

Connecting Disciplines Through COIL and PBL: Industrial Safety and Mathematics Education Synergies

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Abstract: In an era of digitalization, globalization, and complex societal challenges, universities are called to prepare students not only with disciplinary expertise but also with transversal competences such as critical thinking, teamwork, communication, intercultural understanding, and digital collaboration. Project-Based Learning (PBL) offers a well-established pedagogical approach for developing these competences through engagement with authentic, real-world problems. This paper explores how PBL can be enriched through Collaborative Online International Learning (COIL), focusing on interdisciplinary collaboration between students of industrial safety (HSE) and mathematics education. The proposed COIL initiative connects students from different disciplinary and national backgrounds, offering them opportunities to collaborate in international teams on shared project topics that integrate both pedagogical and technical perspectives. Future mathematics teachers contribute structured, abstract thinking, didactic skills, and inclusive communication strategies. While HSE students bring applied knowledge in areas such as risk management, machinery and system safety, occupational hygiene and ergonomics, and incident prevention. This collaboration fosters reciprocal learning, where mathematics becomes more tangible and relevant, and safety expertise is adapted for educational settings. Rather than prescribing fixed themes, the initiative encourages exploration of thematic intersections – such as risk modelling, safety data analysis, communication, or the co-design of teaching materials for technical content. Assignments are intentionally designed to promote active engagement, mutual respect, and the co-creation of meaningful outcomes, while supporting transversal competence development. The paper outlines the pedagogical rationale, competence mapping, and project ideas, emphasizing the potential of combining PBL and COIL. This integrative approach mirrors real-world collaboration across disciplines and borders and offers a flexible, inclusive model of internationalization at home. It enhances students' readiness for professional environments where interdisciplinary teamwork, digital literacy, and cross-cultural cooperation are essential. The initiative is part of the Erasmus+ project COLOSH, which promotes innovative, digital, and international learning in Occupational Safety and Health (OSH) and related fields.

Keywords: Collaborative Online International Learning (COIL), Project-Based Learning (PBL), Interdisciplinarity, Mathematics Education, Industrial Safety, Higher Education

1. Introduction

The increasing complexity of today's world, shaped by digitalization, globalization and rapid social change, challenges universities to prepare students not only with expert knowledge but also with transversal competences such as critical thinking, teamwork, digital literacy, communication and intercultural awareness (ILO 2021, OECD 2018, UNESCO 2015). Frameworks like the *Key Competences for Lifelong Learning* (EUCO 2018), *Global Citizenship Education* (UNESCO 2015) and the *OECD PISA Global Competence Framework* (2018) highlight the importance of collaboration across disciplines and cultures, active citizenship and ethical responsibility. Although not universally defined, transversal competences are widely recognized as essential for personal development, employability and addressing complex global challenges.

In this paper, we explore how higher education can foster these competences through interdisciplinary and international collaboration between two distinct student groups with different career paths but shared developmental needs.

Students of industrial safety (Health, Safety and Environment – HSE), typically educated at technical universities, develop expertise in areas such as risk management, machinery and system safety, incident prevention, occupational hygiene and ergonomics. As future safety professionals, they are expected to apply systematic approach to designing and implementing effective measures that protect health, safety and well-being in the workplace (INSHPO 2017, IOSH 2019).

The core of mathematics teacher education lies in developing a deep understanding of mathematical concepts and the ability to mediate them didactically. Prospective teachers learn to present mathematical ideas, use multiple representations, and foster critical thinking. Central to this process is a deep understanding of concepts, problem-solving, and the capacity to explore the nature of mathematical reasoning. Given that mathematics is

widely regarded as the universal language of science and technology, mathematics teachers play a crucial role in shaping students' attitudes toward these disciplines and motivating them to pursue further study and professional careers in science and engineering.

Despite their disciplinary differences, both groups need to operate in digitally connected, intercultural and problem-based environments. Their strengths are complementary. Mathematics students bring analytical thinking and didactic competencies, while HSE students contribute applied knowledge and real-world relevance. These qualities create opportunities for meaningful mutual learning.

