Development of Emerging Technology-driven NordPlus Competence Network in the Baltic and Nordic Regions

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***Abstract*—This paper outlines the creation of a multi-disciplinary NordPlus competence network aimed at integrating the best teaching-oriented, technology-driven engineering education practices to support the green transition in the Baltic and Nordic regions. The network focuses on a comprehensive initiative to integrate electrical engineering and automation, mechatronics, information and communication technologies (ICT), informatics engineering, and cybersecurity, tailored to meet the evolving needs of the green industry. Methodologically, this interdisciplinary collaboration across the Baltic and Nordic regions addresses the specific challenges within these areas, such as optimizing energy efficiency, enhancing sustainable manufacturing processes, securing green technology from cyber threats, and innovating in smart infrastructure development. The outcomes of the NordPlus network's initiatives are instrumental in cultivating engineers equipped with not only technical knowledge and skills but also a profound dedication to sustainability principles. This preparation ensures they are more than ready to tackle the complex challenges associated with transitioning towards a sustainable future.**

I. Introduction

The European Green Deal initiates tasks to make the European Union's economy sustainable and climate-neutral by 2050 [1]. It has the potential to significantly impact and align closely with emerging educational concepts, including the necessary skills for students' future success as well as the content and focus of educational programs. This means that the future of emerging education needs to play a key role in promoting sustainable development [2]. This creates a strong demand for engineers with skills and knowledge in areas such as renewable energy, sustainable automation, sustainable computing and communications, *etc*. Emerging education also underscores the necessity of equipping students with essential skills for thriving in the digital era [3], such as digital literacy, problem-solving, critical thinking, and creativity, which are at the top of the priorities in the green industry.

Emerging education in the fields of electrical engineering, informatics engineering, ICT, and cybersecurity is crucial for addressing the challenges of the Green Deal initiated by the European Commission. The development of new technologies and systems for transitioning to a green industry requires the preparation of the next generation of professionals and leaders with the knowledge, skills, and values needed to address the complex challenges of sustainable development [4]. Emerging education can help to raise awareness and understanding of the environmental, social, and economic challenges facing society and the role that different sectors and stakeholders can play in addressing these challenges. This can be done by incorporating emerging technologies and sustainable development topics and issues into the Higher Education study programs' contents [5]. Consequently, efforts should be concentrated on integrating sustainability-focused insights into the curricula of partner institutions. This facilitates the sharing of experiences, knowledge, and best practices in teaching-oriented, technology-driven education that meets the green industry's needs. The growth of competencies designed to meet the industry's demands in the Baltic and Nordic regions is anticipated. The focus is on developing a technology-driven, multi-disciplinary competence network across the Baltic and Nordic regions.

To reach this goal, the ENERGYCOM network was established. It aims to create a network of competencies from partner institutions for sharing experience, knowledge, best teaching-oriented technology-driven education practices, and achievements in their curricula that correspond to the needs of the green industry. The collaboration among technical

universities in the Baltic—Riga Technical University (RTU), Kaunas University of Technology (KTU), Tallinn University of Technology (TalTech)—and the Nordic region, including Tampere University (TUNI) and Aalto University (partner since 2024), will facilitate the preparation of highly qualified professionals for the green industry. This will be achieved by developing high-tech solutions that leverage scientific knowledge, complex structural, functional, and decision-making expertise, and by fostering social and emotional learning. The latter emphasizes the cultivation of student-oriented personal values, environmental awareness, and responsibility.

Currently, ongoing network activities emphasize the increased utilization of technology-enabled learning, providing students with access to cutting-edge tools and resources. This entails leveraging digital platforms such as online resources, learning management systems, interactive multimedia, and collaboration tools to deliver instructional content. Moreover, there is a heightened focus on hands-on project-based learning and joint workshops, allowing students to apply theoretical knowledge in practical, real-world settings. This approach not only enhances their technical skills but also cultivates crucial soft skills such as communication and teamwork, preparing them for the dynamic and collaborative nature of modern workplaces.

