ENVIHEI

Title of the PBL challenge:
Vibration Monitoring System for Predictive Maintenance

Name of the responsible lecturer

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University / Department / Degree program

Silesian University of Technology / Department of Measurements and Control Systems / Bachelor's Degree in Control, Electronic and Information Engineering

Course / Subject in which implemented

2nd Course / Measurement Systems

Implementation period (dates)

May 21, 2026 – June 25, 2026

Total duration (weeks/hours)

5 weeks / 32 hours [16 teaching hours + 16 hours of independent student work]

Number of students involved

16 students

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1. Project Design

1.1 Brief description of the project and the challenge proposed

The pilot was organised around realistic engineering challenges, asking students to investigate how measurement and monitoring can support sustainable machinery operation and responsible use of maintenance resources. The four completed projects concerned CNC resonance and damping, vibration monitoring for predictive maintenance, rotational-speed monitoring, and vibration diagnostics for machinery protection.

Sustainability was a central element of each challenge. Students considered the potential environmental and socio-economic implications of machinery operation and maintenance, including energy consumption, material waste, equipment lifetime, operational costs and workplace safety. They explored how monitoring and informed engineering decisions could contribute to resource efficiency, environmental protection and the wellbeing of workers and the wider community.

The educational purpose was to connect course knowledge with problems that students could define, investigate and explain within this broader sustainability context. Teams were required to make decisions, develop solutions and justify their technical, environmental and socio-economic relevance. Reports and presentations provided opportunities to reflect on these connections and communicate how measurement systems can support more sustainable engineering practices.

1.2 Expected learning outcomes (academic and transversal competences)

The expected learning outcomes were aligned with the Measurement Systems course syllabus approved at Silesian University of Technology (SUT). Students were expected to integrate their knowledge of sensors, data acquisition, measurement software and data interpretation to address a practical engineering problem. They were required to justify their choices, recognise limitations and formulate evidence-based recommendations.

The projects also aimed to develop independent learning, collaborative planning, shared responsibility, problem solving, critical thinking and technical communication. Sustainability provided a broader context for these competences, encouraging students to consider the environmental and socio-economic implications of their engineering decisions.

The selection of project topics and the scope of implementation were constrained by the available laboratory equipment, access to specialist software and the allocated teaching hours. Within these constraints, the designed tasks allowed students to practise the course learning outcomes while exploring how measurement systems can support more sustainable engineering practices.

1.3 Targeted sustainability competences

The pilot targeted systems thinking by connecting equipment condition, operating decisions, maintenance, energy use and material consumption. It encouraged critical thinking about whether a technical solution supports a claimed environmental benefit. Problem framing helped students consider why a measurement task matters beyond the laboratory, while futures thinking encouraged them to consider equipment longevity and future maintenance needs.

Collective action was supported through team-based work. Environmental responsibility was addressed through consideration of avoidable waste and unnecessary resource use. These links are consistent with the GreenComp-oriented schedule. They describe the intended educational opportunities rather than measured attainment of a formal competence standard.

1.4 Sustainability approach and how it is integrated into the project

Sustainability was embedded in the initial challenge, project planning, interpretation and final communication. The guidelines asked students to consider energy consumption, resource efficiency, equipment lifetime and waste reduction. The schedule reserved a specific workshop for sustainability assessment, making environmental reflection part of the project process.

All four projects offered a practical context for discussing potential environmental benefits. Earlier recognition of undesirable machine behaviour may help avoid premature replacement and material waste. More informed maintenance can improve the use of parts and other resources. Avoiding damaging operating conditions may extend the useful life of tools and equipment and reduce losses associated with poor production quality. Students also considered the potential to reduce unnecessary energy use.

The environmental contribution is educational: students were required to relate technical decisions to resource conservation and to explain plausible pathways to environmental improvement. Actual energy savings, avoided waste or extended equipment lifetime were not measured. These remain potential benefits of the proposed solutions.

For the teaching, this approach provides a way to make sustainability concrete within an existing engineering course. Environmental questions can be asked alongside technical ones: Why is this monitoring needed? What resources could be conserved? What evidence would demonstrate an improvement? What trade-offs would remain?

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

ENVIHEI student-centered PBL framework was used, combining problem investigation with the delivery of a team project. The planned process included context analysis, team organisation, self-directed research, experimentation, interpretation, presentation and reflection. The 5W1H method offered a structure for connecting a technical problem with its users, setting and consequences.

The lecturers' intended role was to facilitate learning through guiding questions, progress reviews and technical consultation. The student guidelines emphasise that teachers support inquiry rather than provide a complete solution. Reports and presentations show that teams followed different development paths and encountered practical problems that required decisions.

