playing key leadership roles such as Team Leader, Head of Business, and Directors of Marketing and Communication.

3.3. Phases of the action research process

The implementation of AR in MART follows a cycle of planning, action, observation, and reflection, with each phase adapted to meet the evolving needs of the project. These cycles have been applied from the 2019/20 season through to the current 2024 season.

Planning Phase. In this phase, objectives were defined, and the project's structure was developed to maximise technical and operational efficiency.

- **Objectives.** Initially, MART focused on developing combustion vehicles. However, from the 2021/22 season,

the team expanded its scope to include electric vehicle research and development. Additional goals included MART Academy training initiatives, social outreach through MART Social or MART Academy School, and research dissemination through MART Research.

- **Team Structuring.** As the team grew, MART implemented a formal structure that divided responsibilities between the Technical and Business Areas, enhancing specialisation and project management.
- **Work Schedule.** A detailed timeline was developed, outlining vehicle development stages, research deadlines, and key outreach activities, ensuring a structured approach to each season.

Action Phase. During this phase, MART put its plans into practice across technical, business, and educational domains.

- **Technical Development.** AR cycles guided the design and testing of MART's vehicles, from the combustion models (MA21RT to MA24RT) to the electric iMA24RT. Iterative testing allowed for continuous improvements based on lessons learned in previous competitions.
- **Business and Sponsorship.** The Business Area secured financial backing and established sponsorship agreements, enabling MART to cover vehicle development costs and competition expenses. The team also successfully navigated competitive online exams required for entry into FS events.
- **Educational and Social Outreach.** MART Academy delivered training in technical and soft skills, while

MART Academy School promoted STEAM education among younger students, particularly targeting under-represented groups. MART Social initiatives further engaged the local community through social projects.

Observation Phase. In this phase, MART focused on systematic data collection and performance tracking.

- **Data Collection.** Data were gathered from FS competition metrics, sponsor feedback, and internal evaluations. These data sources provided insights into both the technical performance of the vehicles and the team's interdisciplinary dynamics.
- **Team and Sponsor Feedback.** Weekly meetings served as an internal feedback mechanism, while consultations with sponsors and media assessed MART's visibility and outreach strategies' effectiveness.

Reflection Phase. The reflection phase involved analysing collected data and implementing adjustments for the next AR cycle.

- **Analysis of Competition Results.** Each season's results were thoroughly reviewed, allowing the team to identify technical issues and operational challenges. At the end of each season, design adjustments were made based on feedback from FS judges.
- **Strategic Adjustments.** Reflective analysis led to refinements in MART's organisational structure, additional training for team members, and adjustments to project timelines, contributing to more efficient project execution.

3.4. Data collection instruments

Several data collection instruments were employed to ensure a comprehensive understanding of MART's progress and outcomes throughout the AR cycles:

- **Interviews.** Interviews with students, faculty, and sponsors provided qualitative insights into team dynamics, challenges and personal growth.
- **Surveys.** Regular surveys assessed the impact of AR cycles on technical and soft skill development and measured participants' satisfaction with interdisciplinary collaboration.
- **Team Meeting.** Weekly meetings allowed for ongoing project updates and provided a forum for discussing the effectiveness of implemented strategies. Meeting notes were analysed to track decision-making and team reflections.
- **Performance Data from FS Competitions.** Metrics such as acceleration, endurance, and business presentation scores were analysed to evaluate MART's technical achievements and business strategies.

- **Sponsor Feedback.** Consultations with sponsors provided feedback on MART's progress and communication, helping to refine sponsorship approaches and maintain support.
- **Document Analysis.** Technical reports, project plans, and budgets were analysed to monitor project development, ensuring a structured approach to each AR cycle.

3.5. Data analysis

The data collected were analysed through qualitative and quantitative methods to capture MART's progress holistically.

- **Qualitative Analysis.** Interviews, surveys and meeting discussions were coded and thematically analysed to uncover patterns related to teamwork, leadership, interdisciplinary collaboration and technical challenges. This approach provided insights into the students' learning experiences, team dynamics and the interdisciplinary nature of the project.
- **Quantitative Analysis.** FS competition performance metrics, such as design scores and lap times, were quantitatively assessed to measure MART's technical and operational success. Additionally, survey responses were statistically analysed to evaluate participant satisfaction, skill development and the overall impact of AR on improving project outcomes.
- **Comparative Analysis.** Results from each season were compared to evaluate the cumulative impact of AR on MART's development. Key performance indicators (KPIs) such as competition placements, sponsorship growth and academic outputs (e.g., Final Degree Projects [TFG] and Master's Theses [TFM]) highlighted the evolution of the team and the effectiveness of AR in achieving sustained progress.
- **Reflective Learning.** Qualitative data from student reflections were analysed to understand broader educational impacts, including the development of problem-solving abilities, leadership skills and technical expertise. This reflective learning aspect underscored the holistic educational value of MART's approach.