The aim of this paper is addressed through student and academic teacher mobility programs, encompassing mentoring sessions for students to learn from the experience, knowledge, and practical skills of academic staff. It involves the adoption of new teaching methods, including online learning, and the organization of practical seminars and workshops aimed at enhancing students' skills. The research questions can be summarized as follows:

1) What are ENERGYCOM's attempts to develop the creative potential within the Baltic and Nordic regions while emphasizing sustainable development?
2) How can ENERGYCOM effectively showcase and promote the talents, excellence, entrepreneurship, and accomplishments of individuals from the Baltic and Nordic regions?
3) How can ENERGYCOM empower young people to take creative initiatives and cultivate a strong sense of belonging to Latvia, Lithuania, Estonia, and Finland?

II. Network Strategy

The NordPlus ENERGYCOM network's strategy started with initiatives on engineering education and advances in information, automation, and electrical engineering [6] [7] and evolved into a comprehensive multidisciplinary approach designed to support the European Green Deal's objectives for sustainable development in the green industry (Fig. 1). It focuses on preparing future leaders in key fields such as electrical engineering and automation, mechatronics, adaptronics, information and communication technologies, informatics engineering, and cybersecurity. The goal is to develop professionals equipped with the necessary knowledge, skills, and values to tackle sustainable development challenges.

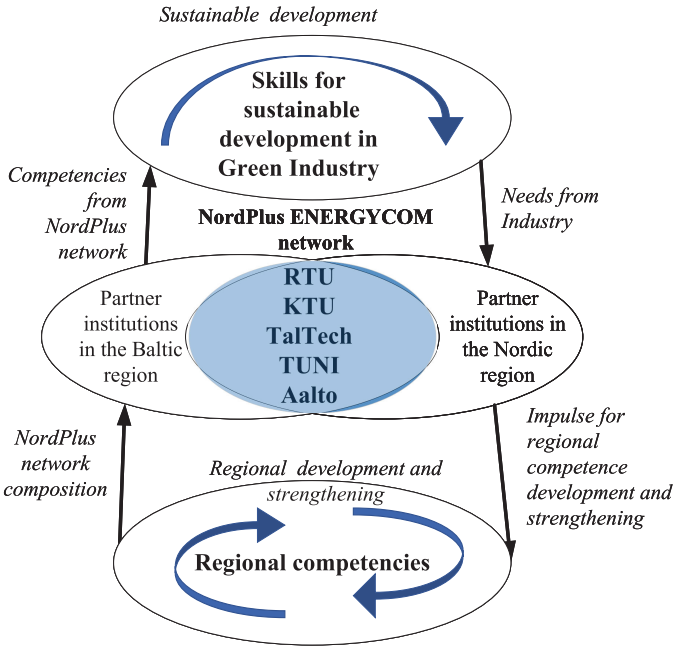

Fig. 1. NordPlus competence network

RTU focuses in the development and implementation of renewable energy systems, automation and adaptronics. By designing efficient power generation, transmission, and distribution systems, they enable the integration of solar, wind, hydro, and other renewable energy sources into the grid. This reduces dependence on fossil fuels, decreases greenhouse gas emissions, and supports the establishment of a sustainable energy infrastructure. Strengthening the Latvia regional competencies and upgrading study program curricula by including advanced topics in renewable energy technologies, smart grids, and energy storage solutions prepares graduates to innovate in these critical areas.

Informatics engineers are at the forefront of creating sustainable computing solutions that reduce the environmental impact of information technology. This includes developing algorithms and systems for energy-efficient computing, designing software that optimizes resource use, and contributing to the circular economy through the improvement of recycling and waste management systems. Through the use of sensors, IoT devices, and data analytics, ICT professionals can provide critical data for climate research, wildlife conservation, and sustainable agriculture. They also develop systems that enable smarter energy use in buildings, reduce water wastage, and improve overall resource efficiency. Integrating subjects such as environmental informatics and smart city technologies into ICT curricula empowers students to contribute to sustainable urban development.