The pilot also allowed flexibility in implementation. One team proposed an alternative software architecture, which the report records as approved by the instructor. This offers a pedagogical example of maintaining common learning objectives while allowing students to build on prior knowledge and take ownership of their approach.

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

Four teams of four students completed the pilot. Responsibilities included coordination, experimentation, programming, interpretation, documentation and presentation. The pilot formed part of the broader Measurement Systems course and involved teams established during earlier laboratory classes. Students freely choose their roles within each team, a process facilitated by their familiarity with one another from previous course activities.

The pilot was structured around four scheduled meetings. Each meeting lasted four teaching hours of 45 minutes, equivalent to 180 minutes. Together, the meetings accounted for 16 teaching hours, or 12 clock hours:

- The first meeting, on 21 May 2026, focused on understanding the problem, forming teams, defining responsibilities and planning the work, including sustainability goals.
- The meeting on 11 June 2026 focused on reviewing progress, developing the systems and testing ideas. Feedback supported students in identifying and addressing difficulties.
- The meeting on 18 June 2026 focused on conducting measurements, introducing and testing modifications to the systems, interpreting evidence, discussing sustainability, refining the proposed solutions and preparing to communicate the results.
- The final meeting, on 25 June 2026, was dedicated to project presentations, questions and discussion. It also provided an opportunity to reflect on learning and consider possible improvements.

Between meetings, students worked independently in the laboratories outside the scheduled sessions and at home. This allowed them to research, develop and document

their projects while maintaining shared milestones. The estimated independent workload amounted to a further 16 teaching hours, equivalent to 12 clock hours.

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

Each team was formally required to prepare a technical report and a presentation and upload both to the Educational Platform of the Silesian University of Technology. These documents also described the other deliverables produced within each project, including a measurement application or code, measurement data and their analysis, sustainability conclusions and supporting technical documentation. The schedule additionally requested intermediate planning and progress outputs, with project finalisation scheduled before 25 June 2026.

Four technical reports and four presentations were supplied. They show how students framed their problems, organised their contributions and explained the environmental relevance of their work. From a teaching perspective, requiring both a report and a presentation created complementary opportunities for written explanation, oral communication and responses to questions.

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

The pilot was supervised by two lecturers. In addition to their support, students could draw on the expertise and practical skills of other academic staff within the department, in accordance with the arrangements permitted at SUT. These consultations primarily helped students resolve technical difficulties encountered during project development. The project design did not include the involvement of experts from outside SUT.

Students also made extensive use of online resources, including AI systems from various providers. The combination of internal academic support and independently accessed resources proved sufficient for the efficient completion of the projects.

2. Project Evaluation

2.1 Assessment criteria and methods used

The student guidelines set out assessment areas covering problem analysis, technical implementation, measurement quality, interpretation, teamwork, creativity, sustainability awareness and presentation quality. This broad scope recognises both the project outcomes and the learning process.

The planned formative methods included progress reviews, consultations and an interim presentation. The final project grade was based on ongoing individual assessment of each student's progress during project implementation, together with assessment of the results presented at a dedicated final session. During this session, each student explained their individual contribution to the work completed and the results achieved. Presentations and demonstrations were followed by questions, discussion and reflection.

All 16 students received a grade of 5.0, equivalent to A, for the PBL project. These grades document the assessment outcome but do not quantify student satisfaction, nor do they provide a separate score for environmental reasoning.

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

The reports and presentations show that students could connect their projects to realistic operating and maintenance problems. They documented task allocation, developed solutions, discussed difficulties and communicated recommendations. This supports a qualitative account of learning through investigation and project work.

In the CNC resonance and damping project, a documented 5W1H analysis and an approved alternative implementation provided evidence of problem framing and initiative. Students connected operating choices with tool life, equipment preservation and reduced waste.

In the vibration monitoring project, the comparison of different measurement channels provided opportunities for critical interpretation. Students explained how reliable monitoring could support earlier intervention and extend the useful life of equipment.

The rotational-speed monitoring project involved integrating several system components, demonstrating planning and interdisciplinary problem solving. The team discussed resource-efficient maintenance while explicitly acknowledging that the potential environmental benefits had not been measured.

In the industrial vibration diagnostics project, practical integration difficulties required troubleshooting and adaptation. Students linked monitoring with the prevention of equipment damage, fewer premature replacements and potential energy benefits.

The strongest documented sustainability outcome is students' ability to explain how their technical work could support environmental responsibility and sustainable resource use. The strongest documented evidence of transversal competences is the production of shared outputs with clearly stated responsibilities.

3. Reflections and Recommendations

3.1 Main achievements and strengths of the project

A key achievement was the successful completion of all four team projects, involving 16 students, within the required timeframe and scope. The pilot produced four technical reports and four presentations. Students demonstrated strong engagement and considerable initiative in developing their solutions and addressing difficulties. The project format encouraged student engagement and gave students opportunities to take responsibility for their work.