We propose that combining Project-Based Learning (PBL) and Collaborative Online International Learning (COIL) provides a powerful and inclusive platform for interdisciplinary collaboration. PBL engages students in authentic, real-world challenges, promoting the practical application of knowledge (Condliffe et al. 2017). COIL fosters virtual collaboration across institutions and cultures, making international learning accessible without physical mobility (Hackett et al. 2024). Together, they integrate experiential learning with global perspectives, mirroring the realities of today's professional environments, where communication, critical thinking, and co-creation across disciplines are essential. This approach supports competence development and inclusive, future-ready mindsets.

The following sections present the pedagogical rationale (Chapter 2), map shared and complementary competences (Chapter 3), propose joint project themes (Chapter 4), and discuss implications for higher education innovation and internationalization (Chapter 5).

2. Bridging Theory and Practice Through PBL and COIL

The integration of Project-Based Learning (PBL) and Collaborative Online International Learning (COIL) presents a powerful pedagogical strategy for bridging the gap between theoretical knowledge and real-world application. While PBL emphasizes experiential, student-centered learning rooted in authentic problem-solving, COIL introduces an intercultural dimension by facilitating virtual collaboration across institutions and national borders. Together, they offer a flexible, inclusive, and competence-oriented approach well-suited to the needs of contemporary higher education.

2.1 Project-based Learning for Real-world Challenges

Project-Based Learning (PBL) is grounded in constructivist and experiential learning theories (Kolb 1984), emphasizing active student engagement in solving complex, authentic problems over extended periods. Research shows that PBL deepens disciplinary understanding while simultaneously fostering transversal skills such as critical thinking, communication, teamwork, and self-regulated learning (Bell 2010, Thomas 2000).

In the context of industrial safety education, PBL enables students to simulate real-world challenges such as risk assessment, incident analysis, and safety management. It supports the development of practical competences critical for professional practice. This approach has been systematically implemented in projects like RiskMan (Building Competence in Risk Management of Future HSE Professionals) (Kocurkova et al. 2022) and OshDigit (Competent university teachers for digital learning in OSH) (Kocurkova et al. 2023), which promoted PBL integration into safety-related curricula and produced publicly available teaching resources.

PBL plays a dual role in the preparation of future mathematics teachers. First, it supports the development of their ability to apply mathematical knowledge to solve real-world problems and to identify meaningful interdisciplinary connections. This fosters an understanding of mathematics as a tool for structuring and interpreting complex phenomena beyond the classroom. Second, PBL itself becomes a model of teaching practice, aligned with constructivist principles, that future teachers are expected to adopt in their own classrooms. By engaging in PBL as learners, student teachers experience the design of meaningful, inquiry-based, and student-centered tasks that encourage exploration, critical thinking, and collaboration. Through this dual perspective, PBL not only enhances their subject-matter and didactic competencies but also prepares them to facilitate similar forms of active, inquiry-driven learning in their future teaching (Capraro et al. 2013, Darling-Hammond et al. 2017, Jumaat et al. 2017).

2.2 Collaborative Online International Learning for Internationalization at Home

COIL is an educational model that links students and educators from different countries and disciplines through structured online collaboration. Pioneered by the SUNY COIL Center, it offers "internationalization at home" by

providing global learning opportunities without the need for physical mobility (Beelen and Doscher 2022, Hackett et al. 2024). It supports the development of intercultural awareness, global citizenship, digital literacy, and collaborative learning (de Wit et al. 2015, O'Dowd 2018).

In our current COLOSH initiative (International Collaborative Learning in OSH) (VSB 2024), we build upon the foundations of RiskMan and OshDigit projects to incorporate COIL methodology into interdisciplinary and safety-related education. COLOSH supports university educators in designing and facilitating COIL projects, with a focus on digital pedagogy and intercultural collaboration. Upcoming pilot activities will bring together students of industrial safety and mathematics education, offering them shared projects with global relevance and mutual learning opportunities.

COIL is an effective tool in the preparation of future mathematics teachers to integrate internationalisation into higher education curricula, while also fostering the development of intercultural and professional competences. As the European Commission notes, international mobility is still relatively rare in initial teacher education (EC 2019). The inclusion of COIL activities may therefore serve as a suitable strategy for implementing the so-called mobility window – a period in the study plan without compulsory courses, designated for international mobility or other forms of curriculum internationalisation. A key added value of COIL is that it provides prospective mathematics teachers with the opportunity to engage in the design, implementation, and evaluation of interculturally oriented projects focused on mathematics and mathematics education. Research also suggests that participation in COIL has a positive impact on motivation and engagement in initial teacher education (Quintana-Ordorika et al. 2023).