As industries adopt more interconnected and automated processes to become sustainable, the need for robust cybersecurity measures increases. Cybersecurity professionals ensure that renewable energy systems, environmental monitoring networks, and other sustainable technologies are protected from cyber

threats. This involves securing data communication in smart grids, safeguarding privacy in environmental data collection, and preventing attacks that could disrupt critical infrastructure. Advanced cybersecurity education that includes a focus on securing IoT devices and critical infrastructure is essential for maintaining the integrity of sustainable systems. KTU and TUNI education in this field is evolving to emphasize sustainable ICT, software and cybersecurity engineering practices and the development of applications that promote environmental sustainability.

Mechanical engineering, with its strong foundation in designing and optimizing mechanical systems, contributes to the network strategy by developing more efficient and sustainable manufacturing processes, energy systems, and materials. Mechanical engineers can design systems that reduce energy consumption, improve the efficiency of renewable energy sources, and create innovative solutions for reducing the carbon footprint of industrial processes. Mechatronics, which combines mechanical engineering, electronics, computer science, and control engineering, plays role in developing smart, automated systems that are essential for the green industry. These systems can monitor and control energy use, optimize manufacturing processes, and ensure the reliability and security of renewable energy sources. By integrating sensors, actuators, and intelligent control systems, mechatronics can create highly efficient and adaptable systems that support sustainable development goals. TalTech and Alto provide and constantly develope these critical skills and capabilities for Baltic and Nordic regions, ensuring that graduates are well-prepared to meet the challenges and opportunities of sustainable industrial development.

ENERGYCOM can effectively showcase and promote the talents, excellence, entrepreneurship, and accomplishments of individuals from the Baltic and Nordic regions through its comprehensive strategy. Organization of events, such as workshops and webinars, that bring together entrepreneurs and experts from the Baltic and Nordic regions, serve as platforms for networking and knowledge sharing, and highlight successful case studies. Collaboration between ENERGYCOM universities and research institutions in the Baltic and Nordic regions helps to identify and promote emerging talents and innovative research projects. This could include mentoring student projects, offering internships, or supporting research initiatives that align with ENERGYCOM's objectives.

By providing educational support to youth-led projects, ENERGYCOM can help young people bring their innovative ideas to life. This approach fosters a sense of ownership and responsibility among the youth, encouraging them to engage more deeply with their communities and the wider Baltic Sea region. ENERGYCOM creates a shared sense of identity and belonging by facilitating collaboration between young people from Latvia, Lithuania, Estonia, and Finland. This can be achieved through joint learning activities, exchanges, and collaborative events that highlight the cultural, environmental, and social ties between these countries.

III. Activities within the Network

The cooperation between partners from Lithuania, KTU and Estonia, TalTech started with teaching activities within the study subject "Cyber Physical Systems and It Security", which was created at KTU in 2021. The curriculum on this study subject underpins the pivotal role of cybersecurity, data processing, the design of systems by selected hardware and software in cyber and physical environments, and the safeguarding of cyber and physical domains in propelling forward the agenda of sustainable development, energy efficiency, and the fortification of green technologies. The main aim of this subject is to impart comprehensive knowledge and develop competencies in the creation, operation, application, and security of cyber-physical systems. This includes a strong focus on the principles of data processing and transmission, computer networks, communications, and cybersecurity, ensuring the secure integration and functioning of these systems within both cyber and physical domains.

The teaching methods in this study subject aim to create an environment that supports inquiry-based learning [8] by combining theoretical and practical approaches (Fig. 2). The

