FuturEng

Deliverable R4: FuturENG Knowledge Triangle Cooperation Methodology

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1.1 Why cooperation between education, research and industry matters

Current education systems, largely based on 20th-century models, are increasingly inadequate in preparing engineering graduates for rapidly evolving workplace demands. The labour market increasingly calls for competences related to digital transformation, sustainability and transversal skills, such as creativity, communication, systems thinking and ethical reasoning. These cannot be acquired through traditional lectures and examinations alone. They come from engaging with real problems, cross-disciplinary work and industry exposure.

This means that university and VET curricula need to translate these demands into practice. Education institutions need to be closer to industry, closer to the labour market. Higher education institutions, research organisations and industry each contribute unique knowledge, perspectives and resources, yet their efforts frequently remain fragmented.

The Knowledge Triangle offers a framework for addressing this challenge by connecting education, research and innovation. In the FuturENG methodology, this is operationalised through structured collaboration among education institutions, research organisations and industry partners. Cooperation among these three partner groups can help address this disconnect, and this is the premise on which the FuturENG project was built. By integrating all three partner groups into the partnership, the project was better positioned to fulfil its purpose: responding to the needs of engineering education, in line with Industry 5.0 demands.

This methodology builds on the experience of the FuturENG project and translates that experience into a practical framework that other organisations can adopt and adapt.

The document explains why Knowledge Triangle cooperation matters, then presents lessons learned from its implementation in FuturENG, before outlining how such cooperation can be managed, applied, supported through practical tools, evaluated, and sustained over time.

Combining lessons learned, practical tools, cooperation models and evaluation approaches, it provides guidance for establishing, managing and sustaining Knowledge Triangle partnerships that support Industry 5.0-oriented engineering education. It is intended for higher education institutions, vocational education providers, research organisations, businesses and other stakeholders seeking to develop more effective and future-oriented forms of collaboration.

1.2 What is the Knowledge Triangle?

The Knowledge Triangle refers to the systematic interaction between education, research and innovation. The concept was formalised by the European Institute of Innovation and Technology (EIT) in 2006 (European Commission, 2006) and remains central to EU education policy.

This concept emphasises a systematic and integrated approach to the interlinkage of education, research and innovation. It is closely related to concepts such as third mission, entrepreneurial university and triple helix, each emphasising different actors and dimensions of this same interaction (Unger & Polt, 2017).

Its core principle is that connecting education, research and innovation creates added value. By working together, these sectors ensure that knowledge stays aligned with current and future societal and economic needs (Unger & Polt, 2017). The Knowledge Triangle expands the impact of these three activities through systematic and continuous interaction.

More recently, the concept has expanded to include a broader set of contributors. The Triple Helix model, for example, highlights the interaction between academia, industry, and government (Etzkowitz & Leydesdorff, 2000). This has been further extended to the Quadruple Helix, which includes civil society (Carayannis & Campbell, 2009), and the Quintuple Helix, which also incorporates the environment (Carayannis & Campbell, 2010).

1.3 The Three Actors and Their Roles

For the purposes of this methodology, the Knowledge Triangle is implemented through three key partner groups:

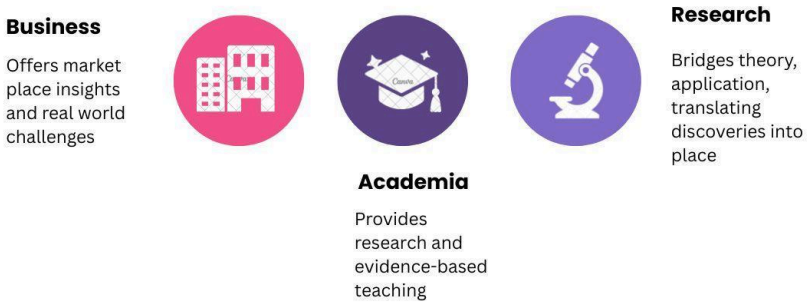


Figure 1 – Knowledge Triangle

These three partner groups have distinct but complementary roles:

- **Education institutions (HEI, VETs)** contribute academic rigour, teaching capacity, and learning environment design. They bring access to student populations and the capacity to embed industry insights into formal curricula, translating one-off industry guest lectures into coherent, credit-bearing learning experiences. They provide inputs for each of the corners of the KT and often incorporate the KT principles into internal organisation and missions (Unger & Polt, 2017).

- **Industry and business partners** ensure industry participation in curriculum design. Employers communicate emerging skills gaps, technological shifts (particularly in digital and green domains), and hiring expectations, so educational provision reflects actual workplace needs. Industry partners also provide internship pathways, mentorship opportunities, and access to real-world challenges.
- **Research organisations** translate emerging technological developments into teaching materials and practical methods**.**

Effective collaboration requires clear structures, shared goals, and accountability. That is what the document aims to convey.

Why this matters: effective Knowledge Triangle cooperation requires clear structures, shared goals, and accountability.

Understanding the principles of the Knowledge Triangle is only the first step. The FuturENG project offers a concrete example of how these actors can work together to co-create educational resources, align engineering education with Industry 5.0 needs, and generate value for all stakeholders. The following chapter presents this experience, highlighting both the achievements and the lessons learned that informed the methodology proposed in this guide

2. Showcasing the FuturENG Knowledge Triangle Cooperation: Lessons Learned

2.1 From a triangle on paper to a triangle in action

FuturENG was designed around a simple but demanding principle: engineering education cannot keep pace with Industry 5.0 if universities, businesses and research organisations work in isolation. The consortium therefore did not treat the Knowledge Triangle as an abstract model. It turned the triangle into a working cooperation structure in which knowledge moved continuously between education, research and industry.

The partnership brought together three engineering-oriented higher education institutions, a technological research and training organisation, an engineering consultancy, an education and training provider, and a foundation working at the interface between education and business. This composition ensured that the development of the FuturENG resources was informed simultaneously by academic standards, emerging technologies, labour-market realities and innovative teaching practice.

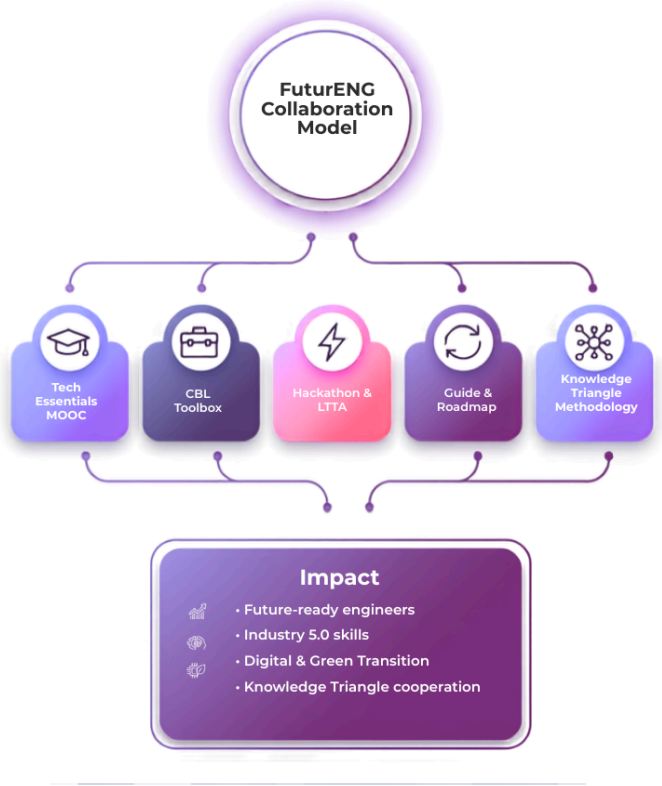
Each partner contributed a distinct part of the picture:

- **George Emil Palade University of Medicine, Pharmacy, Science, and Technology of Târgu Mureș (UMFST), Kaunas University of Technology (KTU)** and **FH Joanneum University of Applied Science**, brought academic expertise, access to STEM students and experience in integrating new content into higher education.
- **ISQ (VET provider and research institute)** contributed research, technological expertise and access to advanced engineering laboratories.
- **MECB Ltd**. as an engineering company introduced the perspective of engineering businesses, industrial practice and the skills expected from future technical professionals.
- **EDITC Education and Information Technology Centre (a VET provider)** contributed digital learning, training-platform and educator-development expertise.
- **Acta Foundation (NGO)** supported challenge-based learning, WebQuest development and the integration of social, ethical and environmental dimensions into technology education.

The strength of this model was not simply the diversity of the organisations involved. Its real value came from the way their expertise was connected through joint development, testing, mentoring, evaluation and reflection.

FuturENG showed that Knowledge Triangle cooperation becomes real when knowledge moves **from research into learning, from industry into challenges, and from students back into the design of education.**

The project's implementation experience—including pilot testing, the digital hackathon, the LTTA at ISQ and the associated co-creation activities—provides practical lessons for other institutions seeking to establish similar partnerships.



2.2 Best Practices & Cooperation Enablers

2.2.1 Cooperation Foundations: Build the relationship before building the result

A shared mission created common direction

The partners entered FuturENG with different institutional priorities. Universities focused on educational quality and student learning; business-oriented organisations were concerned with applicability and labour-market relevance; research partners brought attention to technological advancement and scientific credibility.

These perspectives did not always translated into the same language, but they were connected by a common ambition: to prepare engineering students for the digital and green transitions and for the human-centred, sustainable and resilient logic of Industry 5.0.

This shared mission provided a reference point whenever partners needed to resolve differences in approach. Decisions could be assessed against a common question:

- *Will this make the learning experience more relevant and useful for future engineers?*

A shared purpose does not eliminate disagreement. It makes disagreement productive by giving partners a common basis for choosing between alternatives.

Pre-existing relationships accelerated trust

Partners identified the value of building on relationships developed through previous cooperation. Where organisations already understood one another's working styles, decision-making was faster, communication was more open and emerging problems could be discussed without unnecessary formality.

However, the FuturENG experience also showed that previous cooperation should be treated as a starting advantage, not as a substitute for governance. Trust made collaboration easier, but clear responsibilities, deadlines and quality procedures were still necessary.

Good practice: Build on trusted relationships where possible, but document roles and expectations as though the partners were working together for the first time.

A long-term mindset changed the quality of participation

The cooperation was strongest when partners viewed the project not as a collection of contractual tasks, but as an opportunity to create resources, relationships and models that could continue after the funding period.

This long-term perspective encouraged partners to think beyond immediate deliverables and consider:

- how the MOOC and Toolbox could be reused;
- how educators could apply the resources in different curricula;
- how collaboration with businesses and research organisations could continue;
- and how the methodology could be transferred to other institutions and countries.

The lesson is clear: short-term projects produce stronger results when partners enter them with long-term intentions.

Continuous engagement kept the triangle connected

Knowledge Triangle cooperation weakens when interaction is concentrated around formal meetings or reporting deadlines. FuturENG benefited from continuous contact through online meetings, collaborative documents, peer review, technical exchanges and informal problem-solving.

Regular communication enabled the partnership to:

- detect delays and misunderstandings early;

- compare national implementation experiences;
- adapt resources in response to feedback;
- and maintain a common understanding of project priorities.

The partnership focus group confirmed that continuous dialogue, regular check-ins, feedback loops and informal professional networks were among the most important conditions for effective cooperation.

Lesson for replication: Cooperation should be designed as a rhythm, not as a sequence of isolated events.

