International Cooperation Framework for Next Generation Engineering Students

BEST Practices Guide
International Team Teaching

TECHNICAL UNIVERSITY OF CLUJ-NAPOCA   jamk   Universidad de Jaén   iSR www.isr.es   Valmet   BOSCH Invented for life

Table of Contents

1. Introduction

The Best Practices Guide: International Team Teaching has been designed to document, share, and disseminate the outcomes of the Team-Teaching Pilot Program (TTPP), an innovative initiative developed as part of the International Cooperation Framework for Next Generation Engineering Students (NextGEng) Project.

NextGEng [1] is a three-year Erasmus+ KA2 Cooperation Partnership project, co-funded by the European Union, bringing together a consortium of three universities - Technical University of Cluj-Napoca (TUCN) from Romania [2], JAMK University of Applied Sciences (JAMK) from Finland [3] and University of Jaén (UJA) from Spain [4] - and three industry partners – Integracion Sensorial y Robotica (ISR) from Spain [5], Valmet Technologies Oyj (VALMET) from Finland [6] and Robert Bosch SRL (BOSCH) from Romania [7]. This unique collaboration bridges academia and industry to create a dynamic learning environment that prepares engineering students to meet the challenges of the rapidly evolving global workforce.

The primary objective of the project is to establish an international cooperation framework that supports the upgrading and modernization of engineering curricula in partner higher education institutions (HEIs). The upgraded courses and applied projects are aligned with:

- the European Education Area 2025 vision [8],
- the Sustainable Development Goals (SDGs) [9],
- the strategic development plans of each HEI partner, and
- the needs of industry, ensuring that graduates are equipped with relevant, future-oriented skills.

Central to this effort is the proposed pedagogical model **Tailored Student-Centered Co-Teaching**, which aims to development an international team-teaching approach, which enables instructors from different countries and institutions to collaboratively design and deliver courses. This model fosters intercultural dialogue, pedagogical innovation, and stronger links between academia and industry.

This guide not only outlines the design and implementation of the TTPP, but also highlights the lessons learned from two full cycles of implementation during the academic years 2023–2024 and 2024–2025. It provides practical insights, tools, and templates for HEIs and educators seeking to adopt or adapt similar approaches within their own institutional contexts.

By sharing this comprehensive resource, we aimed to:

- Foster collaboration among universities, companies, and policymakers,
- Promote interconnected higher education systems across Europe and beyond,
- Strengthen the capacity of teachers and institutions to deliver innovative, internationally relevant engineering education, and
- Contribute to the global conversation on modernizing engineering curricula for the next generation of learners.

Ultimately, this guide serves as both a record of achievement and a practical roadmap for those who wish to replicate or scale up international team-teaching initiatives.

2. Team-Teaching Pilot Program (TTPP)

The international team-teaching pilot program was part of NextGEng Work Package 3 (WP3) and aimed to create cross-border co-teaching groups composed of university instructors and industry experts from across the EU, namely Romania, Finland and Spain (Figure 1). These teams worked collaboratively to deliver students state-of-the-art knowledge and relevant, practice-oriented applications. TTPP puts in practice the proposed **Tailored Student-Centered Co-Teaching** pedagogical model, enabling course-specific pedagogical designs in which each co-teaching team adapts teaching strategies, learning materials, and assessment methods to the unique needs of their course. Instead of applying a single generic model, the teams planned their co-teaching sessions collaboratively, integrating complementary expertise from different universities and companies. New teaching materials, including study cases, sustainability-oriented content, laboratory, and problem-solving tasks, are created to align with the specific learning outcomes of each course.

Fig.1. *NextGEng consortium*

The initiative focused on six joint courses, comprising a total of 36 new course modules and 16 new laboratory works across the three partner universities. Each course was carefully redesigned to incorporate innovative teaching methods and updated content, ensuring a modern and engaging learning experience. The redesign process was carried out in close partnership with industry stakeholders to guarantee that the upgraded courses reflected current labor market needs and prepared students for real-world engineering challenges.

The six courses selected for the pilot program (C1–C6) were strategically chosen to cover a broad range of engineering competencies and to maximize the impact of the project on students' skills and employability:

- C1 – Strength of Materials
- C2 – Industrial Automation
- C3 – Design Projects
- C4 – Quality Assurance and Applied Methods
- C5 – Computer-Aided Design (CAD)
- C6 – Manufacturing Technology

The implementation roadmap of the program is presented in Figure 2. The activity started with a training session of all teachers that participated in the program. This session was followed by two rounds of course upgrading. The upgraded courses introduced cooperative teaching approaches through international co-teaching teams, following the project's proposed international cooperation framework. This model emphasized joint planning and delivery of lectures, labs, and project work, thereby encouraging knowledge exchange between educators from different institutions and enhancing students' exposure to diverse pedagogical styles and professional perspectives.

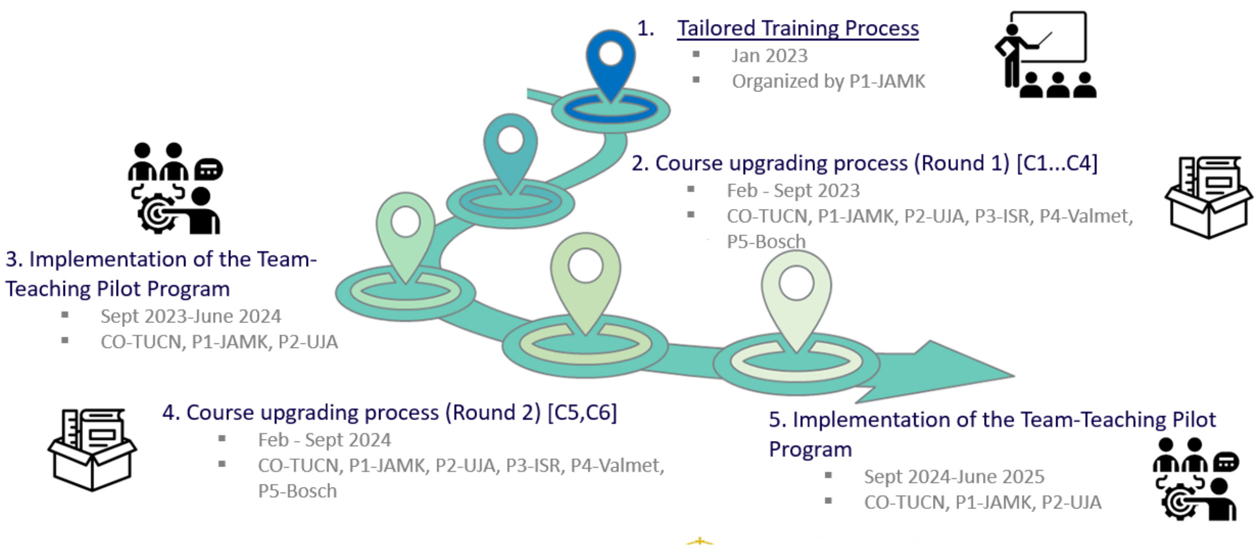


Fig.2. *TTPP implementation roadmap*

All upgraded courses were piloted during the second and third years of the project as part of the regular teaching semesters at the partner HEIs, involving students from six different engineering specializations. These implementations allowed for the real-time testing and refinement of the newly developed teaching methods.

After two complete teaching rounds, comprehensive evaluations were conducted to measure the learning outcomes of students who participated in the pilot program compared to those who followed the standard course delivery.

3. Teacher training and capacity building

A key component of the NextGEng project was building the capacity of educators to deliver innovative, student-centered, and industry-relevant engineering education. Work Package 2 (WP2) was dedicated to engaging teaching staff from partner HEIs and company representatives in structured training activities, designed to support the implementation of international team-teaching and the modernization of selected courses.

The first training round of the NextGEng project was organized by JAMK University of Applied Sciences and took place from 30–31 January 2023. A total of 29 teachers from TUCN, JAMK, and UJA participated in this initial capacity-building activity (Figure 3).

During the first day, participants were introduced to the current status of teaching practices across the partner universities, with a summary of pre-training surveys and assignments. The day included seminars focused on planning, implementing, and assessing courses in a student-centered way. Teachers then worked on developing concrete solutions for implementing student-centered learning in the pilot courses and explored opportunities for joint course delivery (Figure 4).

The second day focused on planning international co-teaching arrangements including methods, pedagogical materials and schedules for each subject area and further enhancing the student-centered orientation of the courses.

To ensure consistency across the consortium, a common template was developed for all co-teaching teams (C1–C6). This template required information on: (1) team members, including names, contacts, and team leader; (2) course modules selected for upgrade at TUCN, JAMK, and UJA; (3) the cooperative teaching implementation schedule (semester and estimated travel dates); (4) laboratory, seminar, or project activities developed in collaboration with companies (name, semester, month); and (5) the co-teaching team's meeting schedule, including organizer and videoconference platform.

Industry partners joined for the "Companies on Stage" session, where they presented opportunities for collaboration and participation in study courses. Participants also visited the JAMK

Fig.3. *Training activity during the 1st Training Round*

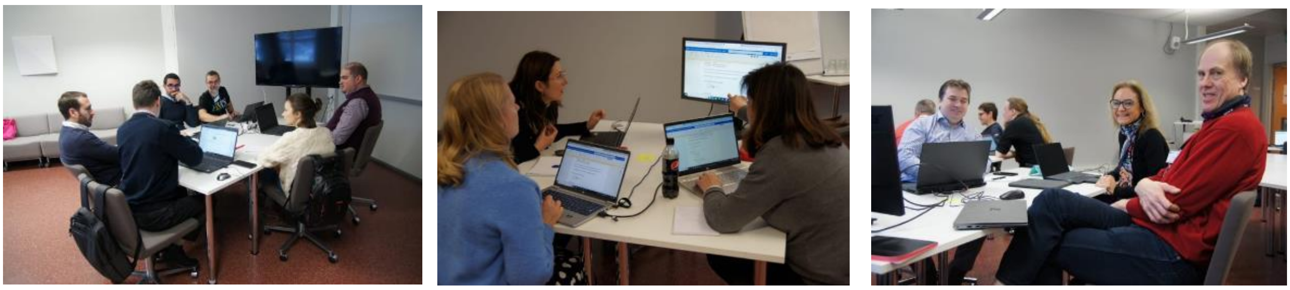


Fig.4. *Co-teaching groups meeting during the 1st Training round*

DigiCenter to explore the development of digital learning materials and tools. The day concluded with group presentations in which participants shared the results of their workshops and co-teaching plans.

These two training days helped participants gain an understanding of the proposed Tailored Student-Centered Co-Teaching model and supported the development of new competencies in innovative teaching methods, learner-centered approaches, and co-teaching approaches before the implementation of the course updates. Teachers were encouraged to reflect on their current practices, experiment with new pedagogical approaches, and collaborate across institutions and disciplines to co-create solutions.

Collaborative networks of teachers were established across six subject areas (**co-teaching teams**), fostering the continuous exchange of ideas and good practices. Feedback from participants confirmed the success of the initiative: the training content and methods were considered highly relevant, practical, and valuable for professional development. The co-teaching teams created through WP2 enhanced the capacity of educators to experiment with new approaches and to integrate digital tools effectively.

4. Phased course upgrading

The selected courses were updated in two rounds. The **first round of course upgrading** took place in the first half of 2023 and involved the redesign and implementation of four courses (C1–C4). These included Strength of Materials, Industrial Automation, Design Projects, and Quality Assurance & Applied Methods.

The second round of course upgrading, conducted in the first half of 2024, focused on the remaining two courses (C5–C6): Computer-Aided Design (CAD) and Manufacturing Technology. These courses benefited from the insights gained during the first round.

The course upgrades were guided by several important principles:

- **Development of New Course Content:** existing content was updated and enriched to reflect the latest trends in engineering education and industry practice.
- **Content Modularity and Flexibility:** each joint course was divided into modules, making it easier to coordinate team-teaching across institutions and implement content flexibly within different HEI curricula.
- **Student-Centered Design:** new materials placed students at the center of the learning process, promoting experiential learning and encouraging active participation. Real-life case studies from industry partners were integrated into lectures, labs, and projects to strengthen practical relevance.
- **Eco-Friendly Concepts:** sustainability principles were embedded into the curriculum, raising student awareness of the environmental impacts of engineering decisions throughout a product's design, production, and life cycle.
- **Digital Compatibility:** all materials were designed to be fully compatible with digital teaching and learning, supporting online delivery, blended learning formats, and easy resource sharing.

A combination of teaching methods was applied to enhance student engagement and learning outcomes. These included:

- **Co-Teaching and Cooperative Teaching:** Teams of instructors from different institutions jointly planned and delivered courses, providing students with diverse perspectives and expertise.
- **Blended Learning:** A mix of face-to-face and online sessions supported flexible learning paths and improved accessibility.
- **Student-Centered Teaching:** Active learning strategies were used to encourage student autonomy and critical thinking.
- **Project-Based Learning:** Students worked on real-world projects, often in collaboration with industry partners, to apply theoretical knowledge in practical contexts.
- **Digital Teaching and Learning:** Modern digital tools were used to create interactive learning materials, support collaboration, and facilitate assessment.

Throughout the two upgrading phases, the modules content was refined via monthly meetings between co-teaching teams. The development work focused on: designing new labs/seminars with industrial partners, defining modularity and complexity, selecting effective teaching methods, and incorporating student-centered, eco-friendly, and real-life case study elements compatible with blended digital delivery. This effort successfully produced a total of 36 new English-language course modules and 16 new laboratory work/tailored seminars in collaboration with P3-ISR, P4-VALMET, and P5-BOSCH. By focusing on real-life applications, the new content not only provided students with essential green and soft skills, but also raised their level of satisfaction, therefore increasing the quality of the didactic process.

Course content developed

Figures 5 to 11 presents examples of laboratory topics developed in collaboration with company partners. These laboratories engaged students on hands-on exposure to modern engineering tools, real manufacturing environments, and authentic problem-solving experiences. Each laboratory aligns with a specific course and emphasizes both theoretical understanding and practical implementation. Together, they form a coherent learning pathway that bridges academic knowledge with industrial practice.

1. Stress and Strain Measurements for PCBs - Figure 5

Course: C1 – Strength of Materials

Industry Partner: P5-BOSCH

This laboratory introduces students to experimental stress–strain analysis applied to printed circuit boards (PCBs). Through dedicated measurement equipment and software, students perform real-time deformation analysis under controlled loading conditions. This lab strengthens the link between strength of materials principles and their application in sensitive electronic structures used in automotive engineering.

The activity emphasizes:

- Understanding how PCBs respond to mechanical stress.
- Interpreting strain gauge data and correlating it with analytical beam models.
- Conceptualizing mechanical behavior using simplified theoretical representations.