2.3 The Synergy of COIL and PBL

The combination of PBL and COIL creates a unique educational model that integrates applied, project-based learning with international and interdisciplinary collaboration. While PBL ensures that students engage with real problems in context, COIL adds the dimension of cross-cultural exchange and digital communication. This synergy reflects the demands of modern workplaces, where professionals must co-create solutions across disciplines and cultures.

Both methods align with the EU's Key Competences for Lifelong Learning (EUCO 2018), particularly in promoting communication, learning-to-learn, cultural awareness, and digital skills. They also support the development of numeracy, scientific, and technological competences, i.e. pillars of STEM education (EC 2025), which are essential for understanding and solving complex societal and environmental problems.

The integration of mathematics education and industrial safety within COIL-PBL projects exemplifies the value of STEM-based collaboration. By combining analytical reasoning with applied knowledge, such interdisciplinary experiences help future teachers and safety professionals develop transversal competences and translate expertise across professional and cultural contexts.

This integration mirrors real-world collaboration and shows how students from fields like industrial safety and mathematics education bring complementary strengths. The next chapter explores this synergy through a competence-based lens.

3. Competence Mapping of Shared Needs and Complementary Expertise

Students of industrial safety and mathematics education follow different disciplinary paths, but both groups require transversal competences such as communication, critical thinking, digital literacy, and collaboration. These competences are essential for effective participation in interdisciplinary, multicultural, and digitally supported learning and work environments. At the same time, each group brings distinct domain-specific strengths that can enrich mutual learning. This section compares relevant competence domains to highlight shared needs and complementary expertise as a basis for interdisciplinary collaboration through COIL.

3.1 Frameworks for Competence Development

To understand the common ground and complementarity between the two student groups, this comparison draws on several recognized competence frameworks:

For industrial safety (HSE) students:

- The INSHPO OHS Professional Capability Framework (INSHPO 2017) defines global standards for OSH professionals and practitioners, outlining core knowledge, skills, and responsibilities.
- The IOSH Competency Framework (IOSH 2019) reflects best practice in OSH and sets the standards for the skills, knowledge and behaviours of OSH professionals.
- ENSHPO (2025) supports the mutual recognition of OSH managers and OSH technicians in Europe and promotes shared standards for competence and certification.
- National systems like the Czech National Register of Qualifications (NRQ) provide pathways for recognizing OSH qualifications, including validation of non-formal and informal learning (NRQ 2025a, 2025b).

For mathematics education students:

- The Competency Framework for Graduates of Teacher Education Programs (MŠMT 2023) is nationally binding document that defines the shared professional profile of all prospective teachers in the Czech Republic. As an annex to the national framework for study program accreditation, it must be explicitly reflected in all initial teacher education curricula and serves as a reference point for the self-evaluation and improvement of teacher training institutions.
- The European Qualifications Framework (EQF) (Europass 2025) provides a general reference for education and professional qualifications across Europe, including teaching. It defines learning outcomes in terms of knowledge, skills, and autonomy. Teacher qualifications typically correspond to levels 7 or 8.
- DigCompEdu (Punie and Redecker 2017) is a framework focusing on digital competences of educators, including pedagogical use of technology, digital content creation, and learner engagement.

3.2 Shared Transversal Competences

The European Reference Framework on Key Competences for Lifelong Learning (EUCO 2018) defines eight key competences necessary for personal development, active citizenship, social inclusion, and employability. These competences are highly relevant not only for general education, but also for structuring interdisciplinary and collaborative learning environments in higher education.