2.2.2 Governance and Collaboration: Complementarity by design

The consortium was built as a working Knowledge Triangle. One of FuturENG's most important good practices was the deliberate balance of organisational profiles. The consortium did not consist only of universities with external businesses invited to comment at the end. Business, research, education and civil-society perspectives were represented within the working partnership itself.

This allowed each project result to be examined through several lenses:

- Is the content academically sound?
- Does it reflect current and emerging technologies?
- Is it relevant to the workplace?
- Can it be taught effectively?
- Is it accessible and engaging for students?
- Does it address the human, ethical and environmental implications of technology?

The result was not a linear process in which one partner developed a product, and another validated it. It was a co-development cycle, with partners contributing different types of knowledge at different stages.

Clear roles turned diversity into complementarity

A diverse partnership can become fragmented when responsibilities overlap or remain unclear. FuturENG reduced this risk by assigning tasks according to institutional expertise.

The universities provided technical and pedagogical content, organised student pilots and assessed applicability in real academic environments. ISQ connected the project to research infrastructure and practical engineering environments. MECB brought industrial and consultancy perspectives. EDITC supported the digital learning environment and educator-oriented

resources. Acta contributed expertise in challenge-based learning, WebQuests, stakeholder engagement and the broader societal implications of technological change.

This distribution allowed partners to contribute where they offered the greatest added value.

Good practice: Do not aim for identical participation by all organisations. Aim for balanced ownership based on complementary strengths.

Partners highlighted flexibility as an important enabling factor. Implementation across different universities and countries required space for adaptation. Local academic calendars, student profiles and teaching practices could not always be treated identically.

FuturENG therefore combined a common methodological backbone with local implementation flexibility. The same resources and overall evaluation logic were used, while the universities adapted facilitation and delivery to their institutional environments.

The principle was simple: standardise the purpose and quality criteria but allow flexibility in the route taken to achieve them.

Cooperation becomes stronger when its value is visible

A recurring lesson from FuturENG was that stakeholders participate more meaningfully when they understand what they will gain and what is expected from them.

The value proposition was different for each partner group:

- **Universities** gained tested learning resources and new teaching approaches.
- **Educators** gained support for integrating Industry 5.0 and challenge-based learning.
- **Students** gained knowledge, international exposure and opportunities to work on real-life challenges.
- **Businesses** gained a route for communicating emerging skills needs and engaging with future talent.
- **Research organisations** gained opportunities to translate technological knowledge into educational practice.
- **Training** and intermediary organisations strengthened their capacity to connect formal education with labour-market needs.

Making these motivations explicit helped move stakeholders from attendance to ownership.

Students were co-creators, not only beneficiaries

One of the strongest aspects of FuturENG was the role given to students. They did not simply complete the MOOC and Toolbox as end users. They also:

- evaluated their clarity and relevance;
- tested the WebQuest and CBL approach;
- developed technology-based solutions;
- presented their ideas to an international jury;
- participated in practical laboratory activities;
- reflected on their experience;
- and proposed improvements to project resources.

During the initial pilot phase, 114 students from UMFST, KTU and FH Joanneum tested the Tech Essentials MOOC and CBL Toolbox in real higher education settings. Their feedback helped validate the usability, pedagogical relevance and interdisciplinary focus of the resources. Students particularly valued the connection between theory and real-world applications.

This was an important shift in perspective: students were treated as sources of evidence and innovation, not simply as recipients of educational content.

Faculty facilitation made innovation usable

The pilots also showed that well-designed resources do not implement themselves. University lecturers and project facilitators played a critical role in introducing the activities, supporting students and contextualising complex content.

The CBL approach was most effective when educators:

- clarified expectations;
- helped teams define manageable problems;
- connected technical topics with course content;
- encouraged reflection;
- and provided support without taking ownership away from students.

This demonstrated the importance of educator preparation. Innovative pedagogy requires not only resources, but also confidence and capacity among those applying them.

Student voices were connected to project decisions

The Needs Analysis Workshop held during the LTTA created a direct bridge between student experience and project development. Students and partners jointly reflected on the MOOC and Toolbox through individual feedback, thematic discussions and a World Café-style co-creation process.

The workshop did more than collect opinions. It turned feedback into actionable ideas for resource improvement and ensured that pedagogical decisions reflected the learner experience.

Good practice: Build feedback into the design cycle. Do not ask for feedback only after a result is final.

2.2.3 Practical and Collaborative Activities: Where the triangle came alive

The strongest cooperation did not happen when partners discussed the Knowledge Triangle. It happened when they did something together.

The pilot phase: one framework, three real learning environments

The MOOC and CBL Toolbox were tested across three universities and with students from diverse academic backgrounds. A shared Moodle environment provided a common delivery structure, while university facilitators adapted the implementation to local programmes and learner profiles.

This created a valuable balance between comparability and contextual relevance. Partners could compare feedback across institutions without expecting each pilot to be identical.

The pilot demonstrated a replicable model:

- Develop a common resource.
- Apply it in different institutional environments.
- Gather comparable quantitative and qualitative feedback.
- Discuss differences across contexts.
- Refine the resource collectively.

The digital hackathon: cooperation under creative pressure

The FuturENG Digital Hackathon, AI & Deep Tech for a Better Future, brought together 45 students from Romania, Lithuania and Austria. Working in small teams, they developed and pitched solutions under three challenge areas:

- AI and Deep Tech for Sustainability;
- Deep Tech for Social Good;
- Twin Transition: Digital and Green.

The hackathon connected every part of the Knowledge Triangle:

- **educators** prepared and supported students;
- **technology and research experts** introduced emerging themes;
- **business-oriented partners** considered feasibility and relevance;

- **students** transformed knowledge into solution concepts;
- and a **cross-partner jury** evaluated the results through shared criteria.

The winning ideas illustrated the breadth of innovation generated by this approach:

- **Face the Crash**, using virtual reality and simulated physical feedback to support the re-education of people involved in alcohol-related road accidents;
- an AI-enabled approach to globally adaptable healthcare data;
- and **OpenDyslexic**, a browser extension supporting learners with dyslexia.

These solutions combined technology with social purpose, accessibility, healthcare and responsible innovation. They demonstrated that future engineers need more than technical competence: they must be able to consider users, ethics, sustainability and societal impact.

Why it worked: The hackathon combined a clear challenge, limited time, team responsibility, mentoring, visible evaluation criteria and a meaningful incentive.

What future projects should retain: A hackathon should not be treated as a standalone competition. It should be connected to prior learning, followed by feedback, and linked to further development opportunities.

The Learning, Teaching and Training Activity at ISQ took the cooperation from the screen into an advanced technological environment.

Six hackathon-winning students joined a five-day programme in Portugal that included:

- metrology;
- non-destructive testing;
- electricity;
- additive manufacturing;
- virtual welding;
- technological physics;
- Design Thinking for Engineers;
- team challenges;
- and intercultural collaboration.

Students worked in mixed teams composed of participants from different universities. This encouraged them to communicate across disciplines, nationalities and learning cultures.

The experience was particularly effective because it created a learning journey rather than a series of technical visits. Laboratory exposure was combined with problem-solving, team tasks, reflection and co-creation.

The evaluation results were exceptionally positive: 83% rated the organisation as excellent and 17% as good, while all participants rated the overall experience either 9 or 10 out of 10. Students particularly valued virtual welding, 3D printing, metrology, AI-enabled equipment and networking.

The LTTA demonstrated an important Knowledge Triangle principle:

> Students understand the value of emerging technologies differently when they encounter the people, equipment and working environments behind them.

FuturENG did not rely on a single learning format. Its approach combined:

- online lessons;
- quizzes;
- WebQuests & challenge-based learning;
- digital teamwork;
- pitch presentations;
- laboratory experiences;
- design-thinking activities;
- mentoring;
- peer exchange;
- and reflective evaluation.

This variety supported different learner preferences and enabled each Knowledge Triangle partner group to contribute through the format best suited to its expertise.

> The good practice was not simply the use of multimedia. It was the creation of a connected portfolio of learning experiences: learn online → investigate a real problem → collaborate → pitch a solution → experience technology in practice → reflect and improve.

Evidence-informed resource development

The project used several sources of evidence rather than relying on a single evaluation mechanism:

- structured student questionnaires;
- open-ended feedback;
- facilitator observations;
- common hackathon evaluation grids;
- LTTA evaluation;
- partner reflection;
- and co-creation workshops.

This triangulation provided a richer understanding of what worked and what required adjustment. It also helped distinguish between isolated opinions and recurring implementation patterns.

A credible cooperation methodology must show not only what succeeded, but also where implementation became difficult. Understanding the barriers encountered during cooperation is equally important, as it helps future partnerships anticipate risks and design appropriate mitigation measures from the outset. The FuturENG collaboration identified several risks that can weaken Knowledge Triangle cooper ation. The table below summarises them and the FuturENG lessons learned.

⚠️ Challenge	📌 Why it Matters	💡 FuturENG Lesson
Different actors can share a project but not the same goal	Universities, businesses and research organisations can define success differently (learning quality vs. practical results vs. technological advancement). Left implicit, this fragments cooperation.	Translate shared objectives into actor-specific contributions and revisit alignment throughout implementation, not only at the outset.
Cooperation stays "on paper"	Cooperation can stay purely formal (agreements, meetings, reports) without real joint work. This risk drops when partners are tied to tangible activities: co-developing content, mentoring, evaluating pitches, running labs.	Measure cooperation through joint outputs and shared decisions, not meetings held.
Diverse learner profiles	Pilot students varied widely in discipline and prior knowledge, so a resource accessible to one group could overwhelm another. This calls for clear entry requirements, introductory pathways, flexible challenge levels and educator guidance.	Transferability does not mean using exactly the same implementation everywhere. It means preserving the learning objective while adapting the pathway.
CBL quality depends on facilitation	CBL gives students ownership, but without facilitation teams may pick overly broad problems or split tasks unevenly. Educators need guidance on supporting teams without overriding their decisions.	Every CBL resource should include facilitator guidance, milestone checks, assessment criteria and suggestions for adapting task complexity.
Good ideas do not automatically become implementable solutions	The hackathon produced creative concepts, but some needed more thought on feasibility and user needs. This is a common gap between ideation and innovation, not a weakness specific to hackathons.	Ask teams who will use the solution, what it requires, what risks it creates, and what a realistic first step would look like.

Sustainability cannot depend on individual enthusiasm	Strong personal relationships drove FuturENG, but partnerships relying on a few committed individuals remain vulnerable. Institutional embedding, documented knowledge and clear governance make cooperation less dependent on any one person.	Turn personal cooperation into organisational cooperation before the project ends.

Table 1 – Risks and Lessons from FuturENG collaboration

The lessons presented in this chapter reveal a common theme: successful Knowledge Triangle cooperation depends as much on relationships and communication as it does on technical expertise.

Even when stakeholders share a common objective, differences in organisational culture, priorities and expectations can create barriers to collaboration. For this reason, effective communication and stakeholder alignment must be treated as strategic components of cooperation rather than administrative tasks.

The following chapter explores the communication practices and alignment strategies that help sustain productive partnerships over time.

3. Guidelines & Strategies for Identifying Common Goals and Fostering Open Communication

As Chapter 2 has shown, Knowledge Triangle cooperation among education institutions, research organisations and industry partners delivers value only when it is actively managed rather than left to happen on its own.