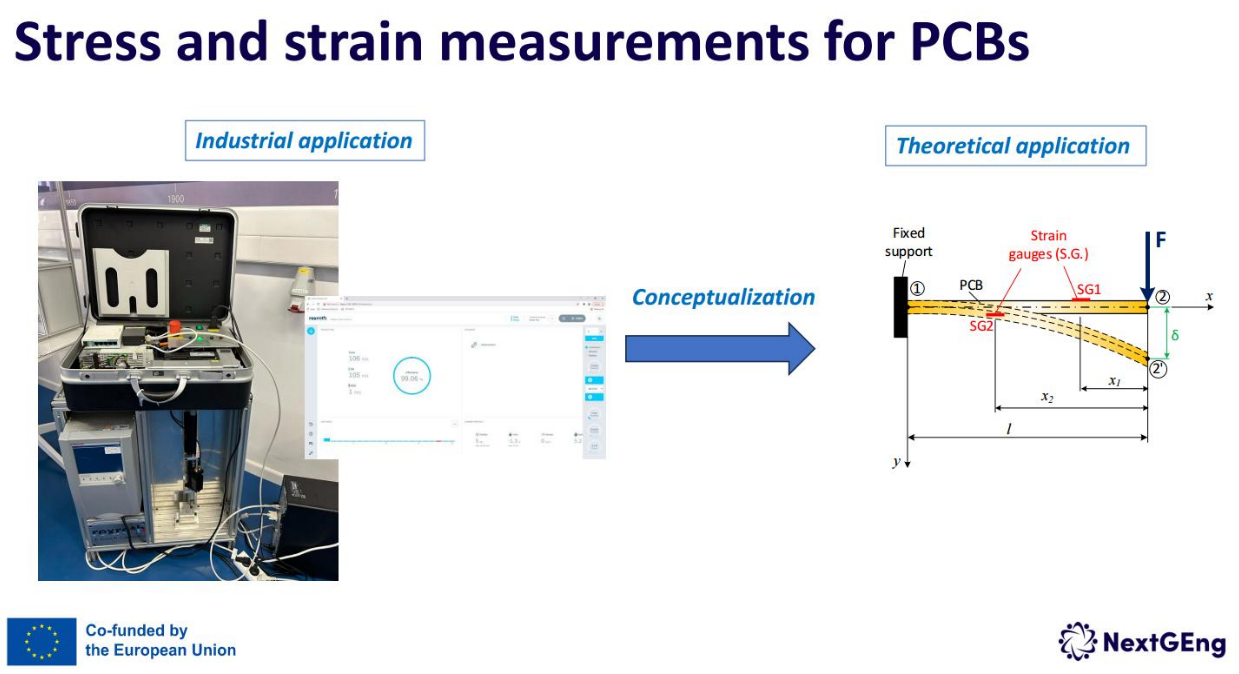


Fig.5. *Example of laboratory work on course C1*

2. PLC Programming Using the Sequential Function Chart (SFC) – Figure 6

Course: C2 - Industrial Automation

Industry Partner: P5-BOSCH

Students learn to design and implement industrial control sequences using IEC 61131-3 languages, with a primary focus on the Sequential Function Chart (SFC). The laboratory mirrors real-world mechatronic production lines, preparing students for modern automation environments.

Working with modular mechatronic systems, they:

- Understand the hierarchy of industrial control systems (planning, supervisory, control, field).
- Develop PLC programs using multiple languages (LD, FBD, IL, ST, SFC).
- Apply structured design methods to manage complex automation tasks.

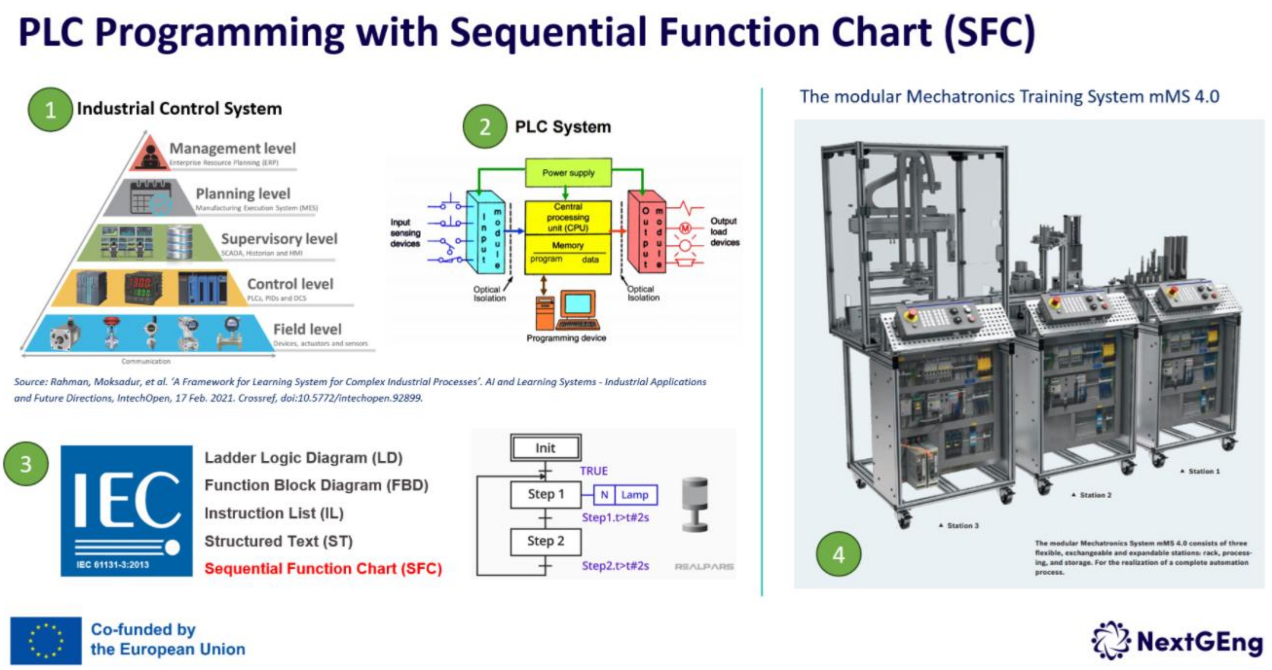


Fig.6. *Example of laboratory work on course C2*

3. Ergonomic Assessment and Workplace Design – Figure 7

Course: C3 - Design Projects

Industry Partner: P5-BOSCH

The goal is to develop skills in workplace analysis, worker safety, and design optimization for productivity. This activity focuses on evaluating and improving a manual assembly workstation.

Students conduct ergonomic assessments using established methodologies to:

- Identify stressors and inefficiencies in manual work environments.
- Propose redesign solutions based on ergonomic principles.
- Apply human-centered design to a real workstation setup.

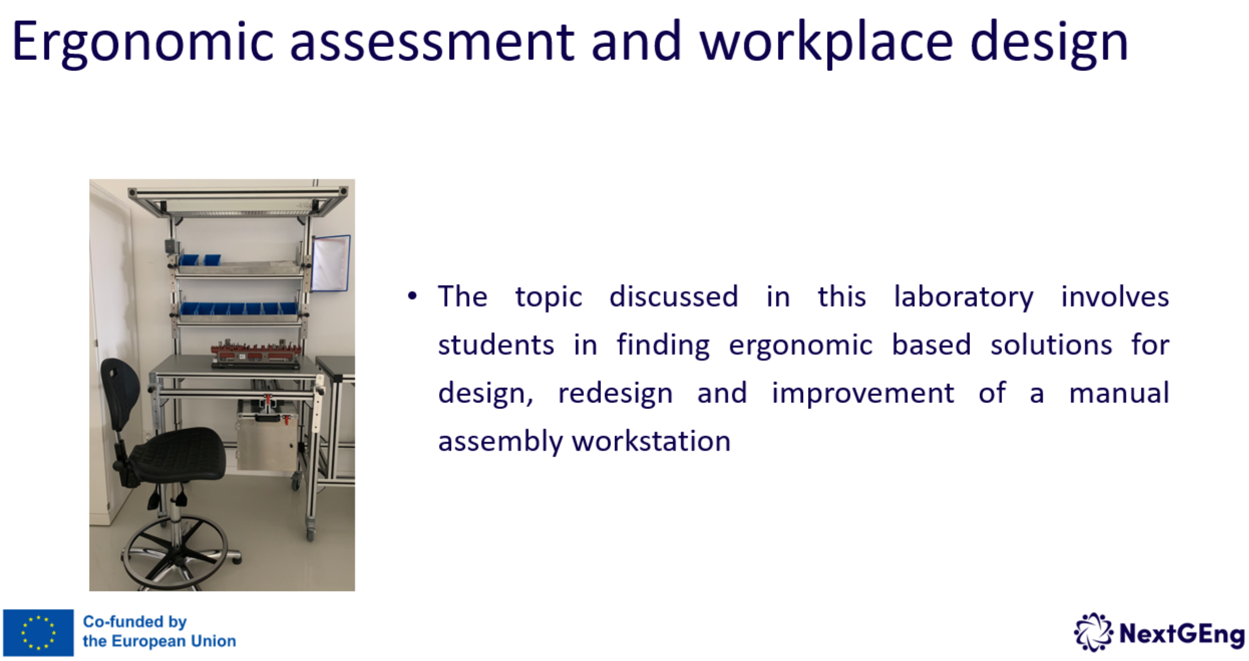


Fig.7. *Example of laboratory work on course C3*

4. Calibration of the "Smart Function Kit Press" – Figure 8

Course: C4 - Quality Assurance and Applied Methods

Industry Partner: P5-BOSCH

Students engage with an industrial grade pressing system integrated with a force sensor. The activity reinforces metrology principles while exposing students to intelligent mechatronic subsystems widely used in automated production.

The laboratory guides them through the complete calibration workflow:

- Understanding sensor characteristics and sources of measurement error.
- Performing precision calibration procedures.
- Validating force measurement accuracy for industrial manufacturing processes.

Fig.8. *Example of laboratory work on course C4*

5. Design of Parametrized Parts for Logistics Applications – Figure 9

Course: C5 - Computer-Aided Design (CAD)

Industry Partner: P5-BOSCH

In this laboratory, students practice parameterized 3D modelling for components used in logistics systems. Students develop both CAD proficiency and analytical reasoning essential for modern product development.

The workflow includes:

- Creating flexible, scalable part models following engineering drawing requirements.
- Performing structural analysis (FEA) to assess mechanical performance.
- Integrating design and simulation for functional optimization.

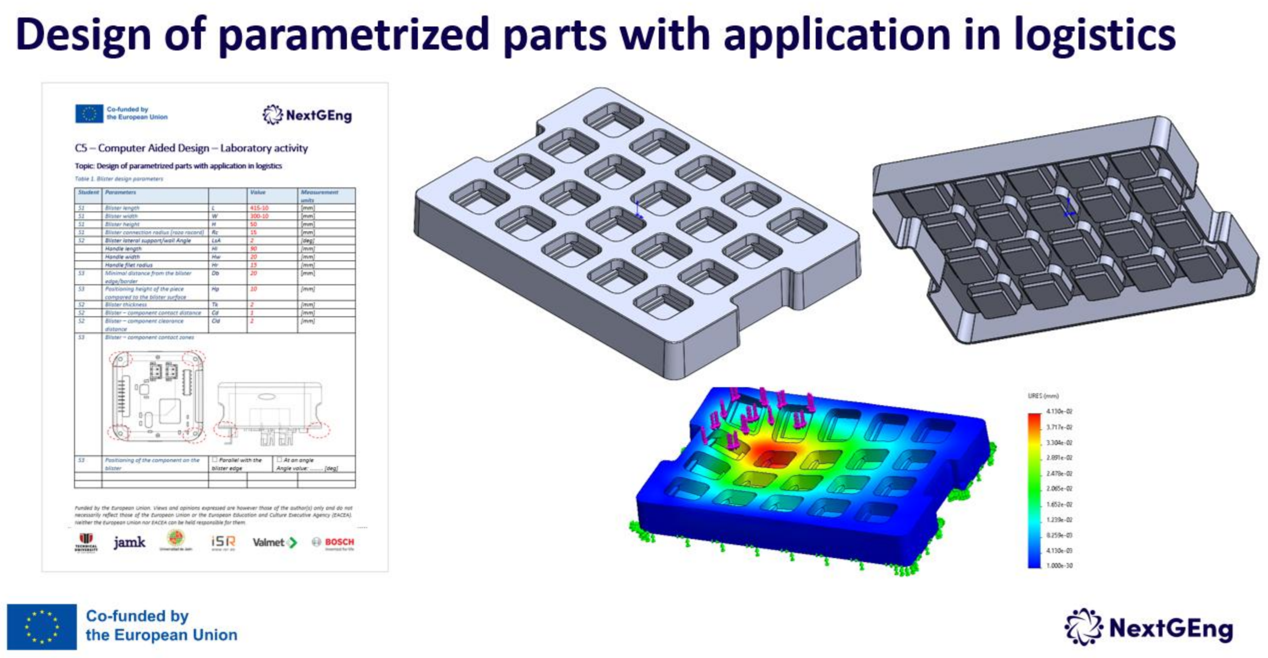


Fig.9. *Example of laboratory work on course C5*

6. Additive Manufacturing at Valmet – Figure 10

Course: C6 - Manufacturing Technology

Industry Partner: P4-VALMET

This laboratory introduces students to design-for-additive-manufacturing (DfAM) principles using real industrial examples. The lab bridges design theory with real additive manufacturing workflows to produce functional engineering components.

They learn how to:

- Modify geometry for manufacturability in 3D printing processes.
- Apply strategies such as orientation control, support optimization, or simplified part features.
- Understand constraints and advantages of powder-based metal additive manufacturing.

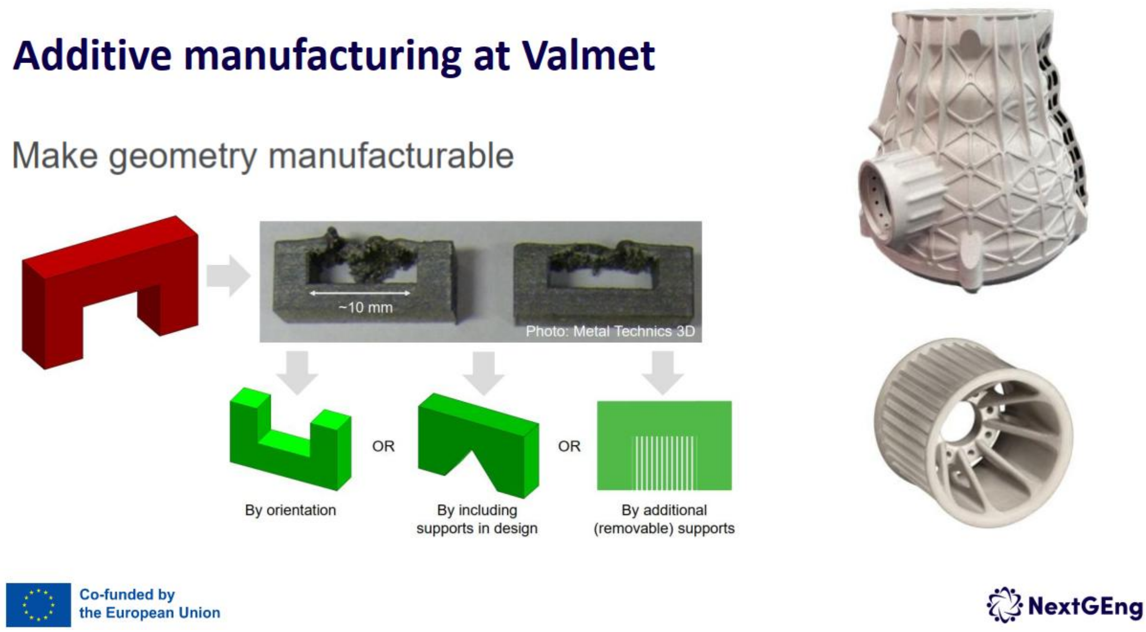


Fig.10. *Example of laboratory work on course C6*

7. How to Scope a Project in an Industrial Tech Company

Course: C3 - Design Projects

Industry Partners: P3-ISR

This laboratory introduces students to the fundamentals of project scoping within an industrial technology environment. Using a real case between ISR and Aspöck Systems, students follow the complete ***Project Planning Cycle****, learning how industrial projects are defined, structured, and prepared for execution. By the end of the activity, students gain practical insight into how engineering companies plan development projects, coordinate with customers, and ensure clear, structured project execution.*

Students work through the main elements of project initiation:

- Identifying stakeholder needs and clarifying project objectives
- Defining deliverables and establishing due dates
- Creating a project schedule with roles and responsibilities
- Preparing a basic budget and communication plan
- Understanding tracking and management processes used in industry

Fig.11. *Example of laboratory work on course C3*

A total of 16 laboratories were developed in collaboration with industry partners aiming to:

- Expose students to authentic engineering challenges.
- Integrate theoretical coursework with practical, industry-oriented tasks.
- Develop competencies in mechatronics, automation, materials, mechanical design, manufacturing, and ergonomics.
- Strengthen collaboration between academia and industry.
- Serve as a comprehensive guide for students to understand how engineering decisions are made and validated in real industrial contexts.

