ENVIHEI

Title of the PBL challenge: **Design, Implementation, and Deployment of an AI-Based Inspection System for Anomaly Detection**

Name of the responsible lecturer

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University / Department / Degree program

University of León / Department of Mechanical, Informatics and Aerospace Engineering / Bachelor's Degree in Computer Science Engineering

Course / Subject in which implemented

3rd Course / Project Management

Implementation period (dates)

September 10, 2025 – December 10, 2025

Total duration (weeks/hours)

13 weeks / 78 hours [24 hours per group (3 groups) + 2 hours final exhibition + 1 hour industry presentation + 3 hours industry visit]

Number of students involved

79 students

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1. Project Design

1.1 Brief description of the project and the challenge proposed

This project is a problem/project-based learning (PBL) experience implemented within the Project Management course of the Bachelor's Degree in Computer Science Engineering at the University of León. It was developed under the framework of the ENVIHEI project, aiming to integrate sustainability and student-centred learning methodologies into higher education.

The challenge was proposed in collaboration with the automotive cluster FaCyL and the multinational company Antolín, providing students with a real industrial problem. The objective was to design, implement, and deploy an AI-based inspection system capable of detecting anomalies in plastic parts used in automotive manufacturing. Due to the scarcity and variability of defects, the problem was approached as an anomaly detection task, requiring students to model normality and identify deviations from it.

Students worked in three independent groups, simulating professional project teams and competing to provide the most effective solution. Each team was responsible for managing the full project lifecycle, from initial planning and requirements definition to implementation and final validation. In addition to developing a functional prototype (including an AI model, a backend service, and a frontend application), students were required to apply formal project management methodologies and produce structured technical documentation. The experience was complemented by direct interaction with the industrial partner, including a company visit and a final presentation before an external jury. A sustainability perspective was integrated throughout the project, encouraging students to consider both the reduction of material waste through early defect detection and the environmental impact of computational solutions.

1.2 Expected learning outcomes (academic and transversal competences)

- Design, plan, and manage an engineering project throughout its full lifecycle, including scope definition, requirements analysis, task decomposition, scheduling, and risk management.
- Apply project management tools and methodologies (e.g., Work Breakdown Structure, project scheduling software, and technical documentation standards) in a realistic context.
- Coordinate technical development processes within a project framework, ensuring alignment between planning, execution, and final deliverables.
- Develop and integrate a functional software solution, including an AI-based anomaly detection model, a backend service, and a frontend application.
- Work effectively in large teams, assuming roles and responsibilities, and contributing to the organization and monitoring of collaborative work.
- Document project activities and decisions in a clear, structured, and professional manner, following engineering standards.
- Communicate and defend project results effectively in a professional context, including presentations to external stakeholders.
- Manage time and resources efficiently, including the tracking of individual contributions and workload distribution.
- Apply critical thinking to evaluate alternative solutions and justify technical and organizational decisions.
- Integrate sustainability considerations into engineering practice, reflecting on the environmental impact of both industrial processes and computational solutions.

1.3 Targeted sustainability competences

- Apply a systems-thinking approach to understand the environmental impact of industrial processes and technological solutions.
- Evaluate how engineering decisions affect resource consumption, waste generation, and energy efficiency.
- Integrate sustainability considerations into problem-solving and decision-making in engineering projects.
- Promote responsible use of digital technologies, considering principles of green computing.
- Demonstrate critical thinking in assessing trade-offs between performance and environmental impact.

1.4 Sustainability approach and how it is integrated into the project

Sustainability is integrated as a transversal dimension of the project, rather than as a separate component. The challenge itself is framed within a real industrial context in which early detection of anomalies in manufacturing processes can contribute to reducing material waste, improving efficiency, and minimizing the environmental impact of production.

In addition, students are required to consider the sustainability implications of their technological solutions. In particular, they are encouraged to reflect on aspects related to green computing, such as the efficiency of AI models, the use of computational resources, and deployment strategies. This includes evaluating trade-offs between performance and resource consumption.

The sustainability perspective is explicitly incorporated into both the development and evaluation of the project. Students must justify how their proposed solution contributes to more sustainable practices, either by reducing waste in manufacturing processes, improving efficiency, or proposing alternative approaches with lower environmental impact.

This approach is aligned with the ENVIHEI framework, promoting the integration of sustainability competences through a student-centred, problem/project-based learning methodology, where students actively engage with real-world challenges and make informed, responsible decisions.