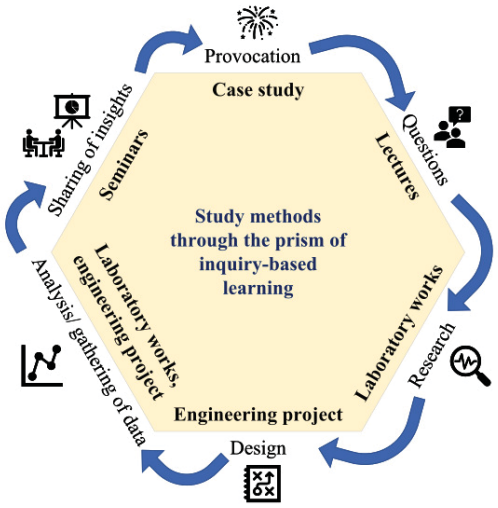

Fig. 2. Study methods in the study subject "Cyber Physical Systems and It Security")

lifecycle of inquiry-based learning unfolds through a series of stages designed to engage students deeply with the subject matter [9]. This process begins with a provocative case study that sparks curiosity, i.e., the need to build a cyber-physical system that helps to manage household waste. The management should include monitoring the filling of waste containers, forecasting when the containers will be full, creating an optimal schedule for the removal of waste from containers, planning the optimal travel route for the waste company's truck to take the waste from citizens, *etc*. Students then embark on a journey of exploration, gathering and analyzing information to form hypotheses. Lectures offer fundamental understanding, whereas seminars encourage detailed discussions and analytical thinking on such topics or even more complicated

ones. The cycle moves towards analyzing findings and synthesizing knowledge, culminating in a phase where students reflect on their learning journey, evaluating their processes and outcomes. Practical assignments and projects are crucial because they engage students in hands-on experiences that replicate situations in the real world. Such teaching method promote students' self-directed inquiry, hypothesis testing, and application of theoretical concepts to practical scenarios. It helps develop crucial skills like analytical thinking, problem-solving, and innovation, which are vital for the field of cyber-physical systems that is part of the green industry today. This study subject uses various teaching approaches to provide technical knowledge and promote inquiry-based learning, preparing students for the changing field of cybersecurity and technology.

A. Digital Twin Workshops at KTU

The initiative of this workshop aimed to introduce digital twin (DT) technology, a key element in Industry 4.0 [10]. Starting with "Getting Started with Digital Twins" in 2022 and evolving into "Hands-On Digital Twins" in 2023, each workshop was designed to merge theoretical knowledge with practical application, facilitating a rich knowledge transfer to students (Fig. 3).

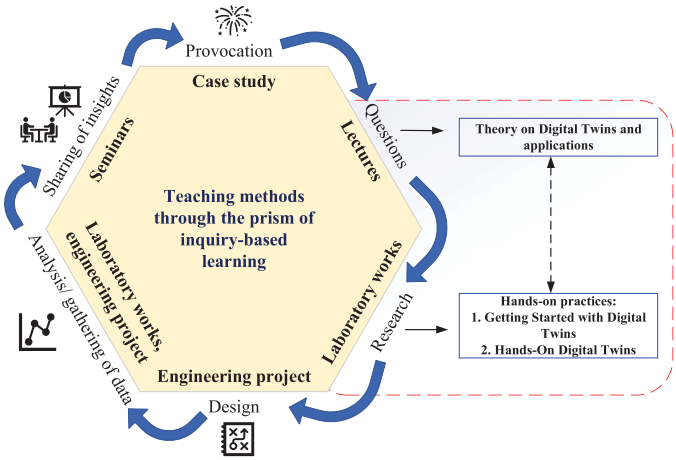

Fig. 3. TalTech teaching activities through the learning process)

The curriculum guided participants through the essential concepts and development stages of DTs. Utilizing tools like Arduino and MATLAB/Simulink, the workshops offered a dynamic environment for students to engage in the creation of DT models, from basic to advanced levels (Fig. 4). The summary of activities during those workshops was as follows:

1) Real-Time Data Acquisition System: Students set up a system using Arduino, Simulink, and variable resistance, learning the fundamentals of real-time data acquisition. This exercise equipped students with the ability to capture and process data from physical sensors, a crucial skill for developing responsive DTs.
2) Driving a Physical LED Model Through Its Digital Counterpart: By creating a DT of an LED and learning to control the physical LED through its digital counterpart in Simulink, students experienced firsthand the direct interaction between DTs and their physical entities. This exercise showcased the potential for remote control and monitoring, enhancing students' understanding of DT applications.
3) Building a Smart Lighting System: Advancing the concept of DTs, this project involved incorporating sensors and control logic to develop a smart lighting system. Students learned to integrate ambient light sensing with digital control, enabling automated lighting adjustments based on environmental conditions. This project demonstrated the application of DTs in smart home technologies, fostering students' innovation in creating energy-efficient systems.
4) Real-Time Smart Heat Sensing System: Participants developed a system capable of sensing temperature changes and responding in real-time. This example allowed students to explore the applications of DTs in environmental monitoring and management, emphasizing the importance of real-time data in operational efficiency and safety.
5) Data-Driven Modeling of cyber-physical system with uncertain parameters: In this advanced module, students tackled the challenge of modeling systems with inherent uncertainties using data-driven approaches. This exercise highlighted the complexities of cyber-physical systems and the role of data in enhancing the accuracy and reliability of DTs, equipping students with the skills to predict and manage system behavior effectively.

Fig. 4. KTU students at workshop "getting started with Digital Twins"

B. Flexible assessment methodology

The study subject "cyber-physical systems and it security" is designed in such a way that it leverages the principles of flexible assessment pathways, thereby enhancing learning inclusivity and adaptability. This approach came from the cooperation between the ENERGYCOM network partnership. It employs a diversified array of assessment methods, including computer-based examinations for theoretical understanding, oral presentations of engineering projects for practical application, and laboratory work defenses for hands-on skill demonstration (Fig. 5).

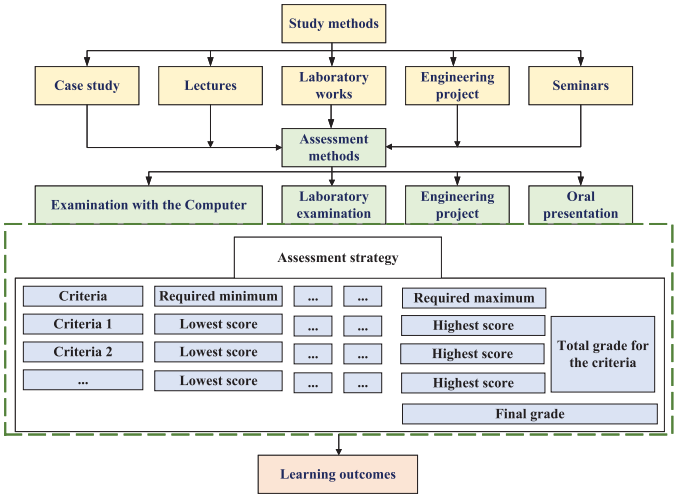

Fig. 5. Strategy for the assessment of students' skills

The assessment of students' knowledge and skills is carried out in accordance with the assessment criteria and the assessment rubrics [11] provided for each of the assessment methods (Table I). The flexibility of such an assessment strategy lies in the students' free choice for the expected results of learning the subject. Each student's activity during the semester is evaluated, and assessment criteria are used for the evaluation. Each criterion has a grading scale from the lowest score to the maximum score, indicating what the grade will be written for. In this way, the student can evaluate their own ambitions and measure how much effort they will have to put in to achieve them.

For example, different assessment criteria were used for the assessment of students' learning during DT workshops and their knowledge about digital twins in the three categories:

- paper report: 30% of the final grade
- defense using the test in the Moodle: 50% of the final grade
- oral defense: 20% of the final grade.

In this case, if a student is not aiming for the maximum grade, they can choose to put less effort into one of the following assessment categories or not at all. However, the final grade still needs to be positive, i.e., at least 5 (this is the lowest positive grade in the Kaunas University of Technology grading system).

This multifaceted approach enables students to engage with the material in various ways, catering to different learning preferences and strengths. By offering choices in how knowledge and skills are demonstrated, the strategy supports a more personalized learning experience, ensuring that assessments are not only about evaluating student performance but also about facilitating deeper engagement with the subject matter.