All these laboratory activities were supported by the newly developed set of 36 English-language modules, which provide the foundational knowledge required to fully understand and apply the concepts explored in each lab.

Two examples of a course module and a laboratory module can be consulted in ANNEX 1 and ANNEX 2 at the end of this document. The developed courses and laboratory works can be downloaded from the project website at the following links:

- C1 – C4 modules – weblink
- C1 – C4 laboratories – weblink
- C5, C6 modules – weblink
- C5, C6 laboratories - weblink

5. Team-teaching implementation rounds

The first round of team-teaching began simultaneously at all partner HEIs in October 2023. Most course sessions were delivered face-to-face, while some were conducted online to accommodate all participants (Figure 12). Laboratory exercises and tailored seminars were held on-site at the organizing HEI, with remote access provided for the other partners (Figure 13). This first round ran according to schedule and concluded in July 2024, with the results thoroughly documented.

Fig.12. *Course activities at UJA and TUCN*

Following the second phase of course upgrades for C5 and C6, the second round of team-teaching commenced at all partner HEIs in October 2024. During this phase, teachers and company experts delivered the updated content for all six courses (C1–C6) throughout the fall semester of 2024 and the spring semester of 2025. The second round was completed on schedule in July 2025, with outcomes carefully recorded.

Fig.13. *Laboratory activity in C3*

The target groups addressed by TTPP were the teachers in engineering from partner HEIs, company experts taking part in the co-teaching teams, and the students enrolled in the pilot program for the selected six joint courses.

Teachers who participated in upgrading and delivering the six joint courses contributed through the first and second round implementation of the pilot program. The project provided opportunities for teachers to collaborate with colleagues with similar expertise, to travel to partner universities, and to teach on-site or online to students from different universities and specializations. This collaboration not only supported the creation of high-quality content/materials shared among them and students but also enhanced teachers' professional development, expanding their international experience, and strengthened their capacity to integrate innovative practices into their teaching. Collaboration among teachers on journal publications [10-11] provided an additional channel for dissemination and contributed to greater visibility of their results.

Company experts contributed by integrating real-life applications and eco-friendly concepts into the developed laboratory activities. The practical applications were implemented in partner HEIs using specialized laboratory equipment. For instance, P5-BOSCH collaborated with CO-TUCN laboratories for courses C1, C2, C4, and C5, and used the Ergonomics laboratory and Production Line at the BOSCH Cluj Plant for courses C4 and C6. Similar collaborations were also carried out between other partners. The project strengthened the collaboration between academic staff and industry experts, leading not only to improved laboratory activities but also giving experts the chance to strengthen their links with universities, being involved in co-teaching activities, sharing their expertise with students, and gaining new technical and teaching skills for their own professional development.

Overall, TTPP involved 27 HEI teachers and 15 industry experts from the partner companies. Their collaborative work created a sustainable model for international team-teaching in engineering education.

Students were mainly engaged as participants in the teaching activities, but they also contributed to quality monitoring of the pilot program through their feedback. The joint courses

C1–C6 were delivered to second, third, and fourth-year students from 14 engineering specializations across all partner HEIs. Within the framework of the team-teaching pilot program, teachers and company experts delivered 68 course team-teaching sessions and 75 laboratory/tailored seminar activities, on-site or in blended format, to more than 1000 students. Teaching activities let students experience how their subjects are taught at other universities by foreign teachers, enhancing their internationalization. The integrated students-centered elements, eco-friendly concepts and real-life examples in the learning materials were positively appreciated in their feedback. Their comments included phrases like “amazing”, “valuable experience”, “engaging”, “new and great way of learning” and “strongly good”.

Throughout the implementation of both rounds, the quality of the pilot program was continuously monitored using feedback from students and teachers. This ongoing evaluation helped to assess the effectiveness of the cooperative teaching approach and identify opportunities for further improvement, ensuring that the program maintained high standards and achieved its objectives. These achievements confirm TTPP’s success in enhancing both pedagogical practices and student outcomes.

6. Feedback mechanisms and lessons learned

To assess the benefits of the proposed pilot program, an initial round of student/teacher feedback was collected during the autumn and spring semesters of the 2022–2023 academic year. These responses form the *control results* and were later compared with the feedback obtained from students and teachers who participated in the TTPP.

The overall experience at the selected course was evaluated by the students and teachers based on a rating score from 1 to 5 (Rating Scale: 1 = Poor, 2 = Fair, 3 = Good, 4 = Very Good, 5 = Excellent) and considered the following aspects:

- learning outcomes
- course content and quality of the teaching materials
- internationalization
- teaching methods used at the course
- interaction with industry

The feedback received from students is presented in Figure 14 while the one from teachers is in Figure 15.

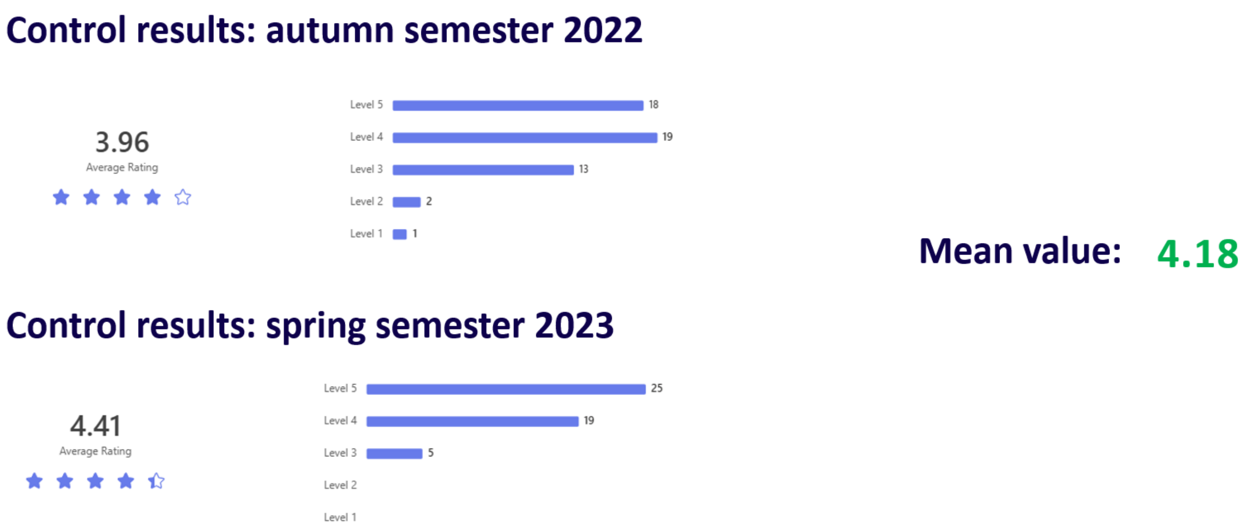


Fig.14. *Feedback from students – control results*

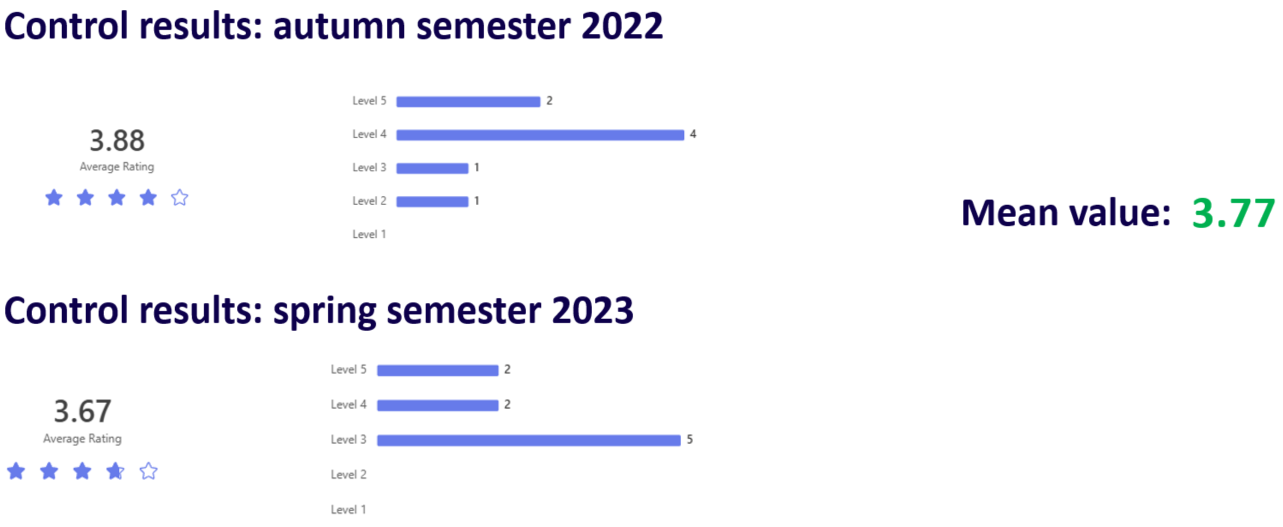


Fig.15. *Feedback from teachers – control results*

For the first-round implementation of team-teaching, the evaluation and feedback activities were initially carried out at the end of each semester. Student feedback was first collected using a single questionnaire that covered both lectures and labs. However, after the first round, it became evident that this approach resulted in a low response rate and limited insights.

To improve participation, separate questionnaires for lectures and labs were introduced and distributed immediately after each teaching session. This change led to a significant increase in responses and provided richer, more actionable feedback during the second round of implementation.

In comparison with control results, the first round demonstrated a stronger upward trend, suggesting that the initial implementation generated greater impact and enthusiasm among students, especially in Spring 2024, where scores exceeded 4.6. The second round confirmed stable satisfaction, reflecting consolidation of the teaching practices. It is important to note that the number of student responses increased substantially across the survey rounds: 102 in the control phase, 158 in the first round, and 522 in the second round. Out of the total 1092 students who participated in TTPP, 680 provided feedback in both rounds, achieving a 62% response rate.

Teacher evaluation of TTPP shifted from moderately positive in the control period (mean 3.77) to strongly positive in the feedback periods (mean values above 4.6). The results highlight that teachers not only observed but also valued the improvements introduced through the program. These outcomes suggest that TTPP was effective not only in increasing student engagement but also in gaining strong support from teachers, who recognized the benefits of cooperative teaching methods, improved course materials, and enhanced alignment with modern learning approaches. Compared to the student evaluations, which showed a stronger improvement during the first round, teacher feedback demonstrated consistently high satisfaction across both rounds.

The following comments are from TTPP participants (students and teachers) and highlight the program's success. Student feedback confirms that the effort and new content were greatly appreciated. Additionally, teachers provided positive evaluations of the co-teaching experience and the adoption of new modern teaching methodologies.

Comments from students that participated in laboratory/lectures activities

"It has been ***one of the best laboratories I have ever taken****. The fact that we could apply the theoretical knowledge on industrial PLCs was absolutely great.* ***I wish there were more practical activities that are industry related****"*

"It was a ***great experience****. I look forward to another one"*

"It was an ***educational experience in which I learned new things and new aspects****"*

"It was great but hopefully we can do ***laboratory live*** *all together next time"*

*"**I really appreciated the team-teaching activity**. It was **engaging** and helpful to hear different perspectives from the experts. One suggestion for improvement could be to include more interactive elements, like Q&A sessions or small group discussions, to keep the audience more involved and make the session even more dynamic. Overall, it was a **valuable experience**."*

*"It was useful to understand how we can **solve problems of real life at the industry.**"*

*"It is a **new and great way of learning**."*

*"**Very nicely done**. Thank you for the lecture!"*

*"It was a **great activity**, and I am looking forward to **more** such learning courses"*

*"Very **interesting lecture** where we learn a lot about production of MEMS"*

*"I just want more of this. It was **amazing**."*

*"It was **very educational and helped us getting more knowledge** on quality and metrology"*

*"Nothing to add, it was a **great experience**"*

*"The course **was very engaging, and the material was interesting**. The visiting professors did a very good job keeping us (students) engaged through the whole course and the fact that they showed us what a typical exam problem in Jaen looks like was a huge bonus. I don't think any improvement is necessary.*

Comments from teachers that participated in TTPP

"To develop teaching activities in collaboration with foreign teachers and experts from companies, ***has been a very productive task.****"*

*"****Great opportunity to create new course*** *content in close collaboration* ***with industry and international teachers.****"*

"It has been ***strongly good*** *to teach with professors from other countries."*

7. Conclusions and future directions

The results confirm the TTPP implementation was highly successful, delivering significant improvements and establishing a path for long-term sustainability. The success of WP3 can be viewed from many perspectives:

Key Achievements

- *Effective content delivery*: The practice of clearly stating learning outcomes at the beginning of co-taught lectures and labs proved highly effective and was validated by positive student feedback.
- *Bridging the Green Skills Gap*: The project successfully addressed a major gap where 80% of teachers believed they taught eco-friendly concepts, but nearly 50% of students didn't recognize them. New TTPP materials, which integrated concepts on environmental impact over an engineering product's lifecycle, have significantly improved student awareness and understanding.
- *Increased internationalization*: Student exposure to international visiting teachers increased from just 6% to over 80%. This success demonstrates that the NextGEng project has created a valuable European learning environment, offered diverse methods and promoted essential soft skills.
- *Full Industry Engagement*: 100% of teachers now incorporate laboratory activities and projects in collaboration with industry partners, a major increase from the initial 33% and a boost for practical relevance.
- *Increased Satisfaction*: The overall satisfaction rating for the course, evaluated by both students and teachers, has clearly improved.

Long-Term Sustainability

- *Curricular Integration*: The newly developed modules (lectures and labs) were integrated into the curricula of the six joint courses at each partner HEI, ensuring the long-term sustainability of the project's output.
- *Program Growth*: The success of the pilot program has allowed co-teaching teams to expand their membership with new teachers (e.g., in course C5).
- *Best practice Guide*: The guide will serve as a reference for other HEIs and industry partners interested in adopting international team-teaching practices, ensuring that the experience and knowledge gained within the consortium continue to generate impact.

Future directions

These findings confirm TTPP's success in enhancing both pedagogical practices and student learning outcomes. The pilot program has established a strong foundation that will ensure the project's long-term impact and sustainability across all partner institutions. In summary, the substantial improvements across all key indicators confirm the NextGEng project's innovative effect on modern engineering education.