1.5 Methodologies and tools used (PBL structure, facilitation techniques, etc.)

The experience is based on a combination of Problem/Project-Based Learning (PBL) and Challenge-Based Learning (CBL), where students are confronted with a real industrial problem and are required to develop a complete solution in a student-centred learning environment.

Driving challenge: The project is structured around a central open-ended question: how to design and deploy an effective system for anomaly detection in an industrial manufacturing context. Students act as project management teams responsible for delivering a solution that meets real requirements.

PBL structure: The project follows a progressive approach in which students move from initial understanding and planning phases to implementation and final validation. The process includes project definition, task planning, development of the technical solution, and final presentation.

Facilitation techniques: The lecturer acts as a facilitator, guiding the process through regular follow-up sessions, feedback, and monitoring. Weekly meetings are used to track progress, discuss decisions, and identify potential issues. Students are required to document these meetings through formal minutes.

Collaborative work and roles: Students work in large teams, assuming professional roles such as project manager and secretary. This structure promotes responsibility, coordination, and organization of tasks within the group.

Tools and technologies:

- Project management tools: Work Breakdown Structure, Microsoft Project, and formal documentation templates.
- Development tools: Python and common machine learning libraries for anomaly detection.
- Collaboration and monitoring: Discord channels for communication and follow-up, and timesheets for tracking individual contributions.
- Deployment tools: container-based solutions for backend services.

Data-driven learning: Students work with real datasets provided by the industrial partner, including both labelled and unlabelled data, which introduces realistic constraints and requires them to address issues such as generalization and validation.

1.6 Organization of the project (group formation, timeline, milestones)

Students were organized into three practical groups (G1, G2, and G3), each working as an independent project team and competing to provide the most effective solution to the proposed challenge. Group allocation was based on students' availability, ensuring compatibility with other laboratory sessions. As a result, group sizes were not fully balanced. In particular, G3 incorporated several incoming Erasmus students who could only attend that time slot, while G2 had a lower number of students from the outset.

Each group attended weekly laboratory sessions of two hours, resulting in a total duration of 13 weeks, including supervised sessions and autonomous work.

The project followed a structured timeline across the semester:

- **Week 1 (Project introduction)**: Presentation of the challenge, context, and objectives by the lecturer.
- **Week 2 (Industry introduction and project setup)**: Joint session with all students (1 hour) in which representatives from Antolín presented the industrial challenge and its context. Students then organized into teams, assumed roles (project manager and secretary), and initiated planning activities.
- **Week 3-9 (Development phase)**: Students worked on project planning and implementation, including requirements definition, task organization, and development of the technical solution. Weekly meetings were held during lab sessions, and students could request feedback from the lecturer at any time.
- **Week 8 (Industry interaction)**: Visit to Antolín facilities (November 7), providing students with direct exposure to the industrial environment and helping them refine their solutions.
- **Week 10-12 (Integration phase)**: Final integration of the system components (AI model, backend, and frontend), validation of the solution, and preparation of the final presentation.
- **Week 13 (Final event)**: Public presentation of the projects before an external jury (December 10), with all groups participating in a joint session.

In addition to scheduled sessions, each group had the possibility to interact directly with the company. A designated contact person at Antolín was available to address questions, and communication was managed through the project manager of each team. This interaction reinforced the professional nature of the experience and allowed students to clarify requirements and constraints in a realistic setting.

The organization emphasized continuous monitoring and formative assessment rather than fixed intermediate submissions. Students were encouraged to share their progress regularly and receive feedback, enabling iterative improvement in both project management practices and technical development.

1.7 Deliverables requested from students (type, format, deadlines)

Project documentation (7 December 2025):

- Complete project report (PDF), including the full description of the proposed solution and its justification structured according to UNE 157801:2007 standards.
- Set of completed project management templates (PDF), including:
  - Project Charter
  - Project Management Plan
  - Requirements documentation
  - Project Scope Statement
  - Work Breakdown Structure (WBS)
  - WBS Dictionary
  - Risk Data Sheet
  - Change request

Project planning (7 December 2025):

- Microsoft Project file, including task definition, scheduling, dependencies, milestones, and resource allocation.

Process tracking (7 December 2025):

- Minutes of weekly meetings, documenting progress, decisions, and task assignments.
- Work registration (timesheets) reflecting individual contributions throughout the project.

Technical solution (7 December 2025):

- Functional prototype of the proposed system, including:
  - AI model for anomaly detection
  - Backend service deployable using containers
  - Frontend application for inspection (image loading, processing, visualization, and results export)

Final presentation (10 December 2025):

- Supporting materials (slides or equivalent) for a 5–10-minute presentation.
- Oral presentation and demonstration of the solution directly to an external jury composed of representatives from the university, FaCyL, and Antolín.