TABLE I. ASSESSMENT STRATEGY FOR STUDENT ACHIEVEMENTS

Assessment form	Assessment criteria
Oral presentation	•Structure of the presentation (clarity of the logical sequence, adherence to the sequence during the presentation). •Introduction (clarity of the purpose and objectives of the report). •Content delivery and its depth, adherence to delivery time. •Conclusions (summary of the presented topics and main points or recommendations). •Answers to questions. •Quality of presentation preparation (volume of the presented text, whether the text is legible, clarity of graphics, absence of grammatical and stylistic errors). •Language use (language is clear, correct, jargon is not used, professional language is used).
Engineering project	• Completeness of the description of the concept of concrete cyber physical system. • Compliance with the technical requirements. • Selection of system components, hardware and parameters required for system operation. • Preparation of technical documentation. • Quality of the task realization. • Quality of project's report preparation and compliance with general report preparation requirements. • Formulation and justification of conclusions. • Reliability of results. • Quality of task analysis.
Laboratory examination	• Analysis of the obtained results and comparison with the theoretical material. • Quality of the work report and compliance with the general reporting requirements. • Presentation of the graphical results (figures, tables, diagrams, etc.). • Formulation and justification of conclusions. • Reliability of results.
Examination with the Computer	• Accuracy of answers to the tasks and questions provided during the exam. • Quality of answers (completeness of answers, ability to adapt and demonstrate methods, techniques, etc. examples). • Proper use of engineering terms.

C. Feedback Collection and Analysis

The quality assessment of the study subject "Cyber-Physical Systems and it Security" was done through the analysis of the students' feedback. This feedback is collected in the centralized intra-system of KTU, where students are asked to answer the questions in a survey and provide their open minds about the study subject quality (teaching methods, assessment methods, learning materials, technologies, lab environment, *etc.*). The numerical statistics on the initial data for the feedback collection are as follows:

- students' feedback is collected since 2021;
- 17 students provided their feedback in 2021: total activity of the students in participation of the survey was 59,72% and the reliability of their feedback is 0,83;
- 19 students provided their feedback in 2022: total activity of the students in participation of the survey was 60,53% and the reliability of their feedback is 0,89;
- 21 student provided their feedback in 2023: total activity of the students in participation of the survey was 100% and the reliability of their feedback is 1,00.

The overall results of the study subject's "Cyber-Physical Systems and it Security" survey clearly show very favorable student attitudes and experiences during the study subject (Fig. 6). The explanation of the scoring in the survey is

provided in Table II. The results show students' positive

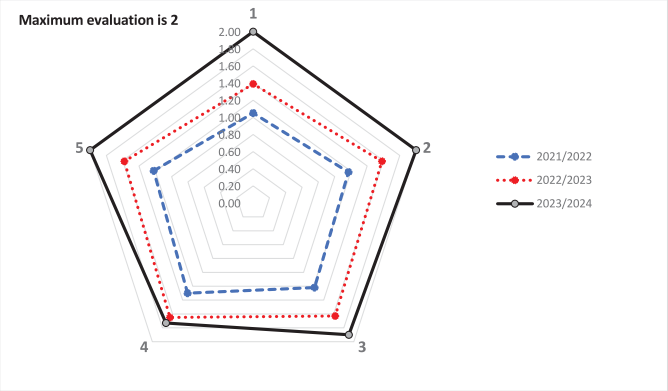

Fig. 6. Overall assessment of the study subject since 2021)

perceptions of the lecturers' performance and the concept of sustainability and indicate that students' motivation and involvement in the learning process are high.

TABLE II. SCORING SYSTEM IN THE SURVEY

Score	Description
1	I am satisfied with this study module
2	The module materials and learning resources are engaging and have contributed to the achievement of the module objectives, outcomes and competences
3	The module uses advanced teaching/learning methods (at least one of the following: problem-based learning, case method, project-based activities, creative tasks, group work, *etc*.)
4	The evaluation criteria and procedures were clear from the start
5	Moodle or other virtual learning environments (hosted learning materials, resources, assignments, *etc*.)