References

[1] N. PROJECT, "NEXTGENG PROJECT - NEXTGENG.EU." ACCESSED: SEPTEMBER 10, 2025. [ONLINE]. AVAILABLE: HTTPS://NEXTGENG.EU/

[2] TUCN, "TECHNICAL UNIVERSITY OF CLUJ-NAPOCA" ACCESSED: SEPTEMBER 10, 2025. [ONLINE]. AVAILABLE: HTTPS://WWW.UTCLUJ.RO/

[3] JAMK, "JAMK UNIVERSITY OF APPLIED SCIENCES" ACCESSED: SEPTEMBER 10, 2025. [ONLINE]. AVAILABLE: HTTPS://WWW.JAMK.FI/EN

[4] UJA, "UNIVERSITY OF JAÉN" ACCESSED: SEPTEMBER 10, 2025. [ONLINE]. AVAILABLE: HTTPS://WWW.UJAEN.ES/EN

[5] ISR, "INTEGRACION SENSORIAL Y ROBOTICA" ACCESSED: SEPTEMBER 10, 2025. [ONLINE]. AVAILABLE: HTTPS://ISR.ES/

[6] VALMET, "VALMET TECHNOLOGIES OYJ" ACCESSED: SEPTEMBER 10, 2025. [ONLINE]. AVAILABLE: HTTPS://WWW.VALMET.COM/

[7] BOSCH, "ROBERT BOSCH SRL" ACCESSED: SEPTEMBER 10, 2025. [ONLINE]. AVAILABLE: HTTPS://WWW.BOSCH.RO/

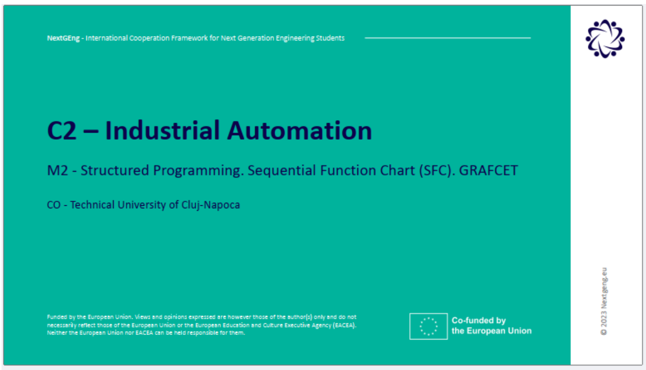
[8] EEAV, "EUROPEAN EDUCATION AREA 2025 VISION" ACCESSED: SEPTEMBER 10, 2025. [ONLINE]. AVAILABLE: HTTPS://EUR-LEX.EUROPA.EU/EN/LEGAL-CONTENT/SUMMARY/A-EUROPEAN-EDUCATION-AREA-BY-2025.HTML

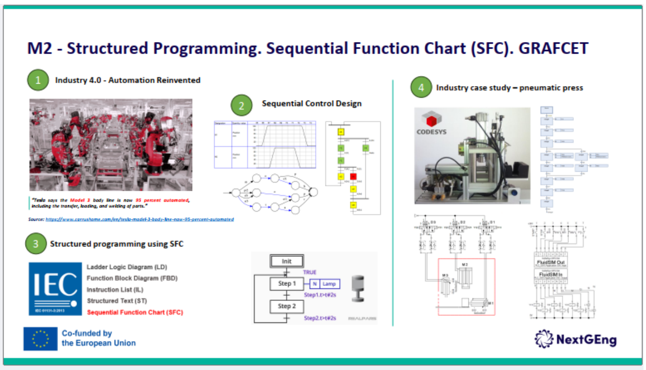
*[9] SDGs, "*SUSTAINABLE DEVELOPMENT GOALS*" ACCESSED: SEPTEMBER 10, 2025. [ONLINE]. AVAILABLE: HTTPS://SDGS.UN.ORG/GOALS*

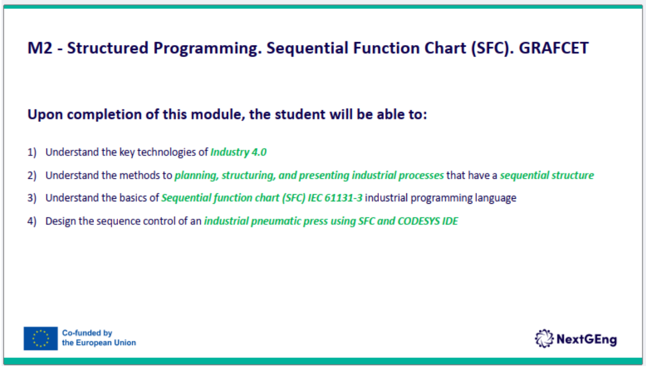
[10] VIOLETA FIRESCU, "INCREASING COLLABORATION BETWEEN HUMANS AND TECHNOLOGY WITHIN ORGANIZATIONS: THE NEED FOR ERGONOMICS AND SOFT SKILLS IN ENGINEERING EDUCATION 5.0," SUSTAINABILITY, 2025, 17(5), 1989; DOI:10.3390/SU17051989.

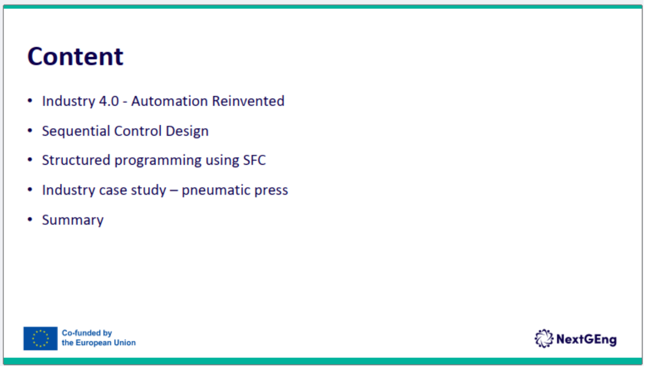
[11] MARTÍNEZ, S. S., GILA, D. M., VICENTE, R. D., RAD, C., & LAPUSAN, C., "EXPERIENCIA DE COENSEÑANZA INTERNACIONAL EN ASIGNATURAS DE AUTOMÁTICA EN EL MARCO DEL PROYECTO EUROPEO NEXTGENG," JORNADAS DE AUTOMÁTICA, 45, 2024.

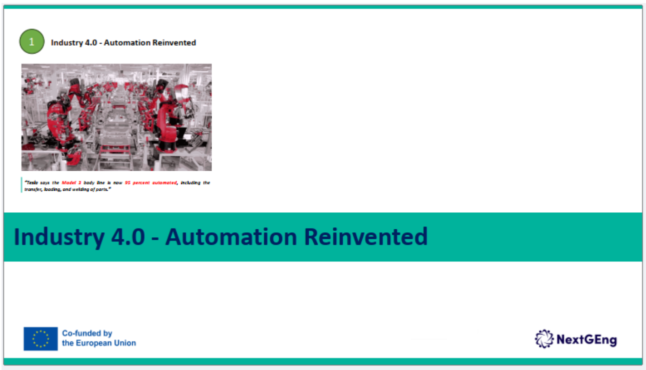
ANNEX 1 – Course module (example)

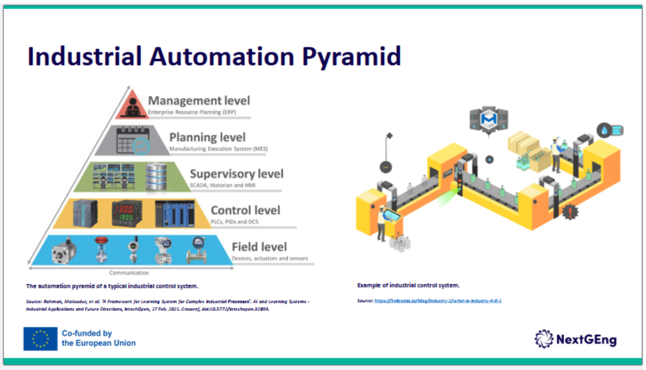


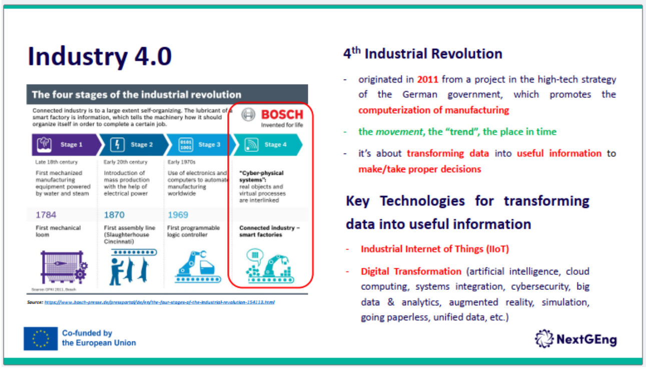


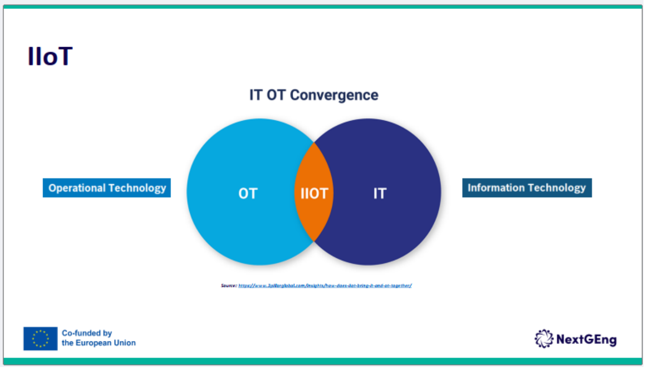


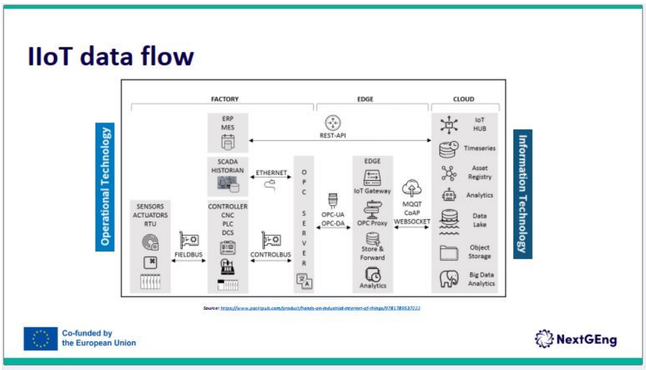


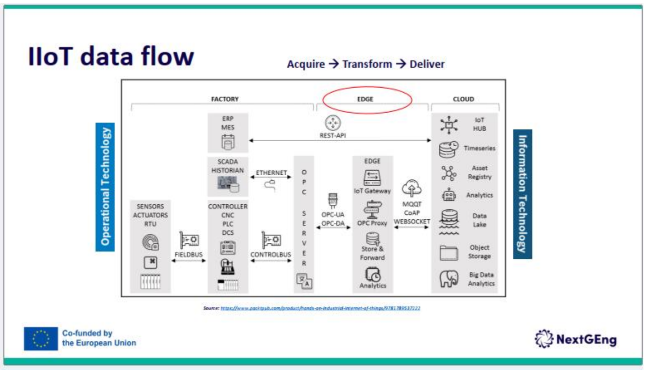


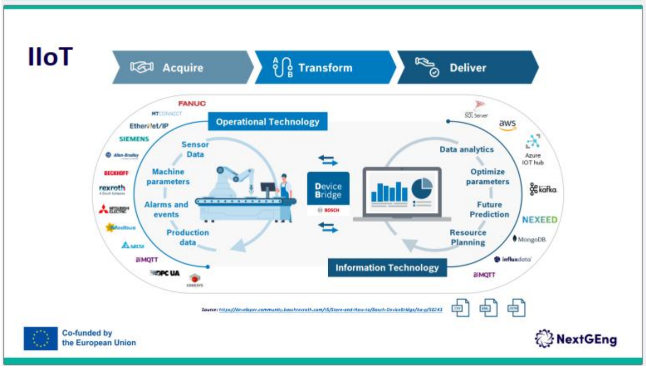


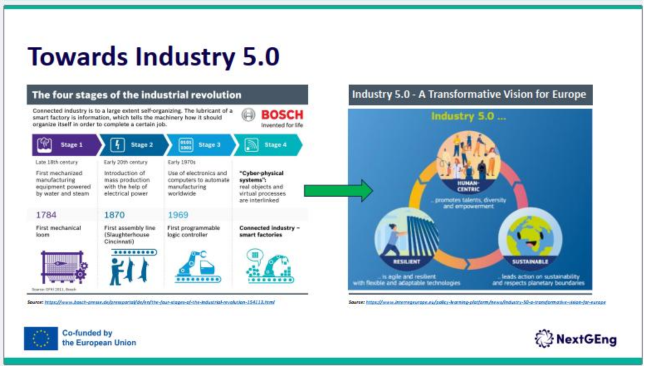




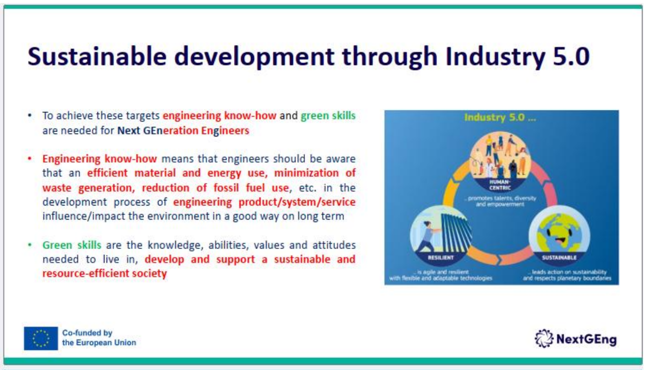

IIoT data flow
FACTORY
EDGE
CLOUD
Operational Technology
Information Technology
ERP
MES
REST-API
SCADA
HISTORIAN
ETHERNET
SENSORS
ACTUATORS
RTU
CONTROLLER
CNC
PLC
DCS
FIELDBUS
CONTROLBUS
OPC SERVER
OPC-UA
OPC-DA
EDGE
IoT Gateway
OPC Proxy
MQTT
CoAP
WEBSOCKET
Store & Forward
Analytics
IoT HUB
Timeseries
Asset Registry
Analytics
Data Lake
Object Storage
Big Data Analytics
Co-funded by the European Union
NextGEng

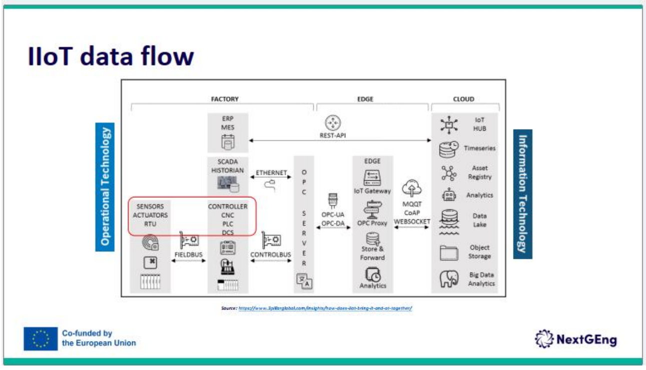

IIoT data flow
Acquire → Transform → Deliver
FACTORY
EDGE
CLOUD
Operational Technology
Information Technology
Co-funded by the European Union
NextGEng

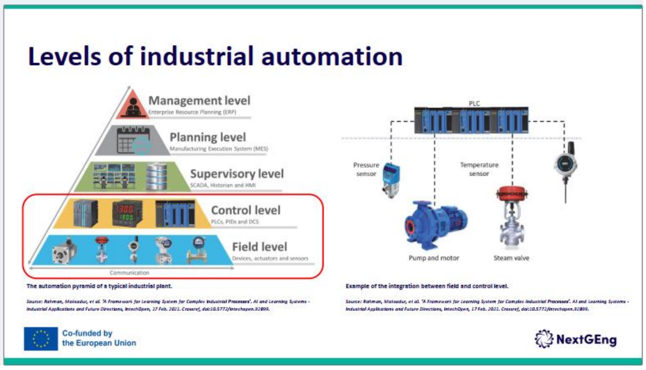

IIoT
Acquire
Transform
Deliver
Operational Technology
Sensor Data
Machine parameters
Alarms and events
Production data
Device Bridge
Data analytics
Optimize parameters
Future Prediction
Resource Planning
Information Technology
Co-funded by the European Union
NextGEng

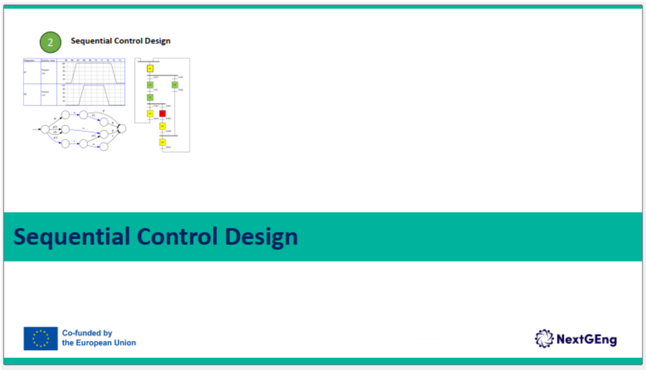

Towards Industry 5.0
The four stages of the industrial revolution
BOSCH
Stage 1
Stage 2
Stage 3
Stage 4
1784
1870
1969
Industry 5.0 - A Transformative Vision for Europe
Industry 5.0 ...
HUMAN-CENTRIC
RESILIENT
SUSTAINABLE
Co-funded by the European Union
NextGEng