1.8 External collaborators involved (mentors, companies, experts...) and their role

FaCyL (Automotive Cluster of Castilla y León):

FaCyL acted as a facilitator, connecting the academic environment with the industrial ecosystem. It contributed to the definition of the challenge and supported the organization of the final event, reinforcing the link between higher education and the regional automotive sector.

Antolín (industrial partner):

Antolín played a central role as the provider of the real challenge and data. The company:

- Defined the problem and provided the initial and extended datasets.
- Presented the challenge and its industrial context in a joint session with all students.
- Hosted a site visit, allowing students to understand the manufacturing environment and constraints.
- Provided a contact person for direct communication, enabling students (through their project managers) to ask questions and clarify requirements during the development phase.
- Participated in the final evaluation as a member of the external jury.

External jury:

The final evaluation involved an external jury composed of representatives from Antolín, FaCyL, and the School of Engineering. Their role was to assess the proposed solutions, provide professional feedback, and select the best-performing project.

2. Project Evaluation

2.1 Assessment criteria and methods used

Assessment was based on a combination of continuous evaluation and final deliverables, using a set of structured rubrics aligned with the different components of the project (available at the following link: https://drive.google.com/file/d/1fFVwQX9-UskYkmvRd4pTdA-667QpOEfN/view?usp=drive_link). The evaluation model aimed to assess both the project management process and the final technical outcome.

The assessment was distributed across several dimensions:

- **Project documentation (25%)**, evaluating structure, completeness, writing quality, level of detail, and consistency of the proposed solution, including the integration of sustainability considerations.
- **Project management templates (20%)**, assessing the correct application of methodologies such as WBS, risk analysis, and change management, as well as clarity and level of detail.
- **Functional solution (30%)**, focusing on the development of a working system, including the AI model, backend, frontend, and their integration. Additional aspects such as documentation, code quality, and sustainability of the solution were also considered.
- **Final presentation (15%)**, evaluating communication skills, clarity, justification of decisions, and the ability to present and demonstrate the solution before an external jury.
- **Supporting elements**, including Microsoft Project planning (5%) and meeting minutes (5%), which assessed planning quality, monitoring, and team organization.

The evaluation emphasized not only the final results but also the development process. Continuous and formative assessment was implemented through regular feedback during weekly sessions, allowing students to improve their work iteratively.

Sustainability was treated as a cross-cutting evaluation criterion, being explicitly assessed both in the project documentation and in the proposed technical solution. Students were required to justify how their approach contributed to more sustainable practices, considering both industrial and computational perspectives.

2.2 Evidence of student learning (examples, outputs, results)

The results of the project demonstrate a high level of achievement in both project management and technical development. All participating groups successfully delivered a functional solution that met the requirements of the challenge, including an AI-based anomaly detection system integrated with backend and frontend components.

From a quantitative perspective, the evaluation results show an overall high performance across the groups, with consistent achievement in the different assessed dimensions (project documentation, planning, functional solution, and presentation). The distribution of grades reflects a generally strong level of competence, with no groups failing to meet the minimum requirements and several achieving high scores across multiple criteria.

From a qualitative perspective, the final presentations provided clear evidence of student learning. During the final event, the industrial partner (Antolín) introduced a set of previously unseen images, which were tested live using the developed systems. This real-time validation scenario highlighted differences in performance between the groups:

- One group (G1) achieved a fully correct detection of anomalies in all test cases, demonstrating a robust and well-generalized solution.
- Another group (G2) showed reasonable performance but misclassified several cases.
- A third group (G3) experienced partial failures in processing some images, although it performed correctly on others.

These results illustrate not only the successful implementation of functional systems, but also the ability of students to face realistic challenges such as generalization to unseen data and system robustness.

In addition, the overall quality of the projects was reflected in the feedback from the external jury, which highlighted the high level of the solutions. This was particularly notable given that many of the technical components involved (e.g., computer vision, web application development, and deployment) were new to the students, requiring them to acquire and apply knowledge autonomously.

Overall, the outputs produced by the students – including complete project documentation, functional software systems, and professional presentations – provide strong evidence of the achievement of both academic and transversal learning outcomes.

3. Reflections and Recommendations

3.1 Main achievements and strengths of the project

The main achievement of this project is the successful integration of project management training, technical development, and sustainability within a real industrial context. Students were able to apply project management methodologies in a realistic setting, taking full responsibility for the planning, execution, and delivery of a complex engineering project.