The feedback in their answers suggests that lecturers have been able to encourage lively communication and active flexibility among students, and that students appreciate their efforts and commitment in developing sustainability awareness. This indicates that the study subject has effectively met the students' expectations and demonstrated efforts of the lecturers to create a supportive learning environment. The results on the subject's survey clearly provided positive developments, especially in terms of additional competencies acquired and attracting teachers from other institutions. These factors are important to enhance the learning experience and prepare students for success in an environment outside the university classroom. A few aspects and highlights on the positive changes in the study subject since ENERGYCOM collaboration in it:

- Additional competences acquired: students have been provided with additional opportunities to acquire and develop a range of competences that not only help them to bridge learning gaps but also provide them with a stronger preparation for a successful career.
- Bringing in faculty from other institutions: positive exposure to faculty from other institutions allows students to gain a variety of perspectives and experiences from a wide range of professionals and specialists. They can share their experiences, provide insights, and help students develop a broader perspective on their field of study.
- Positive change: these changes not only help students to deepen their knowledge and acquire new skills, but also foster their personal development, self-confidence, and understanding of the world. These elements are crucial for their future career success.

IV. CONCLUSION

The development of the NordPlus Competence Network represents a pivotal advancement in engineering education within the Baltic and Nordic regions, specifically tailored to address the urgent demands of the green transition. This initiative has successfully fostered multidisciplinary collaboration, integrating key technological and engineering disciplines to enhance educational practices and research towards sustainable development.

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REFERENCES

[1] E. Commission, "The European Green Deal," 2019. [Online]. Available: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

[2] S. Zotti, "Emerging Education and the European Green Deal: Strengthening Sustainability Education in the EU," *International Journal of Contemporary Education*, vol. 5, no. 2, pp. 1–6, 2022.

[3] OECD, *Innovating Education and Educating for Innovation: The Power of Digital Technologies and Skills*. Paris: OECD Publishing, 2016. [Online]. Available: http://dx.doi.org/10.1787/9789264265097-en

[4] M. Tarrant, S. Schweinsberg, A. Landon, S. L. Wearing, M. McDonald, and D. Rubin, "Exploring student engagement in sustainability education and study abroad," *Sustainability*, vol. 13, no. 22, 2021. [Online]. Available: https://www.mdpi.com/2071-1050/13/22/12658

[5] C. Mader and C. Rammel, "Transforming higher education for sustainable development," *Leuphana University of Lüneburg, Germany and University of Zurich, Switzerland and Vienna University of Economics and Business, Austria*, 2017.

[6] N. Kunicina, "Engineering education and advances in information, automation and electrical engineering," in *2020 IEEE 8th Workshop on Advances in Information, Electronic and Electrical Engineering (AIEEE)*. IEEE, 2021, pp. 1–6.

[7] N. Kunicina, A. Rassõlkin, R. Bruzgiene, and D. Plonis, "Nordplus network in advanced computer-oriented engineering technologies and adaptronics," in *2022 IEEE 63th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON)*. IEEE, 2022, pp. 1–6.

[8] R. Bruzgiene, L. Narbutaite, T. Adomkus, J. Pauliute, and N. Kunicina, "Inquiry-based learning focused on inclusive education in programming of robots: Challenges, experience, and feedback of first cycle students," in *Inclusive Digital Education*. Springer, 2022, pp. 71–95.

[9] T. Eppes, I. Milanovic, and K. Wright, "Improving student readiness for inquiry-based learning: An engineering case study," 2020.

[10] M. Hazrat, N. Hassan, A. A. Chowdhury, M. Rasul, and B. A. Taylor, "Developing a skilled workforce for future industry demand: The potential of digital twin-based teaching and learning practices in engineering education," *Sustainability*, vol. 15, no. 23, p. 16433, 2023.

[11] G. Reynders, J. Lantz, S. M. Ruder, C. L. Stanford, and R. S. Cole, "Rubrics to assess critical thinking and information processing in undergraduate stem courses," *International Journal of STEM Education*, vol. 7, pp. 1–15, 2020.