The adoption of AR has been pivotal to the growth and achievements of MART, guiding the team through cycles of planning, action, observation, and reflection. This iterative framework enabled MART to evolve from a small group of engineering students into a multidisciplinary team capable of competing at the highest levels in FS competitions. The AR process facilitated the development of both technical and soft skills, supported vehicle innovation, enhanced MART's communication with external stakeholders and reaffirmed its commitment to social engagement. The success of AR

reflects its potential as a robust framework for managing complex educational projects, promoting a culture of learning, adaptability and innovation.

4. Results

The implementation of AR within MART has led to significant achievements across technical, educational and social dimensions. This section outlines the main results observed throughout the project, detailing the advancements in vehicle development, educational impact on team members, community engagement and the role of AR in guiding strategic adjustments and problem-solving.

4.1. Technical progress: Vehicle development

Since the adoption of AR, MART has achieved substantial technical progress in the design, development and performance of its vehicles. This iterative approach has facilitated continuous improvements based on lessons learned in previous seasons, contributing to the creation of competitive race cars for FS competitions.

- **Combustion Vehicles.** MART’s journey began with combustion vehicles, achieving significant milestones each season. The MA24RT, developed in the 2023/24 season, represented the culmination of this process. This model demonstrated advancements in acceleration, endurance, and design, allowing MART to secure commendable placements in FS competitions.
- **Electric Vehicle Development.** A major milestone in MART’s innovation trajectory has been the shift toward electric vehicle technology, beginning in the 2021/22 season. Through iterative cycles of research, testing and design, the iMA24RT—MART’s first competitive electric vehicle—was completed and introduced in the 2023/24 season. This shift reflects MART’s commitment to sustainability and alignment with industry trends.

Table 1 summarises MART’s vehicle development and competition performance from the 2020/21 to 2023/24 seasons, highlighting the team’s progression from combustion to electric vehicles and their achievements across technical and business categories in various FS events.

The AR approach facilitated targeted improvements based on feedback from previous competition cycles. For instance, after the 2022 season, specific design changes were implemented to enhance acceleration and endurance, resulting in better performance at FS Spain and FS Germany in 2023. The development of iMA24RT also demonstrated MART’s capacity to adapt to new technical challenges, validating the AR process as a tool for technical growth.

Table 1. Overview of Vehicle Development and Competition Performance.

Season	Vehicle	Key Competitions	Results
2020/21	MA21RT	FS Spain	Spirit Award
2021/22	MA22RT	FS Netherlands	P3 Acceleration, P3 Endurance, P6 Overall
		FS Spain	P4 Acceleration, P3 Endurance, P1 Business, P5 Overall
2022/23	MA23RT	FS Germany	P9 Design, P10 Endurance, P12 Overall
		FS Spain	P3 Acceleration, P2 Endurance, P3 Design, P2 Overall
2023/24	MA24RT	FS Spain	P21 Business, P22 Cost, P18 Design
	iMAR24RT (electric)	FS Austria	P13 Business, P19 Cost, P15 Design, P9 Autocross, P16 Overall

4.2. Educational impact: Skill development and interdisciplinary learning

One of MART’s core objectives has been the development of both technical and soft skills among team members. The structured implementation of AR within MART Academy has significantly enhanced student learning, adapting training programs in response to feedback and ensuring the continuous development of relevant competencies.

- **Technical Skills.** Over the last three academic years, MART Academy has increased substantially its training hours, delivering specialised courses covering vehicle dynamics, materials science and project management. Through AR’s observation and reflection phases, MART was able to identify knowledge gaps and adjust course content, resulting in improved technical expertise, as evidenced by the team’s performance in FS competitions.
- **Soft Skills.** The interdisciplinary nature of the team promoted the development of communication, teamwork and leadership skills. Students gained hands-on experience in collaboration, managing relationships with sponsors and engaging with media. This emphasis on soft skills was strengthened by feedback loops within the AR process, allowing students to continuously reflect on and improve their interpersonal and organisational skills.

Table 2 provides a structured overview of MART Academy training hours from 2021/22 to 2023/24.

Table 2. Overview of MART Academy Training Hours (2021/24).