In both study programs, industrial safety and mathematics education, the following transversal competences emerge as particularly relevant:

- Digital competence: Confident, critical, and responsible use of digital technologies for communication, collaboration, and problem-solving.
- Personal, social and learning-to-learn competence: Self-regulated learning, resilience, teamwork, and constructive interaction with others.
- Citizenship competence: Acting responsibly within society, with attention to ethics, sustainability, and social well-being.
- Entrepreneurship competence: Creativity, initiative, teamwork, and the ability to plan and manage projects with real impact.
- Mathematical and scientific competences: Structured thinking, data analysis, modelling, and evidence-based decision-making across both fields.
- Communication in native and foreign languages: Essential for collaborative work, intercultural dialogue, and dissemination in COIL settings.

These shared competences form a solid foundation for joint learning in digital, interdisciplinary, and intercultural contexts. Through the combined use of PBL and COIL, students are challenged to actively apply and further develop these skills in authentic, real-world inspired projects.

3.3 Complementary Competence Domains From Industrial Safety Students

Although transversal competencies are shared, industrial safety (HSE) students bring distinct expertise that can enrich interdisciplinary collaboration. In particular, in supporting future maths teachers in areas related to health, safety, and well-being in school environments.

Based on the OSH-related Competency Framework (IOSH 2019, INSHPO 2017), three competence domains stand out:

A. Health and Safety Awareness

- Risk Management: Identifying hazards, assessing risks, and applying appropriate control measures in classrooms, during school trips, and in other educational settings.
- Emergency Response: Responding to incidents, administering first aid, and conducting basic investigations to prevent recurrence.
- Health and Well-being: Recognizing risks related to musculoskeletal and mental health and applying straightforward strategies for prevention.

Relevance: Supports future teachers in creating safer, more supportive learning environments and in responding effectively to both physical and mental health concerns.

B. Organisational and Planning Competence

- Safety Culture: Promoting responsibility, inclusion, and proactive safety attitudes within the school community.
- Stakeholder Awareness: Understanding the roles, needs, and expectations of pupils, parents, colleagues, and school leadership.
- Ethics and Sustainability: Embedding ethical, inclusive, and sustainable practices into everyday teaching.

Relevance: Strengthens future teachers' ability to create a positive classroom climate and contribute to broader health and safety efforts throughout the school.

C. Communication and Education in Safety

- Risk Communication: Effectively communicating safety-related information during lessons, activities, and school events.
- Awareness Raising: Creating simple, age-appropriate materials on topics such as ergonomics, mental health, and first aid.

Relevance: Encourages future teachers to integrate safety concepts into everyday teaching and develop relevant didactic tools.

These competences demonstrate how HSE students can offer relevant insights and tools to mathematics education peers, supporting mutual learning in COIL projects. Table 1 summarizes these strengths and their relevance.

Table 1: Competence strengths of HSE students and their relevance for mathematics teacher education

Competence Area	HSE Student Expertise	Value for Mathematics Education Students
Risk Management	Hazard identification, risk assessment, and risk control in classrooms, school trips, and other settings	Safer planning of lessons, excursions, and classroom layouts
Emergency Response	First aid, incident handling, and basic investigation	Greater confidence in managing injuries and emergency situations
Health and Well-being	Recognition and prevention of musculoskeletal and mental health risks	Promoting well-being and resilience among pupils and teachers
Safety Culture	Promoting responsibility, inclusion, and proactive safety attitudes	Modelling safe, inclusive, and responsible classroom behaviours
Stakeholder Awareness	Understanding diverse roles and expectations within the school community	Supporting communication and collaboration with pupils, parents, and colleagues
Ethics and Sustainability	Applying ethical and inclusive practices, awareness of sustainability	Embedding values into daily teaching practice
Risk Communication	Explaining safety topics clearly during lessons, events, and activities	Integrating safety thinking into lesson content and communication strategies
Awareness Raising	Creating materials on ergonomics, mental health, and first aid	Inspiration for relevant and accessible didactic tools

3.4 Complementary Competence Domains From Mathematics Education Students

Future mathematics teachers contribute valuable competences to interdisciplinary collaboration. Their ability to analyse and structure complex problems, facilitate understanding of mathematical concepts, and design meaningful learning activities complements the technical expertise of students in the field of occupational safety and health. These strengths enhance the clarity, inclusiveness, and educational value of joint projects.