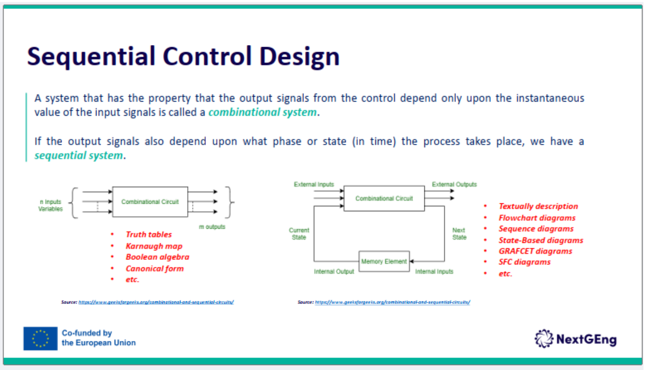

Why Industry 5.0?
It complements the existing "Industry 4.0" approach by specifically putting research and innovation at the service of the transition to a sustainable, human-centric and resilient European industry
Industry 5.0 will lead the digital and green transitions
How to make it happen?
adopting a human-centric approach for digital technologies including artificial intelligence
up-skilling and re-skilling European workers, particularly digital skills
modern, resource-efficient and sustainable industries and transition to a circular economy (green skills)
Industry 5.0 ...
HUMAN-CENTRIC
RESILIENT
SUSTAINABLE
Co-funded by the European Union
NextGEng

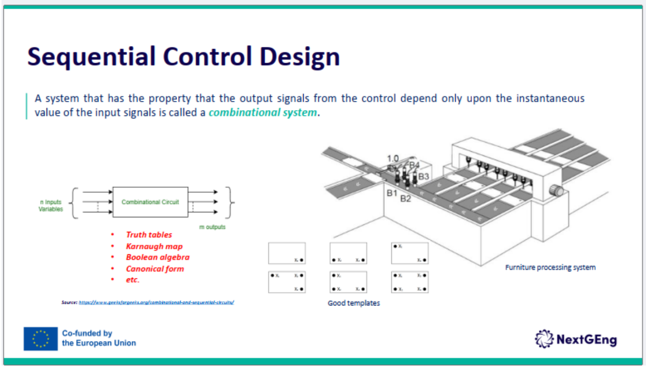

Sustainable development through Industry 5.0
To achieve these targets engineering know-how and green skills are needed for Next GEneration Engineers
Engineering know-how means that engineers should be aware that an efficient material and energy use, minimization of waste generation, reduction of fossil fuel use, etc. in the development process of engineering product/system/service influence/impact the environment in a good way on long term
Green skills are the knowledge, abilities, values and attitudes needed to live in, develop and support a sustainable and resource-efficient society
Industry 5.0 ...
HUMAN-CENTRIC
RESILIENT
SUSTAINABLE
Co-funded by the European Union
NextGEng

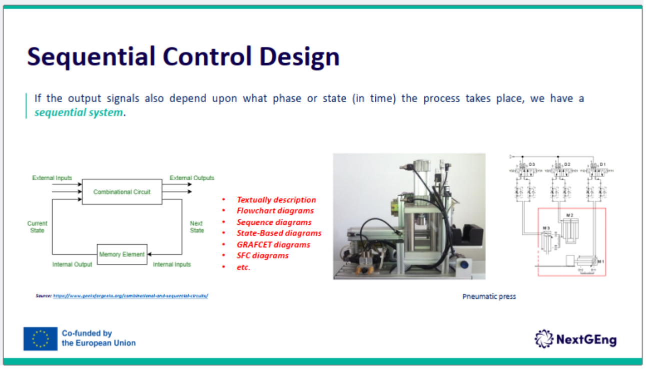

IIoT data flow
FACTORY
EDGE
CLOUD
Operational Technology
Information Technology
SENSORS
ACTUATORS
RTU
CONTROLLER
CNC
PLC
DCS
Co-funded by the European Union
NextGEng

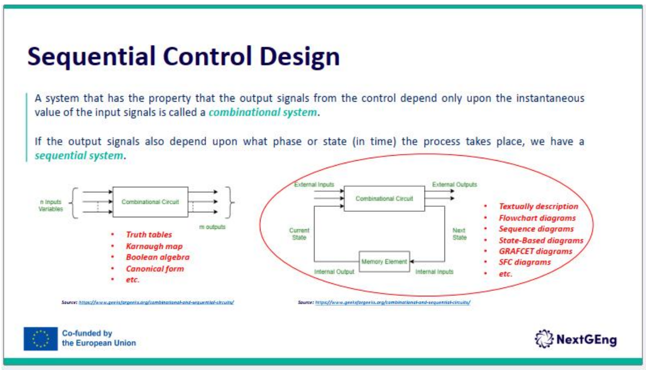

Levels of industrial automation
Management level
Planning level
Supervisory level
Control level
Field level
PLC
Pressure sensor
Temperature sensor
Pump and motor
Steam valve
The automation pyramid of a typical industrial plant.
Example of the integration between field and control level.
Co-funded by the European Union
NextGEng


2 Sequential Control Design
Sequential Control Design
Co-funded by the European Union
NextGEng

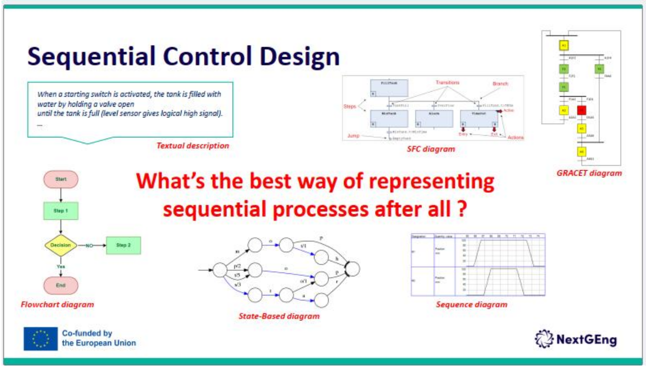

Sequential Control Design
A system that has the property that the output signals from the control depend only upon the instantaneous value of the input signals is called a combinational system.
If the output signals also depend upon what phase or state (in time) the process takes place, we have a sequential system.
Combinational Circuit
Truth tables
Karnaugh map
Boolean algebra
Canonical form
etc.
External Inputs
External Outputs
Current State
Next State
Memory Element
Internal Output
Internal Inputs
Textually description
Flowchart diagrams
Sequence diagrams
State-Based diagrams
GRAFCET diagrams
SFC diagrams
etc.
Co-funded by the European Union
NextGEng

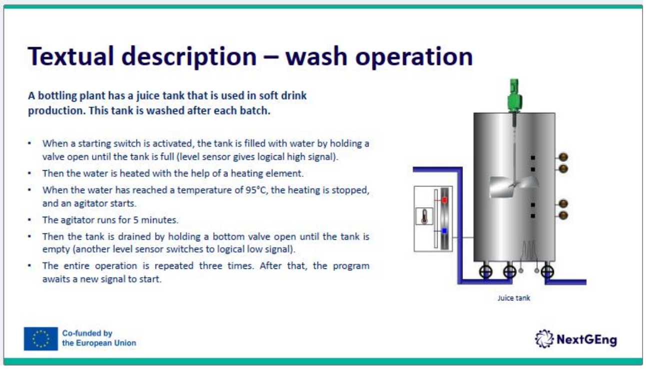

Sequential Control Design
A system that has the property that the output signals from the control depend only upon the instantaneous value of the input signals is called a combinational system.
Combinational Circuit
Truth tables
Karnaugh map
Boolean algebra
Canonical form
etc.
Furniture processing system
Good templates
Co-funded by the European Union
NextGEng

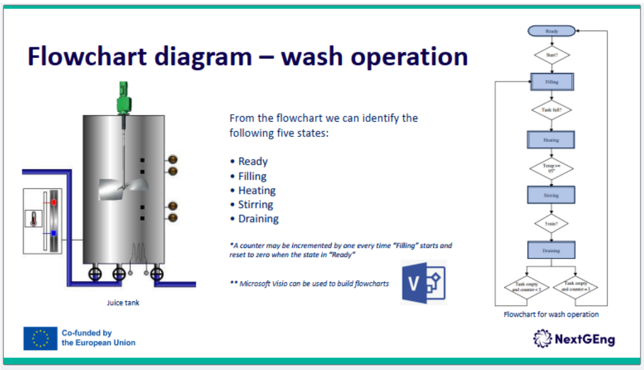

Sequential Control Design
If the output signals also depend upon what phase or state (in time) the process takes place, we have a sequential system.
External Inputs
External Outputs
Combinational Circuit
Current State
Next State
Memory Element
Internal Output
Internal Inputs
Textually description
Flowchart diagrams
Sequence diagrams
State-Based diagrams
GRAFCET diagrams
SFC diagrams
etc.
Pneumatic press
Co-funded by the European Union
NextGEng

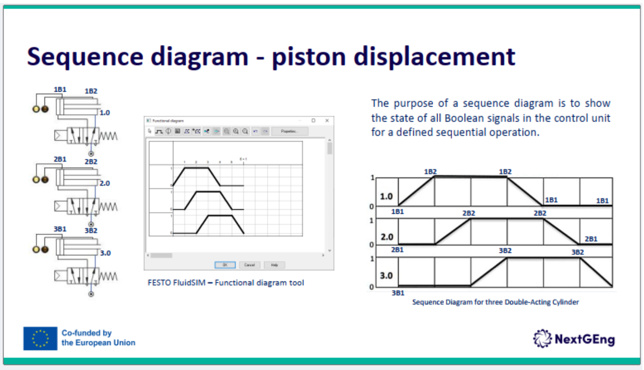

Sequential Control Design
A system that has the property that the output signals from the control depend only upon the instantaneous value of the input signals is called a combinational system.
If the output signals also depend upon what phase or state (in time) the process takes place, we have a sequential system.
Combinational Circuit
Truth tables
Karnaugh map
Boolean algebra
Canonical form
etc.
Textually description
Flowchart diagrams
Sequence diagrams
State-Based diagrams
GRAFCET diagrams
SFC diagrams
etc.
Co-funded by the European Union
NextGEng

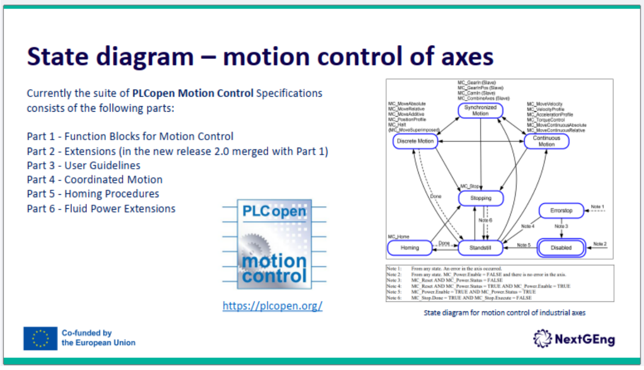

Sequential Control Design
The functional description of an industrial process can be presented graphically or textually
If the industrial process is very complex, it is recommended to use a graphical representation (diagrams)
Diagrams are more powerful for planning, structuring, and presenting processes or production procedures that have a sequential structure
Graphical representations can be helpful also in working out the PLC algorithms for the sequential process
"A PICTURE IS WORTH A THOUSAND WORDS"
FALSE.
YOU CAN'T MEASURE HOW MANY WORDS A PICTURE IS WORTH.
Co-funded by the European Union
NextGEng

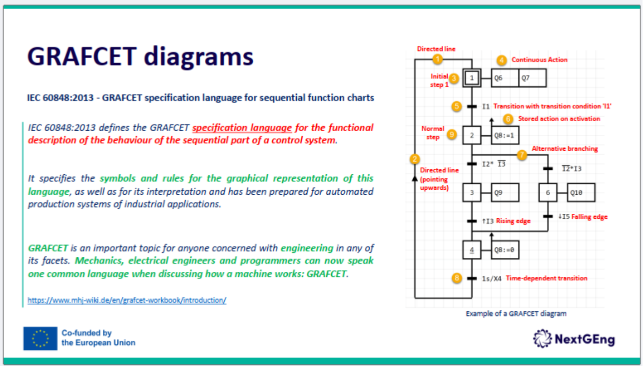

Sequential Control Design
When a starting switch is activated, the tank is filled with water by holding a valve open until the tank is full (level sensor gives logical high signal).
Textual description
SFC diagram
GRACET diagram
What's the best way of representing sequential processes after all ?
Flowchart diagram
State-Based diagram
Sequence diagram
Co-funded by the European Union
NextGEng

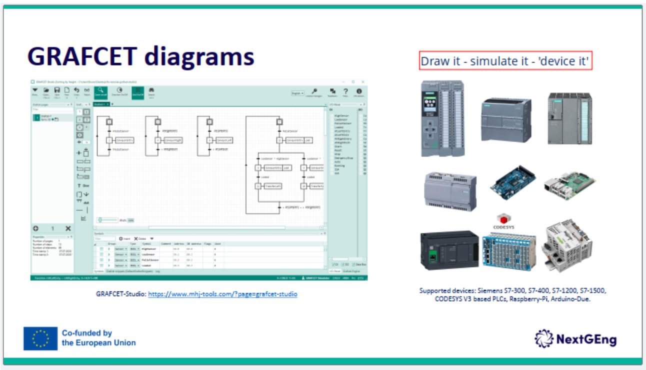

Textual description – wash operation
A bottling plant has a juice tank that is used in soft drink production. This tank is washed after each batch.
When a starting switch is activated, the tank is filled with water by holding a valve open until the tank is full (level sensor gives logical high signal).
Then the water is heated with the help of a heating element.
When the water has reached a temperature of 95°C, the heating is stopped, and an agitator starts.
The agitator runs for 5 minutes.
Then the tank is drained by holding a bottom valve open until the tank is empty (another level sensor switches to logical low signal).
The entire operation is repeated three times. After that, the program awaits a new signal to start.
Juice tank
Co-funded by the European Union
NextGEng

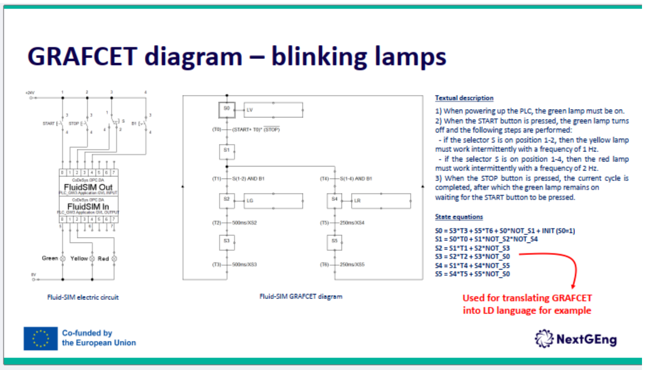

Flowchart diagram – wash operation
From the flowchart we can identify the following five states:
• Ready
• Filling
• Heating
• Stirring
• Draining
*A counter may be incremented by one every time "Filling" starts and reset to zero when the state in "Ready"
** Microsoft Visio can be used to build flowcharts
Juice tank
Flowchart for wash operation
Co-funded by the European Union
NextGEng