For the teachers, a major achievement was delivering projects that actively involved students while connecting highly technical and specialised content from the approved course syllabus with broader sustainability issues. Environmental and socio-economic considerations became directly relevant to engineering decisions, including resource use, equipment lifespan and responsible maintenance.

The implementation also provided practical lessons about course design. Open problems gave students space to make and justify decisions. Shared milestones supported independent work while maintaining student responsibility. Explicit sustainability prompts helped students move beyond describing a device to explaining the broader implications and purpose of their solutions.

The variety of team solutions demonstrated the value of flexibility. A common challenge and assessment framework accommodated different tools and implementation approaches while maintaining the intended learning outcomes. Technical difficulties created opportunities for troubleshooting, adaptation and reflection, contributing to both technical learning and the development of transversal competences.

In the teachers' assessment, all intended student learning outcomes were achieved. The pilot also allowed the teachers to test, in practice, an approach that integrates sustainability into student-centered engineering education. Both students and teachers were satisfied with the experience and would welcome further opportunities to undertake projects using this approach.

3.2 Challenges faced and how they were addressed

A major challenge for both students and lecturers was adapting to a different model of teaching and learning. Students had to take a more active and independent role than in conventional laboratory classes. Completing their tasks required substantial individual work, including searching for information, learning unfamiliar tools and making decisions within their teams.

The open nature of the projects also introduced unexpected problems. In traditional laboratory classes, students usually follow established procedures and repeat tasks whose practical difficulties are already familiar to the lecturers. During the pilot, teams encountered different integration, programming and data-handling problems as their solutions developed. Consultations and progress reviews helped students reconsider their assumptions, investigate possible causes and adapt their approaches. Where appropriate, students could also consult other academic staff within the department.

For the lecturers, supervising four projects simultaneously was demanding. Each team needed time and support to address its own difficulties, particularly technical problems. The lecturers had to balance attention across the teams and respond to different needs while preserving students' responsibility for finding and implementing solutions. The experience highlighted the importance of allocating sufficient teaching time for consultation and troubleshooting.

The technical nature of the Measurement Systems course created an additional responsibility. Students used advanced and varied equipment, requiring the lecturers to provide instruction in its safe operation and ensure safe working conditions throughout the project activities. Supporting independent work therefore required careful attention to both students' technical preparation and the safety of the tasks they undertook.

3.3 Lessons learned for future implementations

Future implementations should retain realistic, open problems and staged milestones, with a clear educational purpose for each stage. Project activities should be spread over a longer period to allow sufficient time for investigating unfamiliar issues, exploring alternative solutions, introducing modifications and discussing results with lecturers. The schedule should accommodate repeated cycles of development, testing and improvement.

Time should be allocated separately to joint project seminars and practical laboratory work. Joint seminars should bring all teams together to present progress, discuss difficulties and exchange ideas. Laboratory sessions should provide time for focused technical work on team-specific and individual tasks. This distinction would support shared learning while allowing each team to develop its own solution and receive appropriate specialist guidance.

Sustainability should remain visible throughout the project. Each team could define an environmental question at the outset and revisit it at subsequent milestones and in the final presentation. Where feasible, a measurable indicator should be selected, such as energy use, material waste or component replacement needs. Where direct

measurement is not possible, students should explain the anticipated benefits and underlying assumptions, clearly distinguishing demonstrated results from claims requiring further evidence.

Assessment should recognise collaboration, reflection and environmental reasoning alongside technical achievement. Brief reflections at each milestone, individual accounts of contributions and peer feedback could help document participation and teamwork more systematically. Initial and final questionnaires could provide additional evidence of students' perceptions and learning experiences. Short lecturer observation and reflection notes after each meeting could also record how facilitation developed and what the lecturers learned from the implementation.

The main transferable lesson is that sustainability-oriented PBL can be integrated into an existing engineering course through the framing of problems, the sharing of responsibility and the discussion of results. Future implementations should provide sufficient time for investigation and iteration, strengthen evidence of the learning process and make the lecturers' professional learning more explicit.

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/17cM8NyEdjpi4FwYH07LDK5MxBrr3g8_5?usp=drive_link

4.2 Deliverables produced by students, final presentations or pitch materials

An example of deliverables produced by students is available in the following link:
https://drive.google.com/drive/folders/1FDPHH9ZBVinqMc7Go4RaJhYkZZ8xdytJ?usp=drive_link

Students' final presentations are available in the following link:

https://drive.google.com/drive/folders/1X_3c6kIX8Pku893NCaFZGqUQza7sAlfV?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/1xUVOtO5jqMOMnFe6d-RnIN-Ld2I1pqHT?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/1riST68-HctqgagXeetOn2CgtPHDe5UWx?usp=drive_link