Drawing on national and European frameworks (MŠMT 2023, Europass 2025, Punie and Redecker 2017), the following competence domains are particularly relevant:

A. Mathematical Reasoning and Use of Representations

- **Conceptual Understanding and Modelling:** Ability to abstract and model complex situations using mathematical language, representations, and tools.
- **Didactic Transformation:** The ability to communicate content in a clear and factually accurate manner, using appropriate methods, representations, and tasks, in alignment with learners' educational needs and levels.

Relevance: Enhances clarity in problem formulation and supports the creation of effective instructional and training materials.

B. Learning Design and Reflective Practice

- **Design of Meaningful Tasks:** The development of learner-centred activities, tasks, tools, and models that create meaningful learning opportunities and are clearly aligned with defined educational objectives.
- **Reflective Practice:** The ability to critically evaluate the processes of teaching and learning and to use feedback to improve instructional effectiveness.

Relevance: Supports structured planning, iterative development, and critical reflection throughout team-based project work.

C. Inclusive Pedagogy, Communication, and Ethical Awareness

- **Creating Supportive Environments:** Promotion of equity, psychological well-being, and safe collaboration spaces.
- **Ethical and Professional Conduct:** Capacity to act responsibly, empathetically, and respectfully within diverse interdisciplinary teams.

Relevance: Strengthens teamwork, sensitivity to mental health and well-being, and awareness of the social and ethical dimensions of safety in both educational and workplace settings.

These competence domains illustrate that mathematics education students can serve as facilitators of structure and clarity within interdisciplinary teams. Their skills in analytical thinking, didactic reasoning, and inclusive communication contribute to the success of COIL-PBL projects and foster mutually beneficial learning.

Table 2: Competence strengths of mathematics education students and their relevance for industrial safety students

Competence Area	Mathematics Education Student Expertise	Value for HSE Students
Conceptual Understanding and Modelling	Ability to abstract and model complex situations using mathematical language, representations, and tools	Enhances accuracy in problem formulation and supports the development of effective training materials
Didactic Transformation	Ability to communicate content clearly and accurately, using appropriate methods, representations, and tasks, in alignment with learners' educational needs and levels	Facilitates communication of technical topics and contributes to accessible dissemination of domain-specific content at an appropriate level
Design of Meaningful Tasks	Development of learner-oriented activities, tasks, tools, and models that create opportunities for meaningful learning and are aligned with defined educational objectives	Supports structured planning and enhances the didactic quality of training materials and other project outcomes
Reflective Practice	Ability to critically evaluate teaching and learning processes and to use feedback to improve instructional effectiveness	Promotes team development through self-reflection and adaptive approaches

Competence Area	Mathematics Education Student Expertise	Value for HSE Students
Creating Supportive Environments	Promotion of equity, mental well-being, and psychologically safe spaces for collaboration	Strengthens team collaboration and increases sensitivity to psychosocial risks in educational settings
Ethical and Professional Conduct	Capacity to act responsibly, empathetically, and respectfully in diverse interdisciplinary teams	Reinforces ethical awareness in relation to safety and supports culturally sensitive and responsible communication

4. Designing Joint COIL Project Topics

Based on the competence mapping in Chapter 3, joint COIL projects are designed to connect the strengths of industrial safety and mathematics education students. The aim is to foster active, interdisciplinary learning through authentic, real-world challenges that benefit from both technical and pedagogical expertise.

Each proposed topic seeks to:

- Address relevant problems in education and safety.
- Promote equal, respectful collaboration between disciplines.
- Develop transversal skills such as teamwork, communication, digital literacy, and ethical thinking.

Table 3 outlines suggested project themes, highlighting their purpose and value for both student groups.

5. Conclusion

Innovation in higher education is essential, and COIL offers a flexible and inclusive way to support this transformation. By making international and interdisciplinary collaboration accessible to all students, regardless of their discipline or mobility opportunities, COIL enables broader participation and richer learning in a global context.

Combining COIL with Project-Based Learning (PBL) creates powerful opportunities for competence development. Through real-world, co-created projects, students engage deeply with professional and transversal competences while learning from and with peers from different disciplines and cultural backgrounds.