Academic year	Number of courses	Total training hours	% Increase
2021/22	10	265	-
2022/23	15	320	20.7%
2023/24	18	385	20.3%

- Additionally, MART has contributed to academic development by facilitating the defense of thirty-eight TFG and TFM from 2017/18 to 2023/24. This involvement underscores MART's role in supporting student research and academic growth, with thesis projects distributed as follows: one in 2017/28, three in 2018/19, two in 2019/20, three in 2020/21, four in 2021/22, twelve in 2022/23 and thirteen in 2023/24. Currently, there are four projects in progress, spanning nine different degree programs at the UMA, highlighting the multidisciplinary impact of MART's activities. MART has also made notable strides in knowledge dissemination, with two papers published in JCR-indexed journals, two book chapters and twelve presentations at international scientific congresses. This scholarly output reflects MART's commitment to advancing educational research, as well as the broader academic and professional community.
- As suggested by Smeds et al. (2018), AR plays a crucial role in fostering a culture of inquiry and reflective practice within educational research. For MART, the AR framework has facilitated systematic evaluation and continuous academic growth, promoting a substantial increase in publication output and enhancing the learning process. This approach not only supports teaching and learning advancements in higher education but also underscores MART's impact as a model of interdisciplinary educational innovation.

4.3. Social impact: Community engagement and educational outreach

MART's commitment to social responsibility is demonstrated through its outreach programs, particularly those facilitated by MART Social and MART Academy School. These initiatives aimed to create a positive impact within the local community and promote STEAM vocations among young students.

- MART Social. Over the past two years, MART Social has implemented fifteen social projects, including environmental awareness campaigns, educational workshops, and community events. The AR framework facilitated these activities' alignment with community needs, allowing MART to adjust its strategies based on the feedback received during the observation phase.

- MART Academy School. Launched in the 2022/23 season, MART Academy School has conducted outreach visits to secondary schools and training centers, targeting underrepresented groups in STEAM, particularly young women. The AR process enabled MART to adapt and refine these outreach strategies based on feedback from teachers and students, ensuring engaging and effective activities.

Through these initiatives, MART has contributed to community development and strengthened its public presence, aligning with the SDGs, particularly in social responsibility and education.

4.4. Evaluation of the action research approach

The application of AR has been instrumental in shaping MART's approach to technical challenges, educational objectives and community engagement. By continuously cycling through phases of planning, action, observation, and reflection, AR has provided MART with a robust framework for adaptive learning and improvement.

- Problem Identification. The observation phases within AR allowed MART to identify both technical and operational challenges early on. For instance, feedback from competitions revealed specific areas for improvement in vehicle design, leading to targeted changes that enhanced MART's competitive performance in subsequent seasons.
- Strategic Adjustments. Each reflective phase enabled MART to make strategic adjustments based on past performance and stakeholder feedback. These adaptations extended to organisational changes, such as refining communication strategies with sponsors and enhancing interdisciplinary collaboration.
- Sustainability and Innovation. AR's iterative nature encouraged MART to explore innovative approaches, such as the shift to electric vehicle technology. Reflections on the environmental impact of combustion engines influenced MART's decision to develop an electric vehicle, aligning with both sustainability goals and industry trends.

In summary, the results achieved by MART through AR demonstrate the effectiveness of this approach in fostering both tangible and intangible outcomes. From technical improvements in vehicle design to skill development among team members and impactful social initiatives, AR has provided a foundation for MART's continuous growth and success. These results highlight AR's capacity to manage complex, multidisciplinary projects while contributing

positively to both the university community and the local society.

5. Discussion

The implementation of AR within MART has led to substantial accomplishments, offering valuable insights into the potential of AR as a tool for managing complex, interdisciplinary educational projects. The discussion below examines the successes, challenges and comparative insights of the MART project in the context of the theoretical framework and research objectives.

5.1. Successes of the project

One of the primary successes of the MART project is its ability to integrate technical, educational and social objectives within a single and cohesive framework. By applying AR cycles of planning, action, observation and reflection, the team effectively addressed real-world engineering challenges while simultaneously developing essential professional skills among students. The structured AR approach enabled MART to iteratively refine its vehicle designs, secure financial and technical support from sponsors and implement impactful social outreach initiatives.

Through continuous feedback loops, AR also provided a mechanism for identifying and capitalising on educational opportunities. For example, the iterative nature of AR allowed MART Academy to adapt its training programs in response to students' evolving needs, resulting in significant skill acquisition in areas such as teamwork, leadership and interdisciplinary collaboration. These achievements align with findings from previous studies that emphasise AR's ability to foster active learning and adaptability (Cebrián et al., 2015; Miño-Puigcercós et al., 2019). Overall, the AR approach proved instrumental in achieving both technical and educational goals, supporting MART's mission of creating a holistic learning environment.