Cooperation between these groups is not always easy. Each stakeholder has different goals, expectations, and ways of working. Because of these differences, clear communication and good alignment are necessary to ensure successful collaboration.

This chapter explains the way communication supports long-term collaboration between different stakeholders and also discusses strategies on how to improve communication, align goals between stakeholders and build trust and cooperation.

3.1 Role of Communication in Collaboration

Without effective communication, misunderstandings can occur, leading to delays and failure. The following sections set out how effective communication contributes to cooperation, and the specific tools that support it.

3.1.1 Why Communication is Important

Two-way communication supports collaboration in several ways:

- it helps stakeholders to remain informed about project progress, goals, challenges;
- stakeholders develop a shared understanding of goals, terminology, each other's roles, limitations and expectations;
- encourages knowledge sharing and improves decision-making;
- trust develops gradually through honest communication, reliability, respect, and fairness.

3.2 Communication enablers

Communication enablers are tools and practices that improve how stakeholders interact: continuous and structured communication, informal networks and connectors, multi-channel communication, and tailored communication, each discussed below:

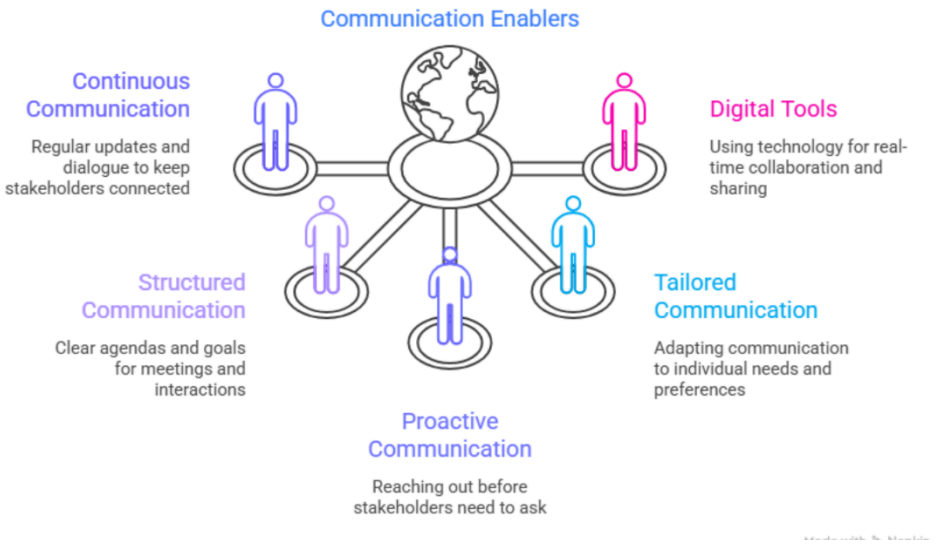


Figure 4 – Communication enablers

3.2.1 Continuous and Structured Communication

Regular, transparent, structured and proactive communication keeps all stakeholders connected during the collaboration process. It is beneficial if communication occurs regularly and not only during major project milestones. Stakeholders need regular updates on project progress, upcoming issues, and how previous input has been used. Regular updates promote transparency and facilitate immediate feedback. Communication must be well structured: a meeting, for example, should always have a clear agenda and defined goals. Communication also needs to be proactive, reaching out before stakeholders need to ask, and it should be adapted to their needs and preferences.

Organisations can improve communication by using weekly or fortnightly check-in meetings, continuous dialogue, shared terminology, feedback loops, digital tools like Microsoft Teams, Zoom and cloud-based systems. These technologies allow stakeholders to collaborate in real-time and share documents efficiently.

These practices improve transparency and make sure that information is equally shared among all stakeholders. Good, structured communication reduces confusion and ensures that all partners stay informed.

3.2.2 Leveraging informal networks and connectors

Informal networks are particularly important in cooperation environments. While formal communication supports organisation and accountability, informal communication strengthens relationships and trust. FuturENG illustrated this directly: as Chapter 2 describes, partners who already knew one another moved faster and communicated more openly than those meeting for the first time.

Some individuals function as “connectors” between stakeholder groups. These people help organisations communicate more effectively by translating ideas, solving misunderstandings, and connecting different organisational cultures.

Informal interactions often create opportunities for open discussions and creative problem-solving. Conferences, networking events, workshops, and coffee meetings can improve relationships and encourage knowledge sharing.

3.2.3 Multi-Channel Communication

Successful collaborations usually use both official and unofficial communication channels.

Official communication channels are formal meetings, emails, reports, online platforms, video meetings and workshops. Unofficial communication channels are phone calls, messaging, informal discussions and social networking.

Using different channels in communication has many advantages:

- **Increases reach**: Using multiple channels helps reach a wider audience, since different people prefer different channels.
- **Strengthens communication**: Repetition of information through various platforms emphasizes its significance and boosts recall.
- **Increases engagement**: Using different communication channels keeps the audience more engaged and interested.
- **Improves clarity**: Some concepts are better explained through certain channels. Using a mix allows for clearer explanations.

Both channels are important because formal communication provides structure and informal communication builds relationships and trust.

3.2.4 Tailored Communication

Different stakeholders require different communication styles. For example, industry may prefer short and practical information; academic partners may prefer detailed explanations on technical and scientific information and policymakers may prioritize strategic and social outcomes.

Providing tailored communication to each stakeholder group helps ensure better understanding of a project's goals and stronger engagement.

3.3 Alignment Strategies

Communication on its own is not enough for successful collaboration; stakeholders must also stay aligned around shared goals and expectations, maintain a common understanding, and coordinate their actions and commitments throughout the project. Many projects fail because of poor stakeholder alignment, not because of bad ideas.

To stay aligned with the goals, stakeholders need to be engaged. Stakeholder management alone is not enough. Building stakeholder engagement requires understanding stakeholder priorities, building trust with them, tailored approaches and turning feedback into continuous improvement (Freeman, 1984).

3.3.1 Key Alignment Approaches

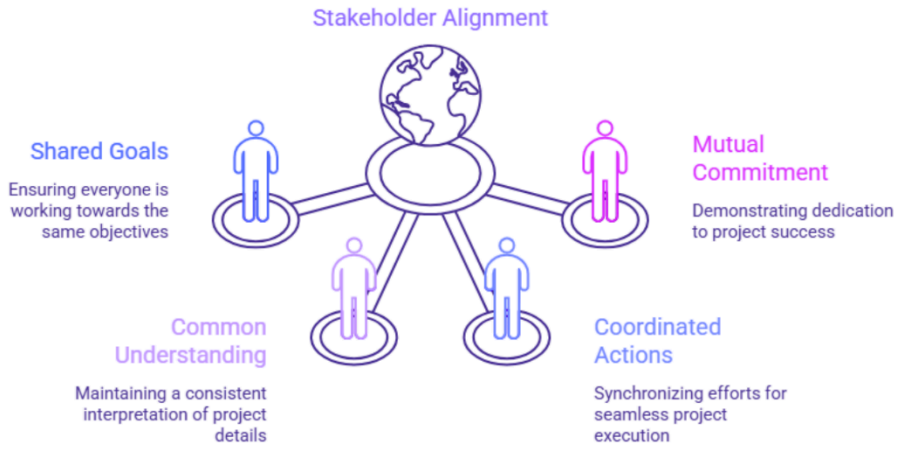


Figure 5 – Stakeholder alignment strategies

Alignment Workshops

Alignment workshops are useful because they bring stakeholders together to define shared goals, discuss expectations, build common understanding, discuss challenges, and solve misunderstandings. Alignment workshops encourage active participation and collaborative decision-making. These are useful at the beginning of projects but can also be organised during the implementation phases of the project to resolve misunderstandings and review priorities.

Joint Activities

During joint activities, like seminars, discussions, and collaborative work stakeholders can discuss research findings, challenges they face, opportunities they see, and technological developments. Joint activities improve knowledge sharing, help partners understand one another's perspectives and priorities, and strengthen relationships between academia and industry; thematic discussions, often lead directly to problem-solving and new ideas.

Regular Meetings and Check-ins

Regular meetings and check-ins are vital for several reasons:

- **Share vision**: Meetings ensure stakeholders are aligned on goals, objectives, and expectations.
- **Address concerns:** Meetings provide a platform to address concerns, issues, and challenges.
- **Establish trust**: Regular meetings help build trust and strengthen relationships.
- **Strategic planning**: Regular meetings enable partners to discuss and adjust strategies.
- **Encourage open discussion**: Foster an environment of open and honest communication.

Governance and Decision-Making Structures

Good governance structures help maintain alignment and improve collaboration management.

Common governance mechanisms include steering committees, advisory groups, coordination teams, project leadership boards. These structures improve accountability and decision-making clarity.

Inclusive governance is especially important because stakeholders need opportunities to participate in important decisions. Governance frameworks should also include conflict resolution mechanisms because disagreements may occur during collaborative projects.

3.4 Best Practices for Effective Cooperation

Although the FuturENG project fostered open communication and used alignment strategies, several challenges remained. These included misaligned goals between academia and industry, different expectations, limited practical implementation, low motivation among stakeholders, and difficulty turning ideas into real solutions.

Overcoming these challenges requires improved communication strategies, early stakeholder involvement, clearly set goals, and ongoing feedback and evaluation.

The following best practices are recommended:

Communication	Alignment	Collaboration
Maintain continuous, transparent, structured and proactive communication	Alignment Workshops	Encourage active participation
Use multiple channels of communication (formal and informal communication channels) and tailored communication	Joint Activities	Build trust
Use informal networks and individuals acting as connectors	Regular Meetings and Check-ins	Focus on real-world outcomes
Use digital tools like Microsoft Teams, Zoom and cloud-based systems	Governance and Decision-Making Structures	Promote knowledge sharing

Table 2 – Best Practices on Communication and alignment for Knowledge Triangle Partnerships

Continuous cooperation between academia, industry and research organisations depends on effective communication and alignment strategies. Structured communication, regular meetings, informal networks, and multi-channel communication approaches all support collaboration effectiveness. Alignment strategies such as workshops, seminars, joint activities, and good governance structures help stakeholders maintain shared understanding and coordinated action. Clearly defined shared goals, trust, openness, stakeholder engagement, and inclusivity are also critical for long-term cooperation, as organisations that invest in communication and relationship-building are more likely to achieve innovation, knowledge exchange, and sustainable partnerships.

Effective communication and stakeholder alignment provide the foundation for collaboration, but they are not objectives in themselves. Their ultimate purpose is to enable stakeholders to work together towards meaningful outcomes. In engineering education, one of the most important outcomes is ensuring that graduates possess the knowledge, skills and competences required by a rapidly changing labour market. The next section examines how educational provision can be systematically aligned with emerging industry and societal needs

4. Aligning HE Engineering Education with Labour Market Needs

4.1 Context & Importance

Traditional curricula lag behind rapid technological and societal change, leaving graduates unprepared and employers underserved.

This chapter sets out the practical mechanisms, from trend scouting to co-designed curricula, through which higher education institutions can keep engineering programmes aligned with a labour market that changes faster than traditional curriculum-revision cycles.