Our analysis showed that students of industrial safety and mathematics education bring complementary strengths. Future mathematics teachers offer strong analytical thinking, abstract reasoning, and pedagogical skills, while HSE students contribute applied expertise and real-world contexts for safety and health-related challenges. Mathematics serves as a foundational instrument for understanding technical disciplines, while didactic skills of future teachers can enhance the training role of HSE professionals. In turn, HSE students provide practical settings and problem scenarios that give deeper meaning to mathematical thinking.

The competence mapping in this paper was conducted at a generic level due to the lack of compatible frameworks. Still, we used established sources (e.g. INSHPO 2017, IOSH 2019, MŠMT 2023, Punie and Redecker 2017) to identify overlaps and complementary areas. A more detailed mapping would support future COIL designs and maximize mutual learning potential.

Our next step is to pilot COIL projects during a “mobility window” semester, supported by staff training and outcome evaluation. We believe this approach can foster inclusion, innovation, and internationalization and contribute to a more connected and future-ready higher education landscape.

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Ethical Statement

The submitted manuscript is original, has not been published elsewhere, and is not under review by another journal or conference. All authors contributed significantly and all sources are properly cited. The research is based solely on anonymous or publicly available data. According to Czech legislation and institutional guidelines, no ethical approval was required.

AI Statement

During the preparation of this paper, the authors used ChatGPT (OpenAI 2024) as a supportive tool for checking logical consistency, eliminating redundancy, editing language, and reducing text length. All content suggestions provided by the tool were critically reviewed and revised by the authors. No generative AI was used for content creation, data analysis, or interpretation of findings. Table 3: Proposed COIL topics with aims and learning opportunities

Topic	Main Aims	Learning Opportunities for HSE Students	Learning Opportunities for Mathematics Education Students
1. Risk assessment in educational settings	Risk assessment and control in various school environments (e.g. classroom, school in nature)	Apply risk assessment tools to unfamiliar settings; practice non-technical communication	Understand risk concepts; apply safety thinking in planning school events or lessons, and prepare didactically appropriate materials for communication with both students and teachers
2. Emergency preparedness plan and training	Develop school-wide emergency procedures and conduct training activities	Design structured emergency response procedures tailored to specific scenarios	Revise proposed procedures using critical and algorithmic thinking, prepare clear graphical representations, communicate them appropriately at the student level, and reflect on inclusion and psychological safety
3. OSH awareness training for teachers	Design a professional training module on key OSH topics	Apply technical expertise in an educational context	Transform technical content into didactically appropriate formats for peer learning or teacher training
4. First aid education and training toolkit	Create school-based first aid procedures and learning materials	Link first aid knowledge to communication and training tasks	Co-create teaching materials using analytical and algorithmic thinking, including appropriate visual representations
5. Mental health and well-being in schools	Address stress, resilience, and mental health support for students and teachers	Reflect on psychosocial risks and health promotion in schools	Explore mental health awareness and support strategies for learners
6. Ergonomics and MSD prevention in the classroom	Identify and address ergonomic issues for pupils and teachers	Apply ergonomic principles to school environments	Analyse real-life ergonomic problems; propose mathematically informed classroom adaptations, mathematically interpret available data from studies
7. Simulation and modelling of safety scenarios	Use data and simulations (e.g. evacuation modelling, injury trends) to support safety planning	Explore safety modelling; engage in interdisciplinary interpretation	Use modelling and abstraction to interpret data; support interdisciplinary problem-solving
8. Analysis of school safety data	Investigate incident trends and propose improvements based on real or simulated data	Develop skills in root cause analysis and formulating evidence-based recommendations	Apply analytical skills to interpret real-world data; connect safety themes to curriculum goals
9. Evaluation of VR-based vs. traditional OSH training	Compare learner outcomes, engagement, and usability across formats	Evaluate training effectiveness; analyse feedback	Gain insight into technology-enhanced learning and instructional design, compare pedagogical implications of technology use; reflect on learner engagement and outcomes
10. Development of a digital tool for	Co-create a prototype of a simple, school-	Translate expert knowledge into user-friendly systems	Participate in user-centered design and digital tool co-development, contribute to user-centered design;

Topic	Main Aims	Learning Opportunities for HSE Students	Learning Opportunities for Mathematics Education Students
school risk assessment	specific risk assessment tool		apply structuring skills to support intuitive digital tools

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