5.2. Challenges faced

Despite its many successes, the MART project encountered several challenges, particularly in coordinating students from diverse academic backgrounds and managing resources. The interdisciplinary nature of MART introduced complexities in communication and collaboration, as students from engineering, business and social sciences often had differing perspectives, technical vocabularies and project priorities. The AR approach helped mitigate these issues by establishing regular team meetings and structured feedback mechanisms, which facilitated a better understand-

ing of roles and fostered a collaborative culture. However, balancing technical and business responsibilities within the tight timelines required for FS competitions remained a persistent challenge.

Resource management, especially with the transition to electric vehicle technology, also presented difficulties. The development of the iMA24RT demanded specialised knowledge and funding, which were at times insufficient. Although AR cycles allowed the team to adapt strategies and seek additional support from sponsors, future iterations of the project could benefit from stronger external partnerships and access to more specialised expertise.

5.3. Comparison with other projects

Compared to other FS teams and educational innovation projects, MART's experience stands out due to its comprehensive application of AR across technical, business and social domains. While many FS teams focus primarily on technical aspects, MART's multidimensional approach—encompassing MART Academy, MART Social, MART Academy School and MART Research—has allowed it to make significant contributions to both academic and community engagement. This approach aligns with the SDGs, particularly those focused on quality education and innovation, positioning MART as a model for socially responsible engineering education.

Additionally, MART's success in consistently securing high placements in FS competitions, alongside its community engagement efforts, highlights the effectiveness of the AR framework in fostering both competitive excellence and societal impact. Compared to similar educational innovation projects, MART's integration of AR has allowed for greater adaptability and responsiveness, ensuring that the project remains aligned with industry trends and community needs. This experience supports findings in the literature regarding the versatility of AR in educational settings (Teixeira et al., 2020), suggesting that similar projects could benefit from adopting an AR approach to balance technical and social objectives.

6. Conclusion

The MART project exemplifies the transformative potential of AR in the context of interdisciplinary education and engineering. By continuously applying cycles of planning, action, observation and reflection, MART has been able to achieve significant milestones in vehicle development, student skill acquisition and community engagement. The following points summarise the key outcomes, contributions to educational innovation and suggestions for future improvements.

6.1. Impact on academic and social development

The structured implementation of AR within MART has facilitated the development of technical skills, such as vehicle dynamics and project management, alongside soft skills, including teamwork, communication and leadership. These competencies are essential for preparing students for professional engineering roles and interdisciplinary collaboration. Furthermore, MART's commitment to social initiatives, through programs like MART Social and MART Academy School, has encouraged students to engage actively with their local community, promoting STEAM vocations among young learners and addressing local needs through educational outreach.

6.2. Contributions to educational innovation

MART's use of AR contributes to the field of educational innovation by demonstrating how this approach can effectively manage complex and multidisciplinary projects. The iterative and participatory nature of AR allows for continuous adaptation, enabling teams to respond to challenges in real time and refine strategies based on collective reflection. MART's experience underscores the value of AR in fostering holistic educational environments that balance technical and social objectives, supporting previous research on the adaptability and effectiveness of AR in higher education (Cebrián et al., 2015; Miño-Puigcercós et al., 2019).

6.3. Future improvements and recommendations

While the application of AR has been successful, the MART project could benefit from several enhancements to further improve outcomes in future iterations:

- **Enhanced External Partnership.** Developing stronger collaborations with industry professionals and academic institutions could provide MART with access to specialised knowledge and resources, particularly for advanced electric vehicle technologies.
- **Expanded Training Opportunities.** Although MART Academy has successfully adapted its training programs, additional resources and sessions in emerging areas such as electric propulsion and sustainable engineering could further enhance the technical expertise of team members.
- **Improved Resource Management.** Addressing resource constraints remains a priority, especially as the project grows in scope and complexity. Establishing dedicated funding channels and exploring new sponsorship opportunities could help MART secure the financial support necessary to sustain both its technical and educational initiatives.

In conclusion, the MART project illustrates the potential of AR as a methodology for achieving technical, educational and social objectives in interdisciplinary engineering projects. The success of MART provides a valuable model for other educational initiatives seeking to balance competitive excellence with community engagement and sustainability. By fostering continuous learning and adaptation, AR has enabled MART to not only excel in FS competitions but also to establish itself as a leader in socially responsible engineering education.

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