4.2 Practical Strategies for Aligning Engineering Education with Labour Market Needs

4.2.1 How to Identify Emerging Engineering & Technological Trends

Method	Practical Action	Output
Systematic Trend Scouting	Establish a joint "Trend Monitoring Group" (HEI+Industry+Research) meeting quarterly. Use free tools like Google Trends, CORDIS EU results, and patent databases.	Bi-annual "FuturENG Skills Radar" report (one page).
Real-time Labour Market Analytics	Use platforms like LinkedIn Talent Insights or EURES to analyse in-demand skills for graduate roles in real-time.	Dynamic list of top 5 emerging technical & transversal skills.
Student as Sensor	Create a student-led "Junior Trend Watch" unit. Students report on technologies they encounter in internships, hackathons, or self-learning.	Student-generated trend briefs presented to the Industry Advisory Board.
Weak Signal Workshops	Host semi-annual workshops with diverse stakeholders to discuss "what's just appearing on the horizon" (e.g., generative AI for code, synthetic data).	A "Weak Signal Log" to feed into curriculum planning.

Table 3 – Methods and actions to identify engineering and technological trends

Once trends are identified, they need to be checked against real labour-market signals, which is where structured industry consultation comes in.

4.2.2 Industry Consultations & Labour Market Needs

Tool	Implementation	Illustrative Example
Structured Skills Gap Survey	Annual 10-min survey to industry partners: "Rate graduate proficiency in 8 key Industry 5.0 skills (e.g., human-robot collaboration, systems thinking)."	Results can be visualised as a heat-map, highlighting the most critical skill gaps.
Industry Advisory Board (IAB) Deep-Dives	Move beyond general meetings. Each IAB meeting includes a 30-min "Needs Sprint": each member states one missing skill and one obsolete topic.	One partner's response captured the shift in demand directly: "We don't need more CAD courses; we need prompt engineering for designers."
Graduate Outcome Tracing	Track first-destination employment and ask alumni after 12 months: "What did your job require that your degree didn't teach?"	A simple pathway from education to employment, showing where formal training falls short.

Table 4 – Industry consultation tools

Trend scouting and industry consultation together build the evidence base; the next step is turning that evidence into training provision.

4.2.3 Develop Future-Oriented Training Provision with Industry 5.0 Relevance

- **Core principle:** Co-create not just content, but learning formats;
- **Microcredential Fast-Pilot**: Instead of a full module, co-design a 3 ECTS microcredential on a newly identified topic (e.g., "Ethical AI for Production Engineers"). Industry provides a real dataset. Launch within 4 months.
- **Modular "Skill-Slice" Curricula**: Break programmes into 4-6 week "skill slices". Each slice is co-validated by industry as "immediately usable". Students mix slices from different disciplines.
- **Challenge-Based Learning (CBL) Integration**: Replace 20% of traditional lab hours with industry-posted challenges. Example: *"Optimise this production line layout for human-robot collaboration."*
- **Industry 5.0 Competency Framework**: Focus on human-centric (empathy, leadership), sustainable (lifecycle thinking, circular economy), and resilient (adaptability, crisis problem-solving) skills.

Recommendation: Do not start with content. Start with the skills gap. Use the Trend Radar and IAB Needs Sprint to prioritise one specific gap. Then co-design a single microcredential or CBL module as a pilot.

Identifying trends and skills gaps is the first stage of alignment. . The next section therefore focuses on co-creation mechanisms that enable higher education institutions and external stakeholders to transform identified needs into educational practice.

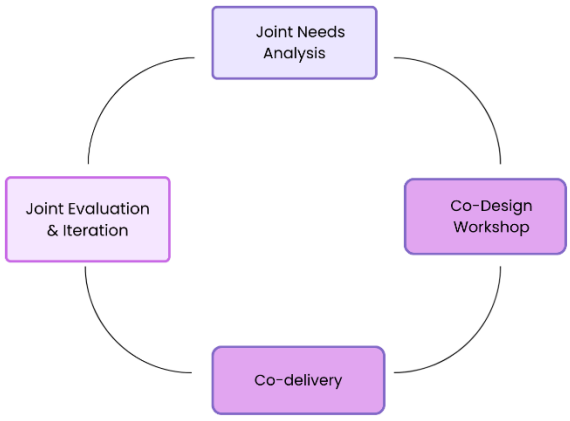
4.3 Co-Creation Approaches

4.3.1 How HEIs and industry co-design relevant educational provision

Once emerging trends and skills gaps have been identified, they need a mechanism for turning into actual curriculum content. Co-creation is that mechanism: it brings higher education institutions and industry partners together to design learning provision jointly, rather than having one side define requirements and the other implement them after the fact. The sections below set out a repeatable co-design cycle, concrete formats for putting it into practice, and how it connects to the Knowledge Triangle model introduced in Chapter 1.

4.3.2 The Co-Design Cycle

The Co-Design Cycle is a core mechanism through which industry needs are turned into credit-bearing learning content. It runs in four recurring stages (Joint Needs Analysis, Co-Design Workshop, Co-delivery, and Joint Evaluation & Iteration), as shown below in two views: the circular diagram emphasises that the cycle is continuous rather than linear, while the timeline sets out the duration and concrete deliverables of each stage. The diagrams below details who is involved, what method is used, and what each stage produces, so the cycle can be replicated by other institutions rather than treated as an abstract model.



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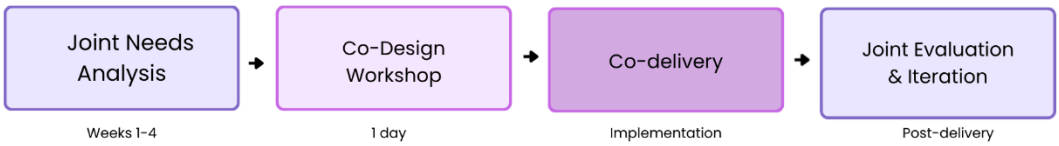

4.3.3 Practical Co-Creation Formats

Format	How It Works	Industry Effort	HEI Benefit
Live Case Sprint	2-week intensive. Industry gives a real unsolved problem. Students propose solutions.	Problem definition (two hours) and final pitch judging (three hours).	Generates fresh solutions and measurably increases student engagement.
Reverse Mentoring	Industry engineers teach a software tool; PhD students	Engineers gain teaching experience.	Builds staff digital skills and strengthens
Co-Designed Assessment	project rubric. Example: "If you were hiring, what would you want to see in a portfolio?"		portfolios match employers' hiring criteria.
Rotating Curriculum Lab	A physical or virtual space where faculty, students, and industry staff co-develop next year's module content monthly.	One industry representative attends for two hours per month.	Keeps curriculum content continuously up to date.

Co-creation is not a one-time event. It is a continuous cycle of design, delivery, evaluation, and improvement.

Table 5 – Practical co-creation formats

4.3.4 How Knowledge Triangle Cooperation Supports Industry 5.0-Oriented Learning

While the formats presented above provide practical ways of organising collaboration, their effectiveness derives from the Knowledge Triangle principles discussed throughout this methodology. Co-creation succeeds because it enables knowledge to move continuously between education, research and industry rather than remaining within organisational boundaries.

- **Research → Education Pipeline:** research partners translate emerging findings, such as a new human-robot collaboration protocol, directly into a short lab exercise, rather than waiting for the usual multi-year curriculum-revision cycle.

- **Industry → Research Feedback**: industry flags a problem (For example, that cobots are underused on the shop floor); research partners design a challenge-based learning module around it, students explore solutions, and industry gains new insights in return.

- **HEI as Neutral Convener:** the HEI hosts and facilitates, ensuring learning objectives remain paramount while balancing commercial and scientific interests.

4.3.5 Implementation Checklist for HEIs

	Trend Monitoring Group that met within the last 60 days
	Industry Advisory Board uses a structured Skills Gap Survey annually
	At least one microcredential or CBL module co-designed with industry in the last 12 months was piloted
	Curriculum includes explicit Industry 5.0 competencies (human-centric, sustainable, resilient)
	Co-design process needs → workshop → delivery → evaluation is documented

Table 6 – Implementation checklist

4.3.6 Example in practice: "Digital Twin for Sustainable Manufacturing"

Example in Practice

- **Need Identified**: IAB survey showed gap in simulation skills.
- **Co-Design**: 1 workshop defined a 6 ECTS module. Siemens provided free access to their cloud-based twin platform.
- **Delivery**: Student teams built a digital twin of a partner's small production cell, optimised for energy use.
- **Outcome**: 3 student projects adopted by SMEs. Developed module integrates core curriculum.

Start small, co-design fast and measure by graduate employment and employer satisfaction. The Knowledge Triangle is not a governance burden; it is an agility engine. Use the FuturENG tools (Trend Radar, Needs Sprint, Co-Design Cycle) to turn labour market noise into curriculum action.

Aligning educational provision with labour market needs requires identifying trends and co-designing curricula, but it also requires practical mechanisms that enable knowledge, expertise and experience to flow continuously between education, research and industry. Once cooperation structures have been established and learning provision has been aligned with stakeholder needs, institutions need appropriate tools to support ongoing collaboration

The following chapter introduces a Knowledge Transfer Toolbox that provides concrete approaches for facilitating knowledge exchange and sustaining cooperation within the Knowledge Triangle.

5 Tools and Resources for Facilitating Knowledge Transfer & Sharing

Effective collaboration within the Knowledge Triangle depends not only on strategic partnerships but also on the practical mechanisms that enable knowledge to be created, shared, and applied across education, research, innovation, and society. Higher education institutions play a central role in facilitating these interactions by adopting teaching approaches, collaboration models, and digital solutions that encourage continuous knowledge exchange among students, researchers, academic staff, industry, and other external stakeholders.

This chapter presents a Knowledge Transfer Toolbox comprising practical tools, learning formats, and cooperation mechanisms that support collaboration within the Knowledge Triangle. The toolbox includes approaches such as open educational resources, micro-credentials, work-based learning, challenge-based learning, mentoring, design thinking, guest lecturers, joint training initiatives, and digital collaboration platforms. Together, these approaches help strengthen institutional partnerships, promote lifelong learning, and create opportunities for the co-creation and dissemination of knowledge.

The toolbox is intended as a practical resource for higher education institutions seeking to strengthen knowledge transfer and long-term collaboration. For each tool, the chapter outlines its contribution to the Knowledge Triangle, illustrates its application through examples from Kaunas University of Technology and international practice, and highlights key considerations for successful implementation. Rather than prescribing a single approach, the toolbox encourages institutions to combine complementary tools that best support their strategic objectives, stakeholder needs, and educational contexts.

5.1 Knowledge Transfer Toolbox

A Knowledge Transfer Toolbox is a practical set of tools, learning formats, and cooperation mechanisms that enable knowledge to circulate between higher education institutions, industry, and research organisations. Within the Knowledge Triangle, knowledge transfer extends beyond publishing research results or organising one-time events. Instead, it relies on repeatable formats through which academic knowledge, research outcomes, industry experience, and professional expertise can be exchanged, adapted, validated, and reused.

The toolbox presented in this section focuses on mechanisms that support long-term collaboration. Each tool facilitates a different type of knowledge flow:

- **Open courses and Open Educational Resources (OERs)** support broad dissemination of knowledge.
- **Micro-credentials** support certified upskilling and lifelong learning.
- **Work-based learning** connects learners with authentic workplace challenges.
- **Guest lecturers and dual teaching roles** integrate external expertise into curricula.

- **Mentoring systems** facilitate the transfer of tacit professional knowledge.
- **Joint training initiatives** create shared learning environments for higher education institutions, businesses, and research organisations.