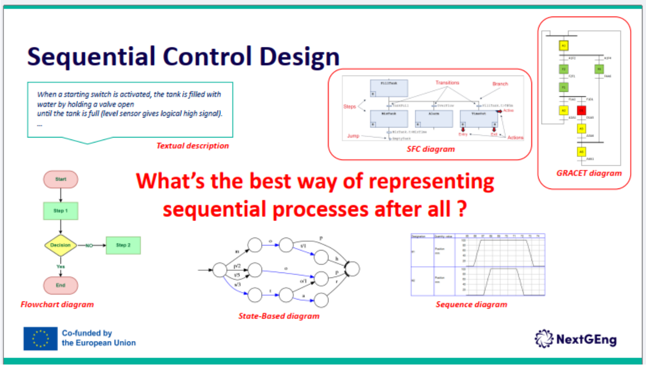

Sequence diagram - piston displacement
The purpose of a sequence diagram is to show the state of all Boolean signals in the control unit for a defined sequential operation.
FESTO FluidSIM – Functional diagram tool
Sequence Diagram for three Double-Acting Cylinder
Co-funded by the European Union
NextGEng

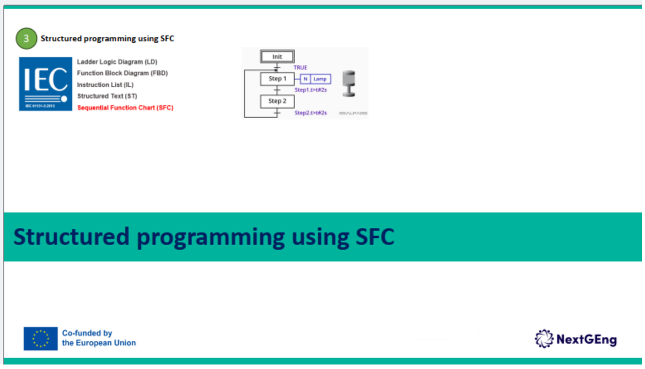

State diagram – motion control of axes
Currently the suite of PLCopen Motion Control Specifications consists of the following parts:
Part 1 - Function Blocks for Motion Control
Part 2 - Extensions (in the new release 2.0 merged with Part 1)
Part 3 - User Guidelines
Part 4 - Coordinated Motion
Part 5 - Homing Procedures
Part 6 - Fluid Power Extensions
PLCopen
motion control
https://plcopen.org/
State diagram for motion control of industrial axes
Co-funded by the European Union
NextGEng

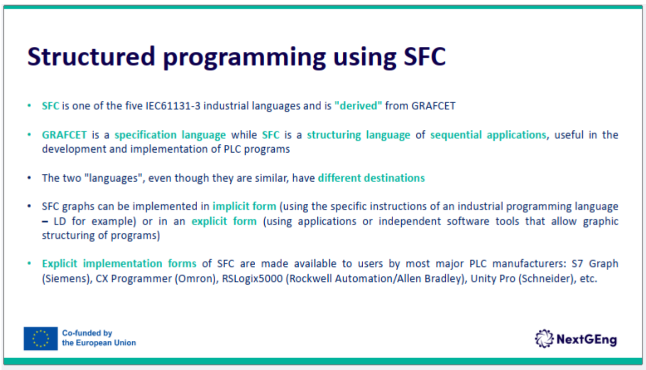

GRAFCET diagrams
IEC 60848:2013 - GRAFCET specification language for sequential function charts
IEC 60848:2013 defines the GRAFCET specification language for the functional description of the behaviour of the sequential part of a control system.
It specifies the symbols and rules for the graphical representation of this language, as well as for its interpretation and has been prepared for automated production systems of industrial applications.
GRAFCET is an important topic for anyone concerned with engineering in any of its facets. Mechanics, electrical engineers and programmers can now speak one common language when discussing how a machine works: GRAFCET.
https://www.mhj-wiki.de/en/grafcet-workbook/introduction/
Directed line
Continuous Action
Initial step 1
Transition with transition condition 'I1'
Stored action on activation
Normal step
Alternative branching
Directed line (pointing upwards)
Rising edge
Falling edge
Time-dependent transition
Example of a GRAFCET diagram
Co-funded by the European Union
NextGEng

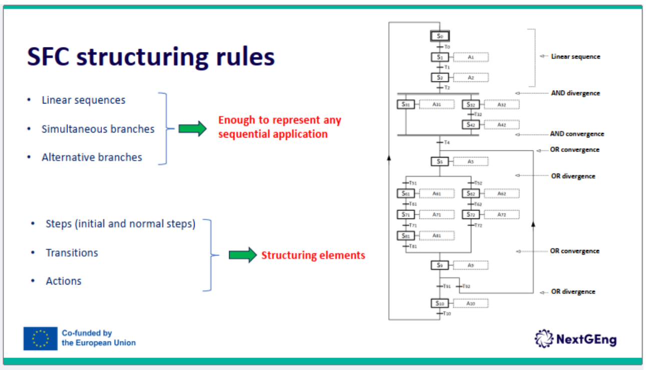

GRAFCET diagrams
Draw it - simulate it - 'device it'
GRAFCET-Studio: https://www.mhj-tools.com/?page=grafcet-studio
Supported devices: Siemens S7-300, S7-400, S7-1200, S7-1500, CODESYS V3 based PLCs, Raspberry-Pi, Arduino-Due.
Co-funded by the European Union
NextGEng

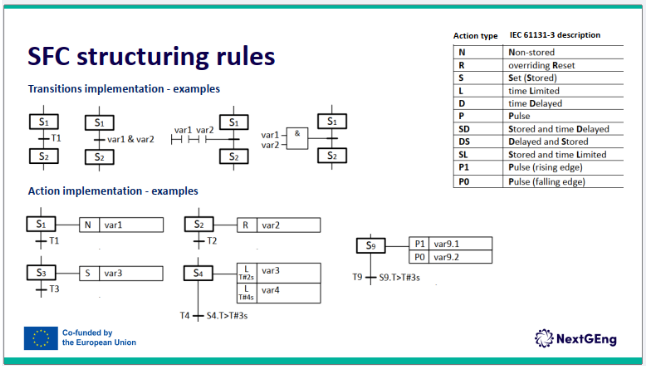

GRAFCET diagram – blinking lamps
Textual description
1) When powering up the PLC, the green lamp must be on.
2) When the START button is pressed, the green lamp turns off and the following steps are performed:
- if the selector S is on position 1-2, then the yellow lamp must work intermittently with a frequency of 1 Hz.
- if the selector S is on position 1-4, then the red lamp must work intermittently with a frequency of 2 Hz.
3) When the STOP button is pressed, the current cycle is completed, after which the green lamp remains on waiting for the START button to be pressed.
State equations
S0 = S3*T3 + S5*T6 + S0*NOT_S1 + INIT (S0=1)
S1 = S0*T0 + S1*NOT_S2*NOT_S4
S2 = S1*T1 + S2*NOT_S3
S3 = S2*T2 + S3*NOT_S0
S4 = S1*T4 + S4*NOT_S5
S5 = S4*T5 + S5*NOT_S0
Used for translating GRAFCET into LD language for example
FluidSIM Out
FluidSIM In
Green
Yellow
Red
Fluid-SIM electric circuit
Fluid-SIM GRAFCET diagram
Co-funded by the European Union
NextGEng

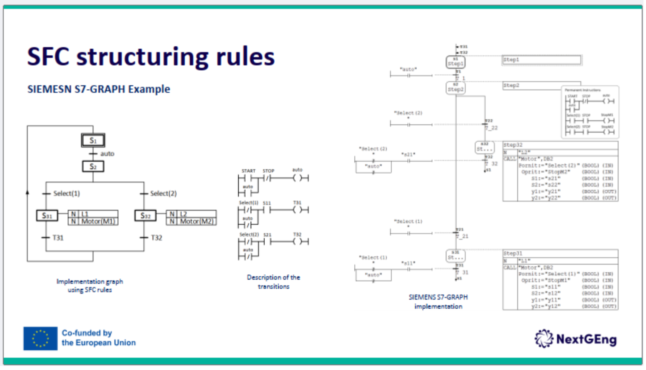

Sequential Control Design
When a starting switch is activated, the tank is filled with water by holding a valve open until the tank is full (level sensor gives logical high signal).
...
Textual description
SFC diagram
GRACET diagram
What's the best way of representing sequential processes after all ?
Flowchart diagram
State-Based diagram
Sequence diagram
Co-funded by the European Union
NextGEng

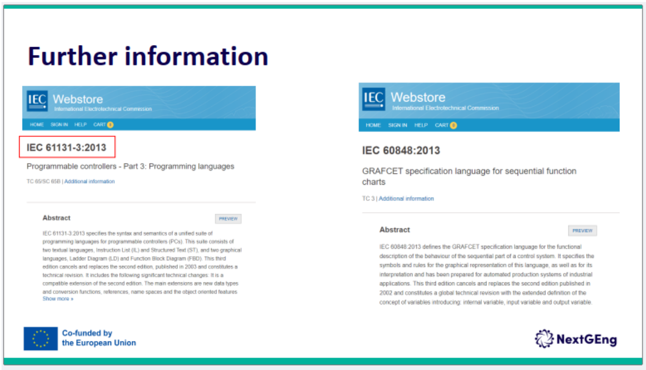

3 Structured programming using SFC
IEC
Ladder Logic Diagram (LD)
Function Block Diagram (FBD)
Instruction List (IL)
Structured Text (ST)
Sequential Function Chart (SFC)
Init
Step 1
Step 2
Lamp
Structured programming using SFC
Co-funded by the European Union
NextGEng

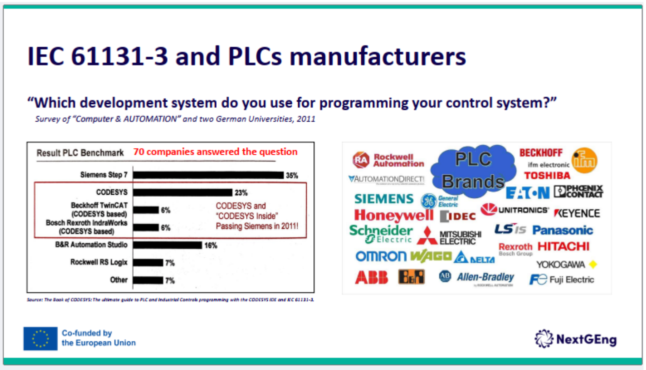

Structured programming using SFC
SFC is one of the five IEC61131-3 industrial languages and is "derived" from GRAFCET
GRAFCET is a specification language while SFC is a structuring language of sequential applications, useful in the development and implementation of PLC programs
The two "languages", even though they are similar, have different destinations
SFC graphs can be implemented in implicit form (using the specific instructions of an industrial programming language – LD for example) or in an explicit form (using applications or independent software tools that allow graphic structuring of programs)
Explicit implementation forms of SFC are made available to users by most major PLC manufacturers: S7 Graph (Siemens), CX Programmer (Omron), RSLogix5000 (Rockwell Automation/Allen Bradley), Unity Pro (Schneider), etc.
Co-funded by the European Union
NextGEng

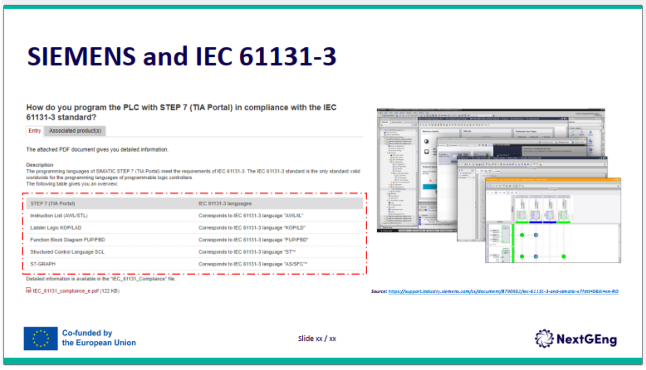

SFC structuring rules
Linear sequences
Simultaneous branches
Alternative branches
Enough to represent any sequential application
Steps (initial and normal steps)
Transitions
Actions
Structuring elements
Linear sequence
AND divergence
AND convergence
OR convergence
OR divergence
OR convergence
OR divergence
Co-funded by the European Union
NextGEng

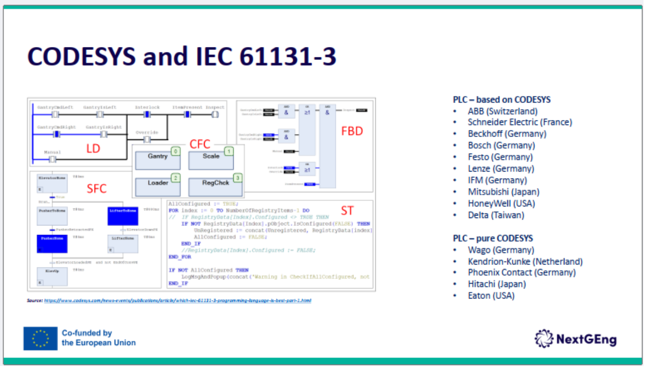

SFC structuring rules
Transitions implementation - examples
S1
T1
S2
var1 & var2
var1 var2
Action implementation - examples
N var1
R var2
S var3
L T#2s var3
L T#4s var4
T4 S4.T>T#3s
P1 var9.1
P0 var9.2
T9 S9.T>T#3s
Action type
IEC 61131-3 description
N Non-stored
R overriding Reset
S Set (Stored)
L time Limited
D time Delayed
P Pulse
SD Stored and time Delayed
DS Delayed and Stored
SL Stored and time Limited
P1 Pulse (rising edge)
P0 Pulse (falling edge)
Co-funded by the European Union
NextGEng

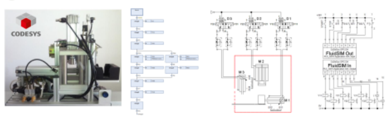

SFC structuring rules
SIEMESN S7-GRAPH Example
auto
Select(1)
Select(2)
N L1
N Motor(M1)
N L2
N Motor(M2)
T31
T32
Implementation graph using SFC rules
START STOP auto
Description of the transitions
SIEMENS S7-GRAPH implementation
Co-funded by the European Union
NextGEng


Further information
IEC Webstore
International Electrotechnical Commission
HOME SIGN IN HELP CART
IEC 61131-3:2013
Programmable controllers - Part 3: Programming languages
TC 65/SC 65B | Additional information
Abstract
PREVIEW
IEC 61131-3:2013 specifies the syntax and semantics of a unified suite of programming languages for programmable controllers (PCs). This suite consists of two textual languages, Instruction List (IL) and Structured Text (ST), and two graphical languages, Ladder Diagram (LD) and Function Block Diagram (FBD). This third edition cancels and replaces the second edition, published in 2003 and constitutes a technical revision. It includes the following significant technical changes: It is a compatible extension of the second edition. The main extensions are new data types and conversion functions, references, name spaces and the object oriented features
Show more »
IEC Webstore
International Electrotechnical Commission
HOME SIGN IN HELP CART
IEC 60848:2013
GRAFCET specification language for sequential function charts
TC 3 | Additional information
Abstract
PREVIEW
IEC 60848:2013 defines the GRAFCET specification language for the functional description of the behaviour of the sequential part of a control system. It specifies the symbols and rules for the graphical representation of this language, as well as for its interpretation and has been prepared for automated production systems of industrial applications. This third edition cancels and replaces the second edition published in 2002 and constitutes a global technical revision with the extended definition of the concept of variables introducing: internal variable, input variable and output variable.
Co-funded by the European Union
NextGEng


IEC 61131-3 and PLCs manufacturers
"Which development system do you use for programming your control system?"
Survey of "Computer & AUTOMATION" and two German Universities, 2011
Result PLC Benchmark
70 companies answered the question
Siemens Step 7 35%
CODESYS 23%
Beckhoff TwinCAT (CODESYS based) 6%
Bosch Rexroth IndraWorks (CODESYS based) 6%
CODESYS and "CODESYS Inside" Passing Siemens in 2011!
B&R Automation Studio 16%
Rockwell RS Logix 7%
Other 7%
Source: The Book of CODESYS: The ultimate guide to PLC and Industrial Controls programming with the CODESYS IDE and IEC 61131-3.
PLC Brands
Co-funded by the European Union
NextGEng