A key strength of the experience lies in its strong connection with industry. The collaboration with Antolín and FaCyL provided an authentic challenge, real data, and direct interaction with professionals, including a company visit and a final evaluation by an external jury. This contributed significantly to student motivation and reinforced the relevance of their work.

Another important strength is the high level of student engagement and performance. All groups were able to deliver functional solutions, and the quality of the results was positively assessed by the external jury. The fact that students successfully developed systems involving AI, backend services, and frontend applications – despite having limited prior experience in some of these areas – demonstrates a strong capacity for autonomous learning and problem-solving.

The project also stands out for its effective use of a competitive and collaborative structure. The organization into independent groups working on the same challenge encouraged diversity of solutions, increased commitment, and simulated real-world scenarios where multiple teams compete to address the same problem.

From an educational perspective, the experience aligns with the objectives of the ENVIHEI project. It successfully implements a student-centred, problem/project-based learning approach in which sustainability is integrated as a meaningful dimension of the challenge. Students were required not only to develop a technical solution but also to reflect on its environmental impact, both in terms of industrial processes and computational efficiency.

Finally, the project achieved a significant level of dissemination and impact beyond the classroom. The final event and its coverage in media and institutional channels contributed to highlighting the value of this type of initiative, positioning it as an example of innovation in engineering education.

3.2 Challenges faced and how they were addressed

One of the main challenges encountered during the implementation of the project was related to group dynamics and collaboration, particularly in one of the groups. Pre-existing interpersonal conflicts, together with differences in motivation among some of the members (including incoming Erasmus students), led to an uneven distribution of workload within the team. While some students showed a high level of engagement, others contributed less consistently, which affected coordination and overall performance.

This situation was addressed through continuous monitoring and feedback during the weekly sessions. Students were encouraged to take responsibility for task distribution and to make decisions regarding team organization. In line with this, a mechanism was proposed allowing groups to identify members who were not contributing sufficiently and, if necessary, separate them from the group, assigning them individual work. Although this measure was not formally applied, it served as a reference to promote accountability.

Another challenge was the allocation of individual grades within group work. Students were asked to distribute the group grade among members based on their contribution, ensuring that the overall average was preserved. However, this approach generated some tension. In one group, the lecturer had to intervene and adjust individual grades to ensure fairness.

More generally, the organization and coordination of work within large groups proved to be challenging, especially in the initial phases of the project. Students were not initially accustomed to self-managed teamwork at this scale, which led to inefficiencies and uncertainty. This issue was progressively mitigated through guidance, role assignment (e.g., project manager), and the use of structured tools such as meeting minutes and timesheets.

3.3 Lessons learned for future implementations

One of the main lessons learned from this experience is the importance of strengthening mechanisms for monitoring individual contributions within group work. Although timesheets were provided, their use was not always consistent. In future implementations, their use will be reinforced by requiring regular validation (e.g., signed by both the project manager and the team member), in order to ensure a more accurate and transparent record of individual effort.

A central challenge is to achieve an appropriate balance between guidance and autonomy. Providing too much structure may limit creativity and ownership, while insufficient guidance can lead to inefficiencies. In future implementations, the objective will be to support students more effectively in the initial stages of project organization, without prescribing specific solutions or workflows, allowing them to retain responsibility for decision-making.

In general terms, this format has proven to be engaging for students and offers them new perspectives on their learning process. While it requires careful planning to mitigate potential risks that could negatively affect the experience, the overall perception among students has been highly positive.

4. Supporting Material

4.1 Lecturers' materials and project documentation

Lecturers' materials and project documentation are available in the following link:
https://drive.google.com/drive/folders/1El53xzsQOU1UYPKbXEA5lMoLIvcPQES2?usp=drive_link

4.2 Deliverables produced by students, final presentations or pitch materials

An example of deliverables produced by students are available in the following link:
https://drive.google.com/drive/folders/1fUV32WypBWJONtAWu-JvUWJHC7Uuzd7u?usp=drive_link

Students' final presentations are available in the following link:

https://drive.google.com/drive/folders/1bmbzSjTjk1-MXiZORXfYrDrszNVE1VX4?usp=drive_link

4.3 Images/videos (with consent)

Photographic and video records were captured with the explicit consent of the participating students, and are available in the following link:

https://drive.google.com/drive/folders/1f37amIHTwGC8YhK-8T8i7nrROOlzlfv_?usp=drive_link

4.4 Any other relevant material

All the materials, including this report, are available in the following link: https://drive.google.com/drive/folders/1Lh8-6sxEj_gYDzfXR-w-mknjcSpGY5rO?usp=drive_link