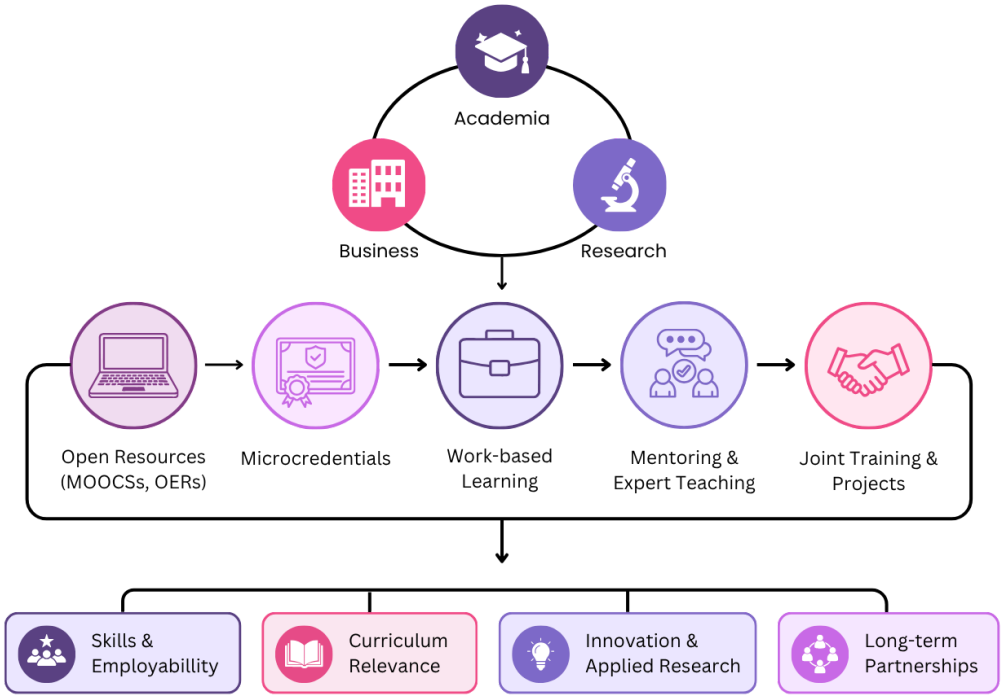

*Figure **8** – Knowledge Transfer Toolbox*

5.1.1 Open Educational Resources (OERs), MOOCs, and Open Learning Platforms

Open Educational Resources (OERs), Massive Open Online Courses (MOOCs), and open learning platforms improve access to knowledge by making high-quality educational resources freely available to diverse learners. Within the Knowledge Triangle, these tools facilitate collaboration between higher education institutions, research organisations, industry, and society by supporting lifelong learning, widening participation, and enabling the dissemination of research-informed knowledge. International frameworks such as the UNESCO Recommendation on Open Educational Resources (UNESCO, 2019) encourage institutions to develop, share, and reuse openly licensed educational materials.

KTU's Open Courses, MIT OpenCourseWare and TU Delft OpenCourseWar are examples of platforms that provide a MOOCs, micro-modules and Open Educational Resources and learning resources that can be reused by students, educators and lifelong learners beyond traditional degree programmes.

To maximise their impact, OERs and MOOCs should be aligned with institutional priorities, regularly updated, openly licensed, and designed to support diverse learners. Collaboration with external partners can further enhance the relevance and quality of learning resources while extending their use beyond individual institutions.

5.1.2 Micro-credentials and micro-modules

Short, targeted educational experiences can be certified as micro-credentials, giving learners a flexible way to have their achievements formally recognised. By certifying clearly defined learning outcomes, micro-credentials support lifelong learning, employability and rapid skills development (European Union, 2022), and let higher education institutions respond quickly to emerging competence needs while strengthening collaboration with industry and other external partners.

ECIU University enables learners to earn microcredentials through challenge-based learning activities co-created with external partners (ECIU University, n.d.).

Micro-credentials are most effective when they are co-designed with employers and research organisations to address identified skills needs. Combined into flexible learning pathways, they can support continuous professional development while providing learners with recognised evidence of competences acquired through formal and non-formal learning.

5.1.3 Work-based learning and internship platforms

Work-based learning connects academic study with authentic professional practice by enabling learners to apply their knowledge in real organisational settings. Within the Knowledge Triangle, it strengthens collaboration between higher education institutions, employers, and research organisations by supporting mutual knowledge exchange, skills development, and curriculum improvement.

KTU's WANTed programme connects students with employers through internships, career counselling and recruitment events, easing the transition from education to employment.

The University of Waterloo and **Northeastern University** show how the same principle scales within degree programmes themselves, embedding structured work-integrated learning so that professional experience and employer partnerships build continuously throughout a degree, not just at its end (University of Waterloo, n.d.; Northeastern University, n.d.).

The greatest value of work-based learning is achieved when placements are integrated into academic programmes, linked to clearly defined learning outcomes, and supported through

effective mentoring and collaboration between universities and employers. Regular feedback from students and industry partners should be used to continuously improve both learning experiences and study programmes.

5.1.4 Challenge-based and problem-based learning formats

Challenge-based and problem-based learning (PBL) engage learners in solving authentic societal and industrial challenges through collaboration with external stakeholders. These approaches strengthen the Knowledge Triangle by connecting education, research, and innovation while enabling students to apply theoretical knowledge to real-world problems.

Aalborg University and **ECIU University** demonstrate how authentic industry challenges can transform theoretical learning into practical innovation experiences, with examples such as the CDIO framework which combines combine authentic engineering challenges with structured pedagogical design

Challenge-based and problem-based learning are most effective when external stakeholders participate in defining authentic challenges and students receive appropriate academic supervision throughout the learning process. Assessment should evaluate not only technical solutions but also collaboration, critical thinking, creativity, and the application of research methods.

5.1.5 Guest lecturers, visiting experts, and dual teaching roles

Guest lecturers, visiting experts, and dual teaching roles enable higher education institutions to integrate external expertise into teaching and learning. By involving industry professionals, researchers, entrepreneurs, and international academics, these approaches strengthen the Knowledge Triangle through the exchange of current knowledge, practical experience, and research-informed perspectives.

KTU Global Faculty Week and the **Virtual Visiting Professors project** bring international expertise directly into teaching and curriculum development.

The greatest benefits are achieved when external experts contribute not only to teaching but also to curriculum design, student supervision, and the development of learning resources. Clear responsibilities, alignment with learning outcomes, and institutional support help ensure that these collaborations create sustainable value for students, educators, and partner organisations.

5.1.6 Mentoring and peer-learning systems

Mentoring supports the personal, academic, and professional development of learners through guidance, experience sharing, and knowledge exchange. Within the Knowledge Triangle, mentoring facilitates the transfer of tacit knowledge and strengthens collaboration between higher education institutions, industry, and research organisations by connecting learners with experienced professionals.

KTU The GUIDed Mentoring Programme and the **ENHANCE Alliance Cross-Border Mentoring Programme** demonstrate how mentoring can foster international collaboration by connecting students and mentors from partner universities, promoting intercultural learning and the exchange of academic and professional experiences.

Mentoring is most effective when mentors and mentees are carefully matched, expectations are clearly defined, and regular communication is supported throughout the programme. Well-designed mentoring initiatives strengthen professional networks, support career development, and promote long-term knowledge exchange across institutional and organisational boundaries.

5.1.7 Design thinking and innovation methodologies

Combining creativity, collaboration and iterative problem-solving, design thinking is a human-centred approach to innovation well suited to complex challenges. It supports Knowledge Triangle collaboration by integrating the diverse perspectives of higher education institutions, researchers, industry partners and learners throughout the innovation process.

The HPI d.school and **Stanford d.school** use interdisciplinary teams and user-centred design to solve real-world challenges through innovation while developing creativity, teamwork and problem-solving skills.

Design thinking is most effective when learners work on authentic challenges in interdisciplinary teams and engage with end users throughout the design process. Successful implementation requires skilled facilitation, opportunities for experimentation and reflection, and active collaboration between universities and external partners to ensure that proposed solutions address real societal or industrial needs.

5.1.8 Joint training programmes and communities of practice

Higher education institutions, research organisations, industry and other stakeholders can learn collaboratively through joint training programmes and communities of practice, exchanging expertise and developing shared educational practices. These approaches strengthen long-term Knowledge Triangle partnerships by supporting continuous professional learning and the co-creation of knowledge.

KTU's Global Faculty Week brings together international academic staff to exchange teaching practices, explore innovative pedagogical approaches, and establish new educational and research collaborations.

European University Alliances use joint training programmes and communities of practice to share expertise and strengthen institutional capacity.

The effectiveness of these approaches depends on sustained engagement rather than one-off events. Institutions should encourage regular interaction, collaborative resource development, and the use of digital platforms to support ongoing knowledge exchange and maintain active professional networks beyond the lifetime of individual projects.

5.1.9 Digital collaboration platforms and knowledge-sharing ecosystems

Digital collaboration platforms support continuous knowledge exchange by enabling communication, resource sharing, and collaborative learning across institutional and geographical boundaries. Within the Knowledge Triangle, they provide the infrastructure that connects higher education institutions, research organisations, industry partners, and learners throughout the collaboration process.

Platforms such as **MIT OpenCourseWare** make educational resources available worldwide, supporting knowledge sharing far beyond a single institution.

The value of digital collaboration platforms depends on active participation rather than technology alone. Institutions should establish clear governance, promote knowledge sharing, and ensure that digital resources remain accessible, up to date, and reusable. Combined with face-to-face collaboration, these platforms provide a sustainable foundation for long-term knowledge exchange and institutional cooperation.

5.1.10 Using the Knowledge Transfer Toolbox in Practice

The Knowledge Transfer Toolbox presented in this chapter is intended as a flexible framework for strengthening collaboration across education, research, innovation, and society. Rather than

applying individual tools in isolation, institutions should combine complementary approaches that address their strategic priorities, learner needs, and partnership objectives.

For example, OERs and MOOCs can broaden access to knowledge, while challenge-based learning, work-based learning, and design thinking enable learners to apply that knowledge in authentic contexts. Microcredentials recognise acquired competences, mentoring supports professional development, and joint training programmes and digital collaboration platforms sustain long-term knowledge exchange between higher education institutions and external partners.

There is no single model for successful knowledge transfer. Institutions should select and combine tools according to their educational objectives, available resources, and stakeholder needs. When implemented strategically, the Knowledge Transfer Toolbox supports stronger collaboration within the Knowledge Triangle, promotes innovation, enhances learner development, and contributes to sustainable institutional partnerships.

5.2 Cooperation & Innovation Activities

Effective Knowledge Triangle cooperation is not achieved through isolated collaboration activities, but through the deliberate design of a cooperation ecosystem that enables continuous knowledge exchange, co-creation, innovation, and long-term institutional partnerships. While individual activities such as internships, hackathons, project-based learning, or joint research each contribute to collaboration, their greatest value is realised when they are implemented as complementary components of a coherent institutional strategy.

Higher education institutions, industry, and research organisations contribute different expertise, perspectives, and resources to the Knowledge Triangle. Consequently, cooperation activities should not be selected based solely on availability or tradition but aligned with strategic objectives, stakeholder needs, organisational capacity, and the intended outcomes of collaboration. Institutions should therefore adopt a portfolio approach, combining activities that collectively strengthen education, research, innovation, and knowledge valorisation.