SIEMENS and IEC 61131-3
How do you program the PLC with STEP 7 (TIA Portal) in compliance with the IEC 61131-3 standard?
Entry Associated product(s)
The attached PDF document gives you detailed information.
Description
The programming languages of SIMATIC STEP 7 (TIA Portal) meet the requirements of IEC 61131-3. The IEC 61131-3 standard is the only standard valid worldwide for the programming languages of programmable logic controllers.
The following table gives you an overview:
STEP 7 (TIA Portal) IEC 61131-3 languages
Instruction List (AWL/STL) Corresponds to IEC 61131-3 language "AWL/IL"
Ladder Logic KOP/LAD Corresponds to IEC 61131-3 language "KOP/LD"
Function Block Diagram FUP/FBD Corresponds to IEC 61131-3 language "FUP/FBD"
Structured Control Language SCL Corresponds to IEC 61131-3 language "ST"
S7-GRAPH Corresponds to IEC 61131-3 language "AS/SFC"
Detailed information is available in the "IEC_61131_Compliance" file.
IEC_61131_compliance_e.pdf (122 KB)
Source: https://support.industry.siemens.com/cs/document/8790932/iec-61131-3-and-simatic-s7?dti=0&lc=en-RO
Co-funded by the European Union
Slide xx / xx
NextGEng


CODESYS and IEC 61131-3
LD
CFC
FBD
SFC
ST
Gantry
Scale
Loader
RegChck
Source: https://www.codesys.com/news-events/publications/article/which-iec-61131-3-programming-language-is-best-part-1.html
PLC – based on CODESYS
ABB (Switzerland)
Schneider Electric (France)
Beckhoff (Germany)
Bosch (Germany)
Festo (Germany)
Lenze (Germany)
IFM (Germany)
Mitsubishi (Japan)
HoneyWell (USA)
Delta (Taiwan)
PLC – pure CODESYS
Wago (Germany)
Kendrion-Kunke (Netherland)
Phoenix Contact (Germany)
Hitachi (Japan)
Eaton (USA)
Co-funded by the European Union
NextGEng

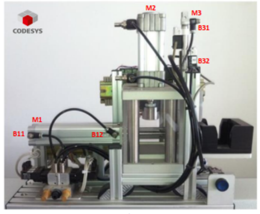


Industry case study – pneumatic press

Industry case study – pneumatic press

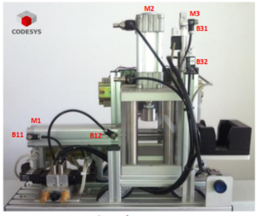
An electropneumatic press is shown in the figure. It includes a press room, a feeding system and a sliding door for securing the press room. The actuating circuit is consisting of three linear pneumatic motors: M1, M2 and M3.

Technical description of the system:
- M1, M2, M3: linear pneumatic motors;
- P: part identification sensor (plastic (1); metal (0));
- B11, B12, B31, B32: position sensors;
- START/STOP: process control buttons;
- Y11, Y12, Y21, Y22, Y31, Y32: electromagnets;
- L1,L2: signal lights.

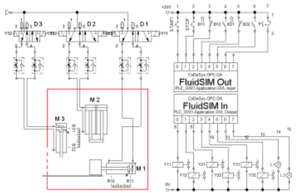


Pneumatic press

Industry case study – pneumatic press

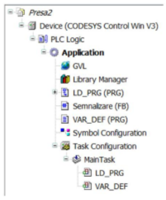


Pneumatic press



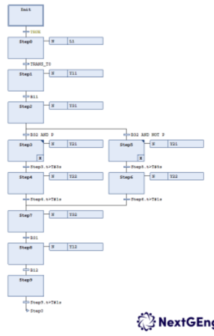
Electropneumatic circuit

Task – Pressing process



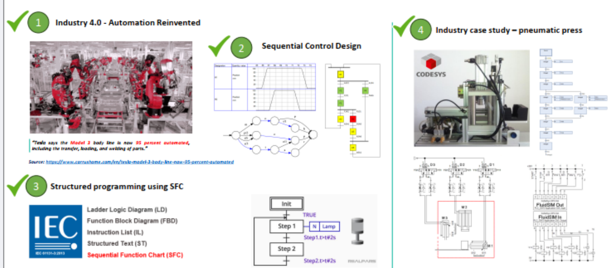
CODESYS project

SFC implementation graph



Summary

M2 - Structured Programming. Sequential Function Chart (SFC). GRAFCET



References

[1] Olimpiu Hancu, Ciprian R. Rad, *Controlere Logice Programabile – Programarea și Dezvoltarea Aplicațiilor Industriale*, UT PRESS, 1st edition, Cluj-Napoca, 2017, ISBN: 978-6067372328.

[2] Dag H. Hanssen, *Programmable Logic Controllers: A Practical Approach to IEC 61131-3 using CoDeSys*, Wiley, 1st edition, September 11, 2015, ISBN: 978-1118949245.

[3] Gary L. Pratt PE, *The Book of CODESYS: The ultimate guide to PLC and Industrial Controls programming with the CODESYS IDE and IEC 61131-3*, ControlSphere LLC, First Edition, October 25, 2021, ISBN: 978-1737821403.

Thank you!

Kiitos!

Gracias!

Mulțumesc!

Contact:
- Ciprian RAD
- E-mail: ciprian.rad@mdm.utcluj.ro

ANNEX 2 – Laboratory module (example)

NextGEng - International Cooperation Framework for Next Generation Engineering Students

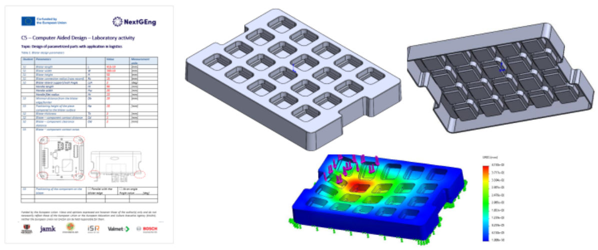
C5 – Computer Aided Design

L2 – Design of parametrized parts with applications in logistics

Developed in collaboration with Bosch Cluj Plant

Co-funded by the European Union

Design of parametrized parts with application in logistics



Co-funded by the European Union · Page 2 / xx · NextGEng

Design of parametrized parts with application in logistics

Laboratory overview:

Objectives	• Design a blister based on a set of prerequisite requirements (manipulated part, materials etc.) • Define the blister geometric parameters to be compatible with manufacturing process
Pre-requisite	• Basic skills and knowledge of SolidWorks • Basic knowledge in technical drawings • Basic knowledge manufacturing and plastic thermoforming
Equipment used for laboratory	• PCs with SolidWorks

Co-funded by the European Union · Page 3 / xx · NextGEng

Design of parametrized parts with application in logistics

Upon completion of this laboratory, the student will be able to:

1) Define parametrized parts
2) Define the negative of a given part that could be used to design dedicated transportation modules (blisters)
3) Design parametrized parts that could be manufactured using plastic thermoforming
4) Implement rapid prototyping procedures for testing blisters

Co-funded by the European Union · Page 4 / xx · NextGEng

Content

- Introduction
- Theoretical concepts
  - Design procedure of a blister used in logistics
  - Defining the negative of a part
  - Parametrized parts / Parametric modelling
- Laboratory task
  - Define the main design parameters and restrictions
  - Desing the blister based on the imposed requirements
  - Testing procedures for the designed part
- Summary, Discussions & Feedback

Co-funded by the European Union · Page 5 / xx · NextGEng

Introduction

Co-funded by the European Union · NextGEng

Introduction

- **Blister** - pre-formed plastic cavity used to securely hold and protect a large variety of products
- **Applications:**
  - Electronics industry
  - Pharmaceutical industry
  - Consumer goods
  - Food industry
  - Production lines

Co-funded by the European Union · Page 7 / xx · NextGEng

Introduction

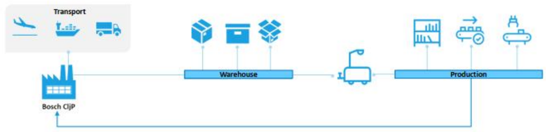
- **Advantages:**
  - Product protection
  - Efficient automation
  - Cost-effective
  - Lightweight
  - Customization
  - Product visibility
- **Limitations:**
  - Limited size and shape flexibility
  - Environmental concerns
  - Lower structural strength
  - Cost of custom tooling

Co-funded by the European Union · Page 8 / xx · NextGEng

Introduction

Logistics processes – *blister role*

- Packaging



Introduction

- **Benefits of using blisters on production lines & logistics**

- automation

- Easy and safe transportation

- Optimal storage

Theoretical concepts

Blister design procedure

Goal – design a blister that is ***functional***, ***efficient*** and ***cost-effective***

Constraints:

- Product properties
- Material used
- Manufacturing technology
- Production processes

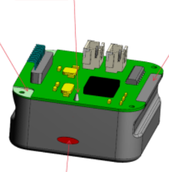
Blister design procedure

Design steps for the blister

I. Understand the Product and Requirements:

Product analysis

- evaluate the ***physical characteristics*** (size, shape, weight) and the manipulated system
- Identify ***sensitive areas*** on the product that needs to be protected (ex. thin sections, protruding components, or smooth surfaces may need extra space or cushioning in the blister design)



Blister design procedure

Design steps for the blister

I. Understand the Product and Requirements:

Logistic specific constrains

- determine how the product is transported, stored, and handled during the logistic process
- *Ergonomic Aspects and Manual Handling*
- *Process Size Limitations (Conveyor Belt, Container, Box, Pallet)*

Blister design procedure

Design steps for the blister

II. Material Selection

- Material selection influence: overall strength, flexibility, environmental impact, and cost of the packaging

PET (Polyethylene Terephthalate)	PVC (Polyvinyl Chloride)	HIPS (High Impact Polystyrene)	PP (Polypropylene)
• good strength • good protection of product from physical damage and env. Factors	• good strength • good protection of product from physical damage and env. factors	• strong impact resistance • cheap	• lightweight • durable • chemically resistant • excellent resistance to moisture and heat

Blister design procedure

Design steps for the blister

II. Material Selection - **Environmental Impact**

Eco-friendly measures in blister packaging:

- **Use of Recyclable Materials**

Polypropylene (PP)	Polyethylene Terephthalate (PET)	High Impact Polystyrene (HIPS)	Polyvinyl Chloride (PVC)
-most eco-friendly due to its recyclability	- highly recyclable and commonly used in packaging	- less environmentally friendly than PP and PET - recyclable in certain facilities	- least eco-friendly - PVC is difficult to recycle - releases harmful chemicals during production and disposal

Blister design procedure

Design steps for the blister

II. Material Selection - Environmental Impact

Eco-friendly measures in blister packaging:

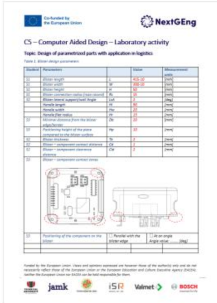
- **Use of Recyclable Materials** - replacing PVC, which is hard to recycle, with more sustainable alternatives like PET or RPET (recycled PET).
- **Modular Design:** Creating reusable or refillable blister packaging that reduces the need for single-use plastics
- **Sustainable Sourcing:** Using backing materials, such as paper or cardboard, from certified sustainable sources

Blister design procedure

Design steps for the blister

III. Blister design specification

- Size and shape
- Thickness
- Contact clearance
- Number of parts / blister
- Contact points

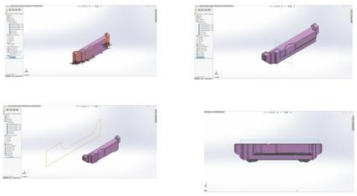


Blister design procedure

Design steps for the blister

IV. Prototyping

- Develop the negative of the part
  - Method 1

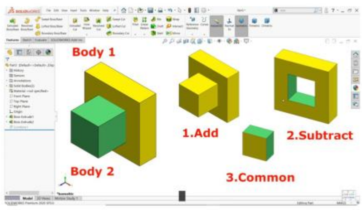


Blister design procedure

Design steps for the blister

IV. Prototyping

- Develop the negative of the part
  - Method 2

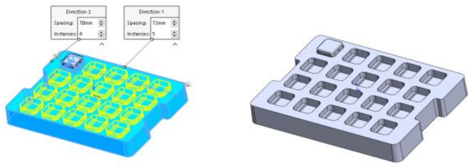


Blister design procedure

Design steps for the blister

IV. Prototyping

- Multiply the negative of the part to obtain the blister



Blister design procedure

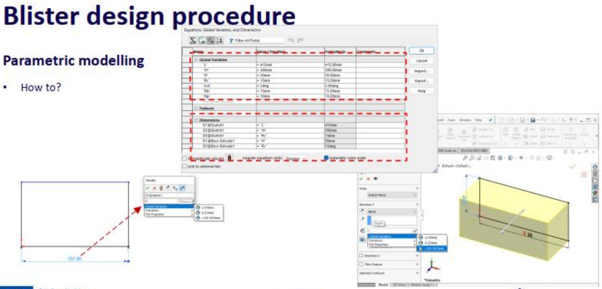
Parametrized parts / Parametric modelling

- Def - **Parametric modelling** is a process where the geometry of a CAD model is defined using dimensional parameters; these parameters help to alter the model geometry just by adjusting their values.
- Advantages
  - Creating dependencies between the dimensions of the part
  - Simplifies the part modification process
  - Mathematical relationships can be used for dimensioning

Blister design procedure

Parametric modelling

- How to?

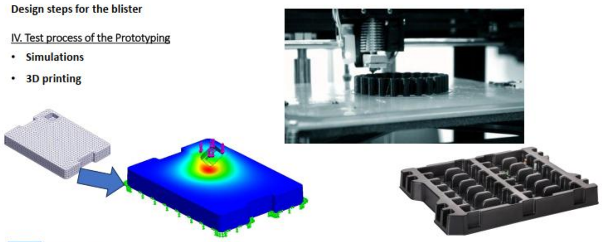


Blister design procedure

Design steps for the blister

IV. Test process of the Prototyping

- Simulations
- 3D printing



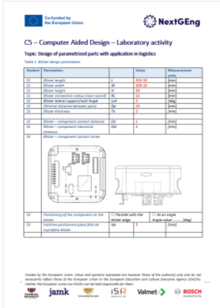
Laboratory work

Design requirements

Working procedure:

- groups of 3 students
  - student 1 – logistics;
  - student 2 – ergonomics & thermoforming
  - student 3 – engineering & production

Task: Each student identifies the parameters specific to its field which influence the blister design and introduce the data inf provided document



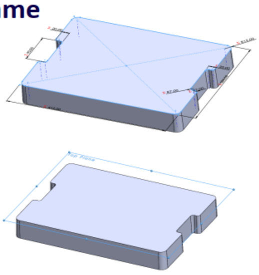
3D model of the blister frame

Working procedure:

- The work is performed by each student individually

Tasks:

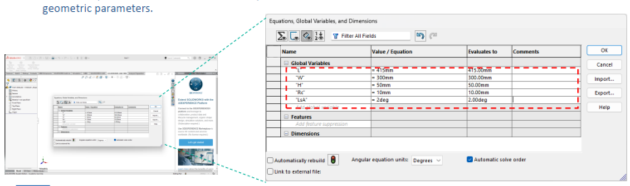
- *Introduce in equations the obtained parameters*
- *Define the bister frames using the eq. param.*



3D model of the blister frame

Step 1

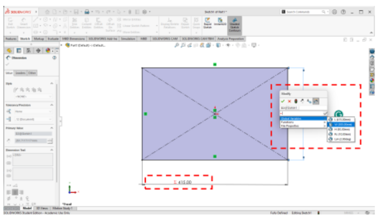
- A new part is created in SolidWorks.
- In the new part, from the *Tools* menu, the *Equation* command is used to define the blister's geometric parameters.