Rather than prescribing a single model of collaboration, this section presents a practical methodology for selecting, implementing, and combining cooperation activities that support sustainable Knowledge Triangle partnerships. (Council of the European Union, 2022; Etzkowitz & Leydesdorff, 2000; European Commission, 2024; OECD & European Commission, n.d.).

5.2.1 Designing a Knowledge Triangle Cooperation Portfolio

Successful Knowledge Triangle cooperation begins with selecting activities that align with institutional objectives and stakeholder expectations. Institutions should design a balanced cooperation portfolio rather than relying on isolated initiatives. Activity selection should be guided by four principles:

Principle	What it means in practice

Strategic purpose	The activity supports institutional strategy, not just individual interest.
Stakeholder participation	Education, industry and research are all meaningfully involved, not just represented.
Reciprocal knowledge exchange	Knowledge flows in both directions, rather than one partner simply delivering to another.
Long-term sustainability	The activity can continue beyond a single project or funding cycle.

No single cooperation activity achieves all of these objectives independently. Institutions should therefore combine complementary mechanisms across the collaboration lifecycle. (Ankrah & Al-Tabbaa, 2015; Chesbrough, 2003; European Commission, 2024; OECD & European Commission, n.d.).

5.2.2 Cooperation Activity Portfolio

The activity portfolio below illustrates how different forms of collaboration contribute to distinct objectives while collectively strengthening Knowledge Triangle cooperation.

Cooperation Activity	Primary Objective	Main Stakeholders	Knowledge Triangle Contribution	Recommended Application
Hackathons	Generate innovative ideas	HEIs, Industry, Research	Collaborative problem-solving	Early-stage ideation
Project-based learning	Apply knowledge	Students, Industry	Co-creation	Curriculum delivery
Internships	Work-based learning	Students, Employers	Knowledge exchange	Skills development
Staff exchanges	Cross-sector mobility	Academia, Industry	Transfer expertise	Partnership strengthening
Academic sabbaticals	Industrial immersion	Academics, Industry	Research-practice integration	Curriculum enhancement
Joint research	Collaborative R&D	All partners	Innovation	Technology development
Industry–HEI seminars	Networking	All partners	Knowledge dissemination	Stakeholder engagement
Innovation showcases	Dissemination	All partners	Visibility	Sharing outcomes
Entrepreneurship	Venture creation	Students, Researchers	Commercialisation	Innovation support
Academic start-ups	Knowledge valorisation	HEIs, Industry	Economic impact	Technology transfer

Table 7 – Portfolio of cooperation activities

The activity portfolio is informed by evidence on university-industry collaboration, knowledge-transfer mechanisms, project-based learning, work-based learning, and entrepreneurial higher education (Ankrah & Al-Tabbaa, 2015; Guo et al., 2020; Hofer & Potter, 2010; OECD, 2019; Rienties et al., 2023).

5.2.3 Combining Cooperation Activities

The effectiveness of Knowledge Triangle cooperation depends not on the successful implementation of individual activities but on the strategic integration of complementary cooperation mechanisms throughout the collaboration lifecycle. Individual activities address different educational, research, innovation, and stakeholder engagement objectives; however, their collective impact is significantly greater when they are deliberately combined to support continuous knowledge exchange, organisational learning, and long-term partnership development. Consequently, institutions should view cooperation activities as interconnected components of an institutional collaboration strategy rather than as independent initiatives.

This integrated approach reflects the ecosystem perspective promoted by recent European knowledge valorisation policy, in which higher education institutions, industry, research organisations and other stakeholders contribute complementary expertise to create social, educational and economic value. Rather than operating sequentially, cooperation activities reinforce one another through continuous interaction, allowing knowledge to be generated, refined and applied across organisational boundaries.

Challenge-based initiatives such as hackathons can generate innovative concepts that are subsequently explored through project-based learning and collaborative research. Internships, staff exchanges and academic sabbaticals strengthen reciprocal knowledge exchange while validating ideas within professional environments. Innovation showcases disseminate outcomes, attract new partners and encourage wider stakeholder engagement, whereas entrepreneurship initiatives and academic spin-offs facilitate the translation of research and educational outcomes into practical and societal impact. Designing these activities as an integrated portfolio therefore creates a continuous pathway linking education, research, innovation and knowledge valorisation.

Institutions should continuously review and refine their cooperation portfolios using evidence generated through evaluation. In doing so, collaboration evolves from a collection of individual activities into a coherent institutional methodology capable of supporting long-term partnership development and continuous improvement. (Chesbrough, 2003; Council of the European Union, 2022; European Commission, 2024; Nonaka & Takeuchi, 1995).

5.2.4 Practical Recommendations

The successful implementation of Knowledge Triangle cooperation depends less on the selection of individual activities than on their integration within institutional strategy, governance and continuous improvement processes. Cooperation mechanisms should therefore be aligned with institutional priorities, regional needs and stakeholder expectations, ensuring that collaborative activities contribute to long-term organisational objectives rather than isolated project outcomes.

Equally important is the active participation of higher education institutions, industry, research organisations and other stakeholders throughout the cooperation lifecycle. Shared ownership strengthens trust, improves the relevance of activities and promotes reciprocal knowledge exchange. Evaluation should be embedded within implementation to provide evidence that informs the refinement of cooperation portfolios and supports organisational learning.

Finally, institutions should systematically capture and reuse the knowledge generated through collaboration. Lessons learned, educational resources and examples of good practice should be incorporated into future initiatives, strengthening institutional capability and ensuring that successful cooperation continues to generate value beyond individual projects. (Ankrah & Al-Tabbaa, 2015; European Commission, 2024; Nonaka & Takeuchi, 1995; OECD & European Commission, n.d.).

6 Measuring Impact and Effectiveness of Knowledge Triangle cooperation

6.1 KPI Framework & Evaluation Approaches

The Knowledge Triangle methodology brings together three partner groups with different institutional logics, timelines and definitions of value. As a result, each partner group defines success differently, so assessing whether the cooperation is working requires asking a different question of each group.

Understanding impact is crucial to the effectiveness of Knowledge Triangle initiatives. This kind of cooperation requires sustained effort from every partner involved, and that effort can only be maintained if partners are able to recognise the value it generates.

Performance indicators provide a structured means of tracking progress over time and across specific activities, translating progress into measurable terms. However, no single indicator can capture every dimension of what cooperation produces, so a comprehensive approach addressing all three sides of the Knowledge Triangle is proposed below.

Higher education and VET institutions, industry and research organisations have different reasons for joining and engaging in a Knowledge Triangle cooperation: teaching capacity, access to talent and relevance to industry needs and technical translation (Valentín, 2000).

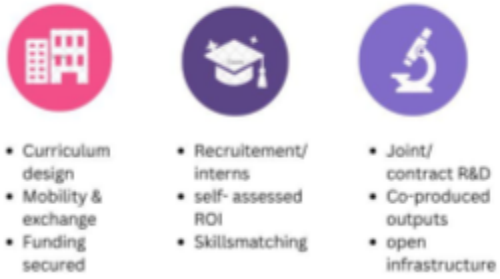

Figure 9 - Added value for educational institutions, industry and research in joining Knowledge Triangle cooperation

Thus, the indicators used to assess success should reflect these differences. This framework therefore proposes a distinct set of indicators for each partner group, rather than a single shared set of performance indicators.

Actor	Indicator	Tool
Educational institutions	New or updated curricula, training modules or learning materials developed as part of cooperation	Institutional curriculum records, review of approved course/programme changes
	N of students/Staff in training, placements or exchange opportunities developed as part of cooperation	Enrolment and participation logs; mobility/exchange records
	Share of students who rate the curriculum/ activity relevant	Feedback surveys
	Industry-linked postgraduates/ doctoral in training programmes	Institutional programme records, curriculum review
	Funding, resources, infrastructure secured through partnership	Arrangement records, financing
Business/ industry	N of graduates/ students recruited, interned	Recruitment records, internships, placements logs
	Self assessment of return to resources committed	Interviews, surveys
	Degree of skill-matching between graduated and company needs	Employer surveys, graduate labour outcome data
Research organisations	Joint/ contract research projects with HE/industry partners	Research contracts
	Publications, outputs co-produced through cooperation	Articles, publication records
	Participation in shared innovation infrastructure (clusters, incubators, open innovation platforms	Institutional records
Cross cutting	All three actors rate the cooperation successful	Survey/interview to each actor

Table 8 – KTM KPI summary table

Adapted from Valentín (2000), Unger and Polt (2017), Perkmann et al. (2011), Perkmann et al. (2013), Ramli and Senin (2021), and the Erasmus+ Impact Handbook (2024).

These indicators should be assessed at two points in the cooperation lifecycle: at the outset, to establish a baseline, and at closure, to assess the impact of the cooperation effort. This allows the actors to see the change attributable to the cooperation, rather than a single snapshot of activity.

These indicators should draw, wherever possible, on records and processes already in place within each organisation, rather than requiring new systems to be built solely for evaluation purposes. Keeping data collection proportionate to the scale of the cooperation helps ensure that partners can sustain it over time, rather than treating measurement as an additional burden layered on top of already limited resources.

6.2 Practical Impact & Implementation Evidence

The KPI framework presented in the previous section identifies what should be measured throughout the lifecycle of a Knowledge Triangle cooperation. However, quantitative indicators alone rarely provide a complete picture of the value generated through collaboration. Numbers such as the number of joint activities, students involved or curricula developed demonstrate the scale of implementation, but they do not explain how cooperation influenced institutional practice, strengthened stakeholder relationships or improved learning outcomes.

For this reason, KPI measurement should be complemented by qualitative implementation evidence. Interviews, focus groups, participant reflections, case studies, testimonials and examples of institutional change help explain why particular approaches were successful, what conditions enabled collaboration, and how the results can be replicated by other organisations. Combining quantitative and qualitative evidence creates a more comprehensive understanding of the effectiveness and sustainability of Knowledge Triangle cooperation.

The FuturENG project provides practical examples of how this evaluation approach can be applied. Rather than considering KPIs as isolated performance figures, the project demonstrates how measurable outputs can be interpreted through evidence of educational innovation, institutional learning and cross-sector collaboration.

6.2.1 Illustrative Examples of Practical Impact

One of the strongest examples of successful cooperation was the co-creation of educational resources by representatives of higher education institutions, research organisations and industry partners, drawing on the complementary partner contributions described in Chapter 2.

The result was a set of learning resources that combined academic quality with practical relevance and reflected the complementary strengths of all Knowledge Triangle partner groups.

Cooperation also extended into experiential learning environments, notably the international Hackathon and the LTTA hosted at ISQ's laboratories, both described in Chapter 2.

These activities demonstrated how Knowledge Triangle cooperation can strengthen not only technical competences but also creativity, teamwork, communication and problem-solving skills that are increasingly valued by employers.

The pilot implementation of the FuturENG learning resources also provided valuable implementation evidence, covering three resources:

- Tech Essentials MOOC;
- Challenge-Based Learning Toolbox;
- Educators' Guide & Roadmap.

All three were piloted with engineering students and higher education lecturers across partner countries. High levels of satisfaction, usability and perceived relevance demonstrated that the developed resources successfully addressed both educational and labour market needs, while participant feedback informed further refinement prior to finalisation.