3D model of the blister frame

Step 2

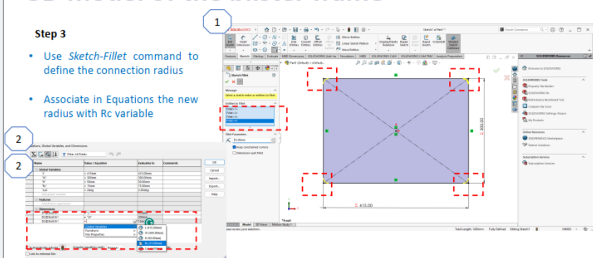
- On the **Top Plane**, a new sketch is created
- define the blister frame using the previously defined parameters.



3D model of the blister frame

Step 3

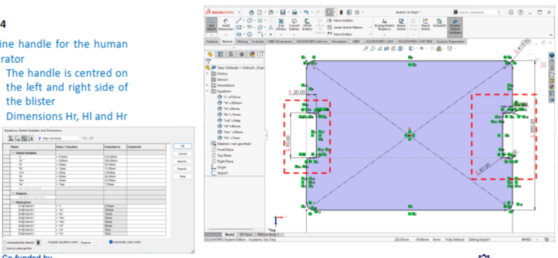
- Use *Sketch-Fillet* command to define the connection radius
- Associate in Equations the new radius with Rc variable



3D model of the blister frame

Step 4

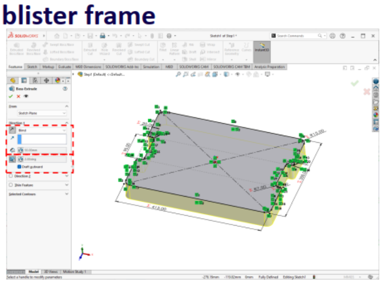
- Define handle for the human operator
  - The handle is centred on the left and right side of the blister
  - Dimensions Hr, Hl and Hr



3D model of the blister frame

Step 4

- Use *Boss- extrude* command to define the blister's body



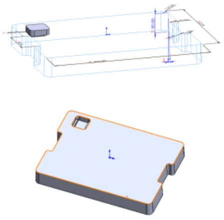
Define the negative of the part

Working procedure:

- The work is performed by each student individually

Tasks:

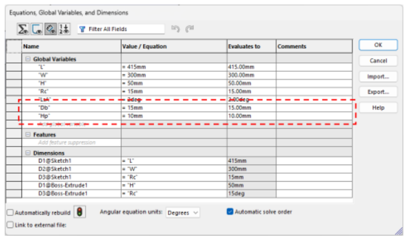
- *Insert the part in SW*
- *Create the negative of the part*
- *Create the nest/cavity for the part*



Define the negative of the part

Step 1

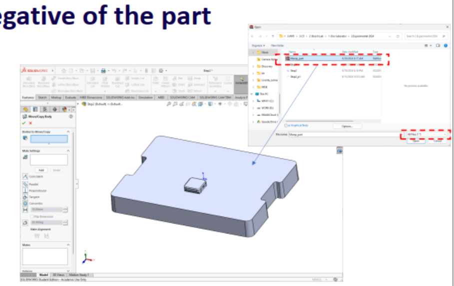
- Define in Equation the parameters for the position of the first part on the blister



Define the negative of the part

Step 2

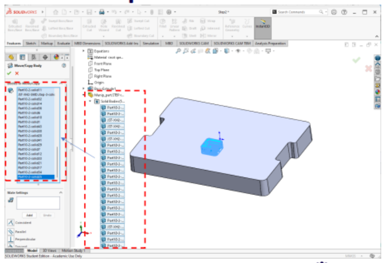
- **Insert the component in the part**
  - Menu ***Insert***, command *Part*
  - In file type select *"All files"*



Define the negative of the part

Step 3

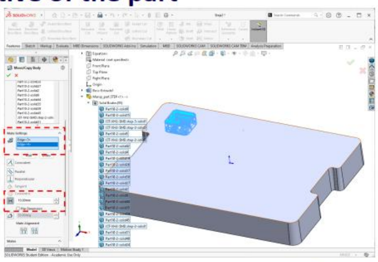
- **Position the inserted component to the first nest location**
  - menu ***Insert/Surface*** command *Move/Copy…*
  - in *Bodies to move* select all bodies from the *step* part



Define the negative of the part

Step 3

- **Position the inserted component to the first nest location**
  - Define distance mates between component and blister margins
  - Define distance mate between the top component face and blister's top face

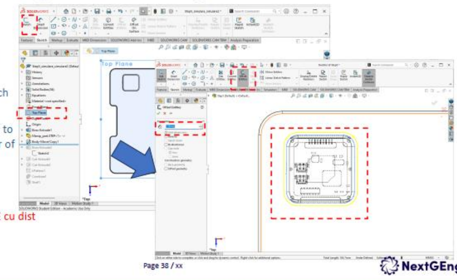


Define the negative of the part

Step 4

- Define the component contour on ***Top Plane***
  - Create a new sketch on *Top plane*
  - Use *Offset Entities* to define the contour of the part

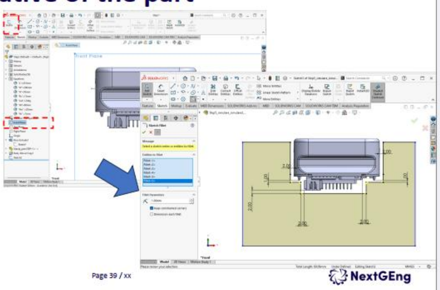
REFACERE POZE cu dist



Define the negative of the part

Step 5

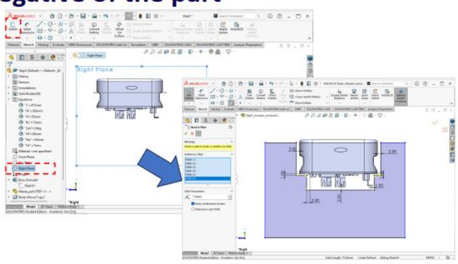
- Define the component contour on ***Front Plane***
  - Create a new sketch on *Front plane*
  - Use *Offset Entities and lines* to define the contour of the part
    - Clearance – 2 mm
    - Contact 1 mm
    - Filet 1 mm



Define the negative of the part

Step 6

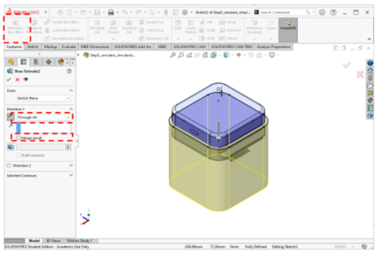
- Define the component contour on ***Right Plane***
  - Create a new sketch on *Right plane*
  - Use *Offset Entities and lines* to define the contour of the part



Define the negative of the part

Step 7

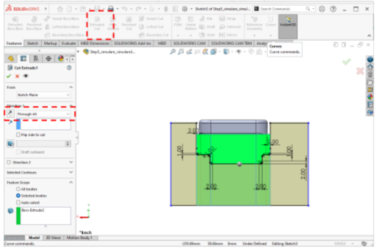
- On *Sketch 2* (Top plane) – use Extrude Boss
  - Through all
  - Unselect *merge result* option



Define the negative of the part

Step 8

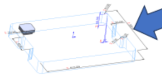
- On *Sketch 3* (Front plane) – use Extrude Cut
  - Option: *Through all*

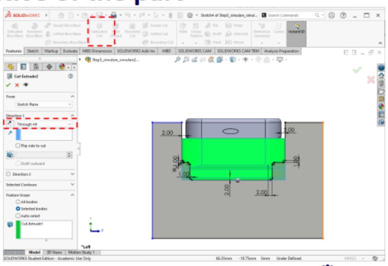


Define the negative of the part

Step 9

- On *Sketch 4* (Right plane) – use Extrude Cut
  - Through all





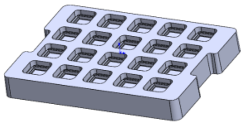
Define all nest on the blister

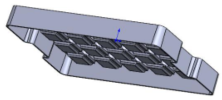
Working procedure:

- The work is performed by each student individually

Tasks:

- *Multiply the negative of the part*
- *Use combine command to obtain the nests*
- *Use shell to create the body of the blister*

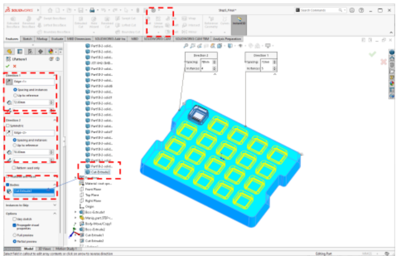




Define all nests on the blister

Step 1

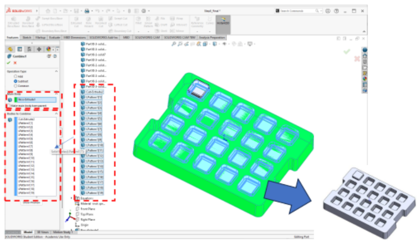
- Use the command *linear pattern*



Define all nests on the blister

Step 2

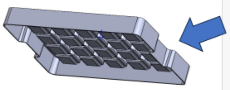
- Create the nests using the command: *Insert/Features/Combine*
  - *Select from Solid Bodies*
    - ***Main Body:*** *Boss Extrude 1*
    - ***Bodies to combine:*** *Cut extrude 1, LPattern 1…n*

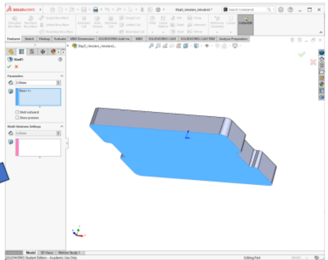


Populate the blister

Step 3

- On *Shell* command with a thickness of 3 mm

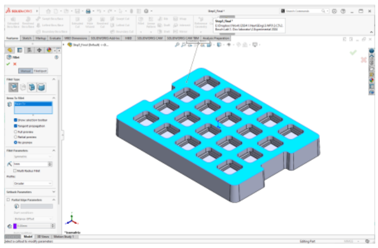


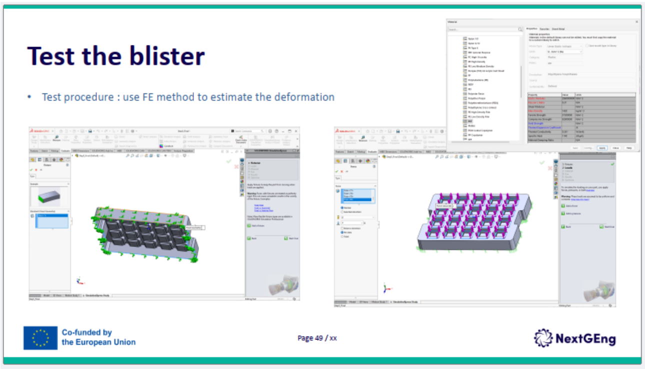


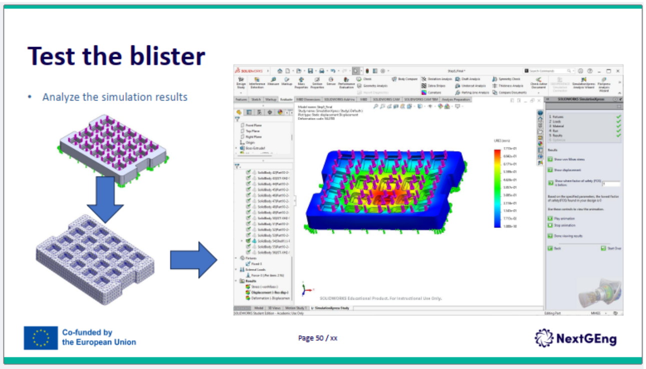
Populate the blister

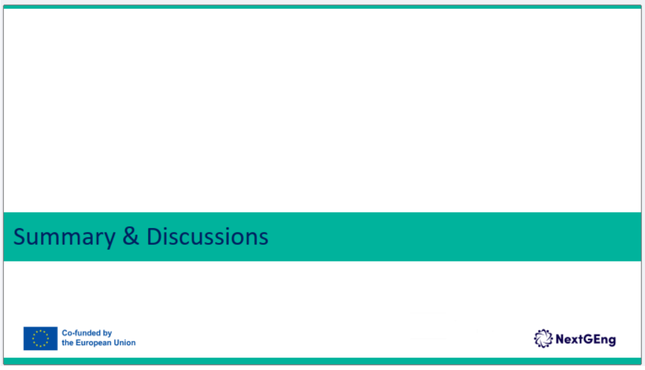
Step 4

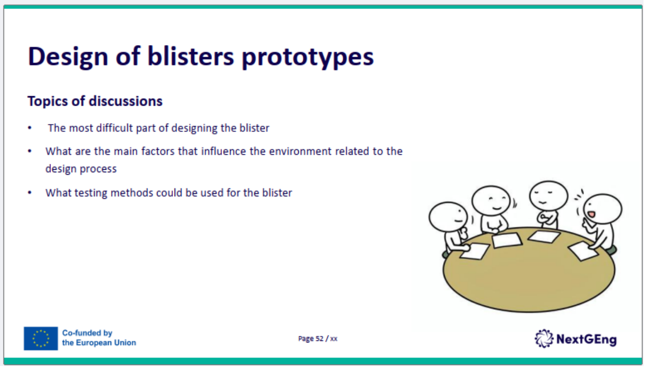
- On *Filet* command with a radius of 1 mm



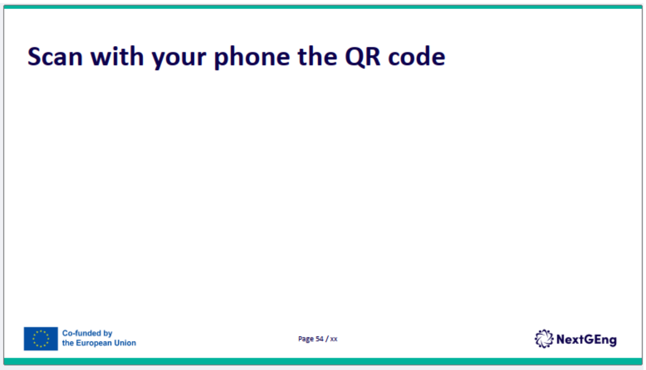

Test the blister
Test procedure : use FE method to estimate the deformation
Co-funded by the European Union
Page 49 / xx
NextGEng

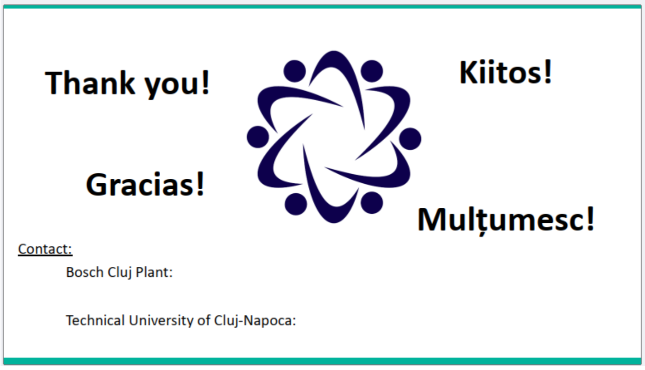

Test the blister
Analyze the simulation results
Co-funded by the European Union
Page 50 / xx
NextGEng


Summary & Discussions
Co-funded by the European Union
NextGEng


Design of blisters prototypes
Topics of discussions
The most difficult part of designing the blister
What are the main factors that influence the environment related to the design process
What testing methods could be used for the blister
Co-funded by the European Union
Page 52 / xx
NextGEng


Feedback
Co-funded by the European Union
NextGEng


Scan with your phone the QR code
Co-funded by the European Union
Page 54 / xx
NextGEng


Thank you!
Kiitos!
Gracias!
Mulțumesc!
Contact:
Bosch Cluj Plant:
Technical University of Cluj-Napoca:


NextGEng - International Cooperation Framework for Next Generation Engineering Students
NextGEng
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.
Co-funded by the European Union
© 2023 Nextgeng.eu