6.2.2 Evidence of Adoption and Uptake

Several of the indicators presented in Section 6.1 can also serve as evidence of adoption and long-term sustainability when monitored beyond the project's implementation period. Typical examples include:

- integration of project-developed learning resources into existing university curricula;
- continued use of MOOCs, Challenge-Based Learning activities and WebQuests after project completion;
- establishment of new university–industry–research partnerships building on previous cooperation;
- continued participation of industry experts in curriculum design, guest teaching and mentoring activities;
- reuse or adaptation of project methodologies within new educational, research or innovation initiatives.

Within FuturENG, these forms of adoption are reflected in partners' commitment to embed the project results into engineering programmes, continue applying Challenge-Based Learning approaches, and expand collaboration through new Erasmus+ and research initiatives. Such evidence demonstrates that cooperation has progressed beyond temporary project activities towards sustainable institutional partnerships and continuous knowledge exchange.

6.2.3 From Indicators to Evidence

The purpose of KPIs is not simply to report performance but to support organisational learning and continuous improvement. Indicators become meaningful when interpreted in relation to broader institutional change and stakeholder experiences. The table below provides examples of how quantitative results can be translated into evidence of successful Knowledge Triangle cooperation.

KPI Result	Evidence of Practical Impact
Share of students who rate Challenge-Based Learning as relevant and engaging	Learning activities are perceived as relevant, engaging and closely connected to authentic engineering practice.
N of students in training, placements or exchange opportunities developed through cooperation	Improved transversal competences including teamwork, communication, systems thinking and innovation capacity.
New or updated curricula and training modules developed	Institutional adoption of Knowledge Triangle cooperation and curriculum innovation.
Continued use of project resources	Sustainability of project results and long-term educational value.
Funding, resources or infrastructure secured through new partnership agreements	Institutionalisation of collaboration beyond project funding and stronger regional innovation ecosystems.
Increased participation of industry experts in teaching	Stronger alignment between curricula and labour market needs, with greater exposure of students to professional practice.

Table 9 – KPI evidence examples

Ultimately, the effectiveness of Knowledge Triangle cooperation should not be judged solely by the number of activities delivered, but by the extent to which collaboration changes institutional practices, strengthens partnerships, improves educational quality and prepares graduates to respond to the challenges of the digital and green transition. Evidence-based evaluation therefore enables organisations not only to demonstrate impact but also to continuously refine and strengthen future cooperation initiatives.

7 Future Directions & Opportunities for Further Development

This chapter explores how Knowledge Triangle cooperation can evolve beyond project-based collaboration into sustainable, adaptable and future-oriented cooperation ecosystems. Figure 6 summarises the key organisational enablers required to embed, sustain, and scale Knowledge Triangle cooperation.

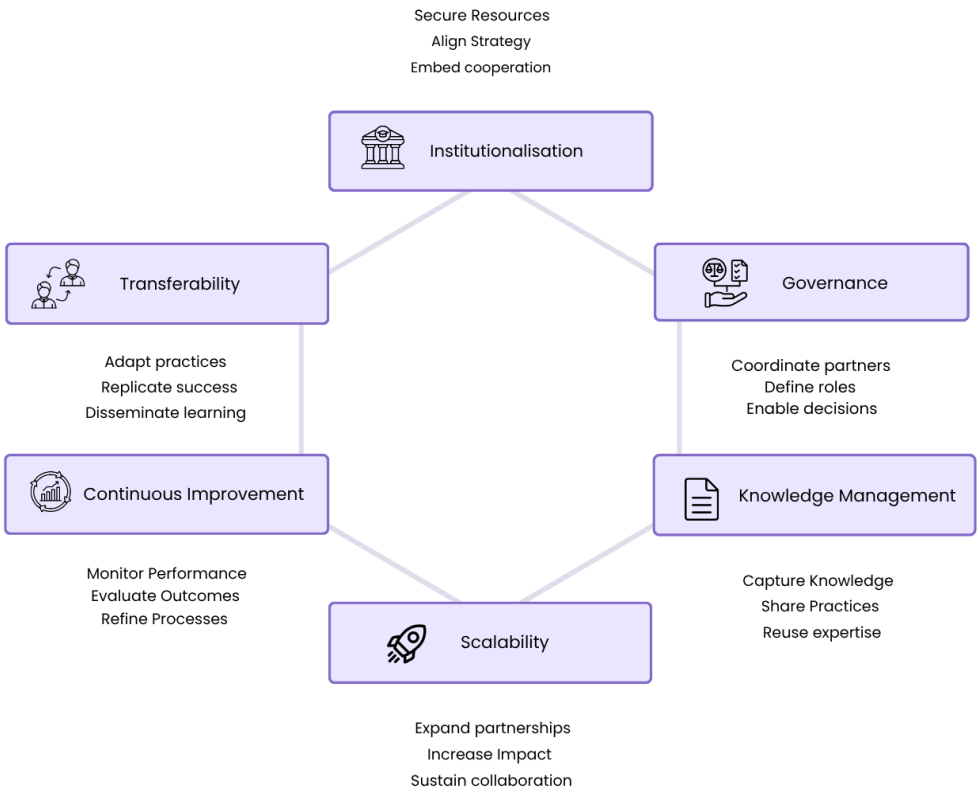

*Figure **10** – Organisational enablers supporting sustainable Knowledge Triangle cooperation*

7.1 Sustainability & Transferability

The long-term success of Knowledge Triangle cooperation depends not only on the quality of individual collaboration activities but also on the ability of participating organisations to sustain, adapt, and continuously improve these activities beyond the duration of specific projects or funding programmes. While many collaborative initiatives generate positive outcomes during implementation, their long-term value is often limited when cooperation remains dependent on temporary funding, individual champions, or isolated institutional efforts.

Sustainable Knowledge Triangle cooperation therefore requires a shift from project-based collaboration towards institutional capability. Rather than treating cooperation as a series of independent initiatives, higher education institutions, industry, and research organisations should establish organisational structures, governance arrangements, and continuous learning mechanisms that enable collaboration to become an integral part of their strategic and operational activities. Equally important is the ability to transfer successful cooperation models to different institutional contexts, allowing good practices to be adapted, replicated, and continuously refined.

Building upon the cooperation activities presented in Section 5.2 and the evaluation approaches described in Section 6, this section outlines the organisational principles that enable Knowledge Triangle cooperation to evolve into a sustainable and transferable model of collaboration. (Council of the European Union, 2022; European Commission, 2024; OECD & European Commission, n.d.; Senge, 1990).

7.1.1 Institutionalising Knowledge Triangle Cooperation

Knowledge Triangle cooperation becomes sustainable when it is embedded within the normal operation of participating organisations rather than being managed as a temporary project. Although external funding frequently provides the catalyst for collaboration, long-term success depends upon institutional commitment that extends beyond the lifetime of individual initiatives. Strategic plans, organisational policies, and operational procedures should therefore explicitly recognise cooperation with industry and research organisations as a core institutional activity alongside education and research.

Institutionalisation also requires leadership commitment. Senior management plays an essential role in establishing organisational priorities, allocating resources, and creating an environment in which collaboration is recognised as an integral component of academic and professional practice. When cooperation activities are embedded within institutional governance, supported through dedicated coordination mechanisms, and reflected in organisational objectives, partnerships become more resilient to personnel changes and funding cycles while creating lasting value for all stakeholders.

Rather than preserving individual projects, institutions should focus on preserving the organisational capability to establish, manage, and continuously develop collaborative partnerships. (European Commission, 2024; OECD & European Commission, n.d.; Senge, 1990).

7.1.2 Governance, Organisational Learning and Knowledge Exchange

Effective governance provides the organisational framework through which Knowledge Triangle cooperation can develop and mature over time. Clear responsibilities, transparent decision-making processes, and regular communication mechanisms enable partners to maintain shared objectives while adapting cooperation activities to evolving institutional and societal needs. Governance should therefore be viewed not simply as an administrative requirement but as an enabler of continuous collaboration.

Equally important is the development of organisational learning mechanisms. Every cooperation activity generates knowledge regarding stakeholder engagement, educational practice, innovation processes, and partnership management. Capturing this experience, reflecting upon lessons learned, and integrating successful practices into future initiatives allows institutions to progressively strengthen their collaboration capabilities. Knowledge exchange should therefore extend beyond the transfer of technical expertise to include the continuous sharing of organisational experience, enabling institutions to build cumulative capability rather than repeatedly recreating cooperation mechanisms from the beginning. (Argyris & Schön, 1978; European Commission, 2024; Nonaka & Takeuchi, 1995).

7.1.3 Knowledge Valorisation and Continuous Improvement

The sustainability of Knowledge Triangle cooperation depends upon the ability of participating organisations to transform knowledge generated through collaboration into long-term institutional value. Educational resources, research outcomes, innovative practices, and organisational experience should therefore be systematically captured, shared, and reused to maximise their impact beyond individual projects. Knowledge valorisation extends the benefits of collaboration by ensuring that successful practices become embedded within institutional processes while supporting innovation, regional development, and lifelong learning.

Continuous improvement provides the mechanism through which this knowledge is translated into future action. Evaluation should not merely demonstrate the success of completed activities but generate evidence that informs subsequent cooperation initiatives. The monitoring approaches presented in Section 6 therefore provide an important feedback mechanism, enabling institutions to identify strengths, recognise opportunities for improvement, and adapt cooperation activities according to changing stakeholder expectations. In this way, evaluation becomes an integral component of organisational learning rather than a final project

requirement (Council of the European Union, 2022; Deming, 1986; European Commission, 2024; Nonaka & Takeuchi, 1995).

7.1.4 Scalability and Transferability

Knowledge Triangle cooperation should be designed so that successful practices can be transferred across different institutional, regional, and international contexts. Transferability does not imply identical replication of individual activities but rather the adaptation of proven cooperation principles to different organisational environments. Institutions vary considerably in size, governance structures, disciplinary focus, and regional priorities; consequently, cooperation methodologies should remain sufficiently flexible to accommodate these differences while preserving the principles that underpin successful collaboration.

Scalability similarly requires organisations to move beyond isolated pilot activities towards institutional implementation. Successful initiatives should gradually evolve into established institutional practices supported by appropriate governance, resource allocation, and continuous evaluation. This approach enables organisations to extend the impact of Knowledge Triangle cooperation while creating resilient partnerships capable of responding to technological, educational, and societal change. (European Commission, 2024; OECD & European Commission, n.d.; Senge, 1990).

7.1.5 Sustainability Outlook

Sustainable Knowledge Triangle cooperation is achieved not through the continuation of individual projects but through the development of organisational capability. Institutions that embed collaboration within their strategic objectives, governance structures, knowledge management practices, and continuous improvement processes are better positioned to establish resilient partnerships that continue generating educational, research, and innovation outcomes beyond individual funding cycles. By combining the cooperation activities presented in Section 5.2 with systematic evaluation and organisational learning, Knowledge Triangle cooperation evolves from a project-based initiative into a sustainable institutional approach capable of supporting long-term regional and societal development. (Council of the European Union, 2022; European Commission, 2024; Nonaka & Takeuchi, 1995; OECD & European Commission, n.d.).

Once organisations have established mechanisms to preserve and transfer successful practices, they must also prepare for emerging technological, educational and societal developments. The next section therefore explores how Knowledge Triangle cooperation may evolve in response to future challenges and opportunities.

7.2 Future-Oriented Cooperation Models

The accelerating pace of technological innovation, digital transformation, demographic change, and sustainability challenges is fundamentally reshaping the way higher education institutions, research organisations, businesses, and society interact. Traditional cooperation models, often characterised by project-based and time-limited partnerships, are increasingly insufficient to address the complexity and interconnectedness of modern challenges. Instead, stakeholders must develop more agile, resilient, and future-oriented forms of collaboration that support continuous innovation, lifelong learning, and sustainable development.

The FuturENG project has demonstrated the value of Knowledge Triangle cooperation in aligning engineering education with labour market needs, strengthening innovation capacity, and promoting collaboration between academia, industry, and research organisations. However, the future requires moving beyond individual initiatives towards systemic and sustainable cooperation ecosystems capable of adapting to technological disruption, evolving workforce requirements, and societal expectations.

Future-oriented cooperation models must therefore be characterised by flexibility, openness, inclusiveness, and a commitment to continuous learning. They should enable stakeholders to jointly anticipate future trends, co-create solutions, and develop educational approaches that prepare learners for a rapidly changing world.

7.2.1 From Project-Based Cooperation to Innovation Ecosystems

Many collaborative initiatives begin as externally funded projects with clearly defined objectives, timelines, and deliverables. While such projects often generate valuable outcomes, their impact may diminish once funding concludes if appropriate sustainability mechanisms are not established.

Future-oriented cooperation requires a transition from temporary partnerships towards long-term innovation ecosystems. These ecosystems create stable frameworks for collaboration that continue beyond individual projects and facilitate ongoing knowledge exchange, joint innovation activities, and stakeholder engagement.

Innovation ecosystems are characterised by:

- Long-term institutional commitment;
- Shared strategic objectives;
- Continuous stakeholder involvement;
- Knowledge-sharing mechanisms;
- Joint decision-making structures;
- Sustainable resource allocation.

Within such ecosystems, collaboration becomes part of organisational culture rather than an isolated activity. Stakeholders maintain regular interactions, continuously identify new opportunities for cooperation, and jointly respond to emerging challenges.

For engineering education, this means creating permanent structures that allow educators, researchers, employers, students, and policymakers to regularly exchange insights, identify future skills needs, and co-develop educational solutions. Such ecosystems can significantly improve the responsiveness of educational institutions while strengthening regional and international innovation capacity.

7.2.2 Industry 5.0 as a Driver for New Cooperation Models

The emergence of Industry 5.0 provides an important framework for the future evolution of Knowledge Triangle cooperation. While Industry 4.0 focused primarily on digitalisation, automation, and efficiency gains, Industry 5.0 places greater emphasis on human-centred innovation, sustainability, resilience, and societal value creation, with significant implications for cooperation between education, research, and industry.

Future cooperation models must support:

Theme	What it means for cooperation
Sustainable Innovation	Embed sustainability principles (circular economy, environmental protection) across curricula, research agendas and innovation activities, so the solutions students design are sustainable by default.
Resilience and Adaptability	Build flexible governance, diversified stakeholder networks and digital collaboration tools, so cooperation keeps running through disruption, as recent global crises have shown is necessary.

7.2.3 Education 5.0 and Lifelong Learning Partnerships

The concept of Education 5.0 complements Industry 5.0 by emphasising learner-centred, personalised, and future-oriented education.

In this context, educational institutions can no longer operate solely as providers of degree programmes. Instead, they must become lifelong learning partners that support individuals throughout their professional careers.

Future-oriented cooperation models should therefore facilitate:

Continuous Skills Development and Personalised Learning Pathways

Technological change is shortening the lifecycle of professional knowledge, and future learners will need more flexible, modular pathways that combine formal education with workplace and research experience. Chapter 5 already sets out the concrete mechanisms for this:

- micro-credentials,
- short learning programmes
- and industry-led training.

The task going forward is less about creating new tools than applying them more continuously and to a wider range of career stages, from initial training through to ongoing reskilling.

Work-Integrated Learning

The boundary between learning and working is becoming increasingly blurred. Chapter 5 already sets out the main mechanisms for this with:

- work-based learning,
- internships
- and challenge-based formats.

The shift ahead is towards using them more continuously across a learner's career, alongside newer formats such as living labs, rather than adding a new set of tools.

7.2.4 Digital Transformation of Cooperation Ecosystems

Digital technologies will play an increasingly important role in shaping future Knowledge Triangle cooperation.
The rapid development of artificial intelligence, virtual collaboration platforms, immersive technologies, data analytics, and digital learning environments creates new possibilities for collaboration that transcend geographical and organisational boundaries.

Digital Collaboration Platforms

Future ecosystems will rely on shared digital infrastructures for project management, resource sharing, stakeholder communication and knowledge repositories, of the kind already piloted through the platforms discussed in Chapter 5. What is new here is scale: these tools need to support cooperation across entire ecosystems of partners rather than single projects, helping maintain stakeholder engagement while increasing efficiency as the number of partnerships grows.

Artificial Intelligence and Data-Driven Decision Making

Artificial intelligence can support future cooperation models by providing insights into skills needs, labour market developments, learner performance, and emerging technological trends. Data-driven approaches can assist stakeholders in:

- Identifying future competencies;
- Monitoring cooperation effectiveness;
- Personalising learning experiences;
- Improving curriculum design;

- Supporting strategic planning.

However, the use of AI must remain transparent, ethical, and aligned with human-centred values.

Immersive and Virtual Learning Environments

Virtual and augmented reality technologies offer significant opportunities for future engineering education. Knowledge Triangle partnerships can support the development of immersive learning experiences that allow students and professionals to engage with realistic simulations, digital twins, and virtual laboratories that would otherwise be inaccessible.

7.2.5 Towards Quadruple and Quintuple Helix Cooperation

While the Knowledge Triangle formally connects education, research and innovation, this methodology operationalises it through cooperation among education institutions, research organisations and industry partners. Future innovation ecosystems increasingly involve a broader range of stakeholders.

The Quadruple Helix

The Quadruple Helix model introduces civil society as an active participant in innovation processes.
Citizens, learners, communities, and end-users can contribute valuable perspectives that improve the relevance and societal impact of educational and innovation activities.
Future cooperation models should therefore encourage:

- Citizen participation;
- Co-creation processes;
- Community engagement;
- User-centred innovation;
- Social innovation initiatives.

The Quintuple Helix

Building on this, the Quintuple Helix model further expands collaboration by incorporating environmental sustainability considerations.
This approach recognises that innovation should not only generate economic value but also contribute to ecological resilience and sustainable development.
Future cooperation models should therefore integrate environmental stakeholders and sustainability objectives into educational, research, and innovation activities.

7.2.6 Building Resilient Cooperation Networks

Resilience will become an increasingly important characteristic of future Knowledge Triangle ecosystems, and resilient cooperation networks tend to share several key features:

Distributed Leadership

Rather than relying on a single organisation or individual, leadership responsibilities are shared across multiple stakeholders. This reduces vulnerability and strengthens organisational commitment.

Flexible Governance

Future partnerships must be able to adapt governance structures as stakeholder needs and external conditions evolve. Governance systems should encourage participation, transparency, and continuous improvement while remaining sufficiently flexible to support innovation.

Continuous Evaluation and Learning

Future-oriented cooperation requires a culture of reflection and learning.

Stakeholders should regularly evaluate:

- Cooperation effectiveness;
- Stakeholder satisfaction;
- Educational impact;
- Innovation outcomes;
- Knowledge transfer activities.

Evaluation findings should inform continuous improvement processes and strategic decision-making.

Strong Knowledge Management

Knowledge generated through collaborative activities must be captured, documented, and shared effectively.

Knowledge management systems can help preserve organisational memory, support transferability, and ensure that successful practices remain accessible to future stakeholders.

7.2.7 Internationalisation and Cross-Border Cooperation

Future challenges increasingly require international solutions. Consequently, future-oriented cooperation models should support stronger international collaboration.

Cross-border Knowledge Triangle partnerships can provide access to:

- Diverse expertise;
- New perspectives;
- Research infrastructures;
- Innovation networks;
- Emerging markets;
- International talent.

Digital technologies further facilitate international cooperation by reducing barriers associated with geography and enabling continuous engagement across countries and regions.

European initiatives such as Erasmus+, the European Universities Initiative, and Centres of Vocational Excellence demonstrate how international cooperation can strengthen educational quality, innovation capacity, and societal impact.

The future of Knowledge Triangle cooperation lies in the development of sustainable, resilient, and ecosystem-based partnerships that extend beyond individual projects and funding cycles. Industry 5.0 and Education 5.0 require closer collaboration between education, research, industry, policymakers, and society to address increasingly complex technological, economic, and societal challenges.

Future-oriented cooperation models must be human-centred, digitally enabled, environmentally responsible, and adaptable to change. By fostering long-term partnerships, embracing digital transformation, promoting lifelong learning, and expanding stakeholder participation through Quadruple and Quintuple Helix approaches, organisations can create innovation ecosystems capable of generating lasting value for learners, employers, research communities, and society as a whole.

The organisations that invest today in collaborative, future-ready ecosystems will be best positioned to shape the engineering education and innovation landscapes of tomorrow.

8 Final Remarks & Recommendations

In this methodology, the Knowledge Triangle gives education institutions, research organisations and industry partners a shared frame for sustained, long-term and results-driven cooperation, linking education, research and innovation in practice. This approach addresses a real tension: current education models do not match Industry 5.0 demands, and no single actor can close that gap alone.

Cooperation of this kind could leverage pre-existing relationships and build toward a governance structure, but this depends on stakeholder clarity and alignment. Within this shared frame, communication and alignment are the mechanism that prevents projects from failing; communication is what makes shared objectives and alignment possible in the first place. Chapter 3 lays out concrete mechanisms to make this work: structure communication, informal connectors, multi-channel and tailored communication, alignment workshops and governance structures.

Chapter 4 builds on these alignment efforts by addressing how labour-market and industry input gets integrated into education itself. Co-creation approaches, such as joint curriculum design and micro-credentials are examples of how this integration takes place. Several activities from FuturENG implementation experience can guide future cooperation. Initiatives such as hackathons, internships and staff exchanges are examples of how knowledge exchange and skills development take place in practice. Chapter 5 catalogues mechanisms of cooperation, presented as a knowledge transfer toolbox and activity portfolio, arguing that these work better combined rather than run in isolation.

None of this can be sustained without knowing whether it is working. Chapter 6 argues that understanding impact is crucial to sustaining cooperation, since partners can only maintain effort if they are able to recognise the value it generates.

The final chapter shifts the attention from sustaining current cooperation to evolving it: institutionalising beyond project funding cycles, extending it toward broader ecosystem models. The Knowledge Triangle methodology continues to evolve. Starting from education, industry and research partners, these initiatives can expand to ecosystem-based cooperation that incorporates civil society and, further still, environmental sustainability considerations.

From the FuturENG experience, a sustainable cooperation framework depends on a deliberate structure: defined governance, institutional embedding and portfolio design. Trust, clear governance and committed leadership are key enabling factors for a successful partnership.

The following recommendations follow from this experience:

- Build governance and institutional embedding early, rather than treating cooperation as something to formalise only once it has already proven itself;

- Treat activities (hackathons, internships, staff exchanges, joint research) as a portfolio, not standalone initiatives, reinforcing each other;
- Invest in communication and alignment mechanisms from the start. Misaligned goals and low motivation tend to persist unless actively managed.
- Secure institutional commitment, not just individual commitment, so that cooperation does not rely on one relationship to hold it together.

The Knowledge Triangle is not a fixed structure to be implemented once, but an evolving practice, kept open to expanding, adapting and improving.

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