Erasmus + Project: Crisis Resistant Digital Education and Training

Applying the CResDET Methodology to enhance the European Product Development Course in Pro Hackin’

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1. INTRODUCTION

This report serves as a deliverable within the CResDET project aimed at advancing the definition and the implementation of guidelines for crisis-resistant design education. As part of the project's Intellectual Outputs, this report focuses on the digitalization of education in the field of mechanical engineering, with a particular emphasis on product design methodologies. In response to the global COVID-19 crisis and the subsequent restrictions on in-person teaching, the need for crisis-resistant education has become more evident than ever. However, these restrictions are not applied anymore in educational contexts during the summer semester of the Academic Year 2021/2022. Therefore, we expect to demonstrate the usefulness and the applicability of the guidelines, as a step by step procedure, that transform four different courses, held at the partners' respective institutions on Product Design and related methodologies, into a unique digital course that is accessible to all of them (Figure 1).

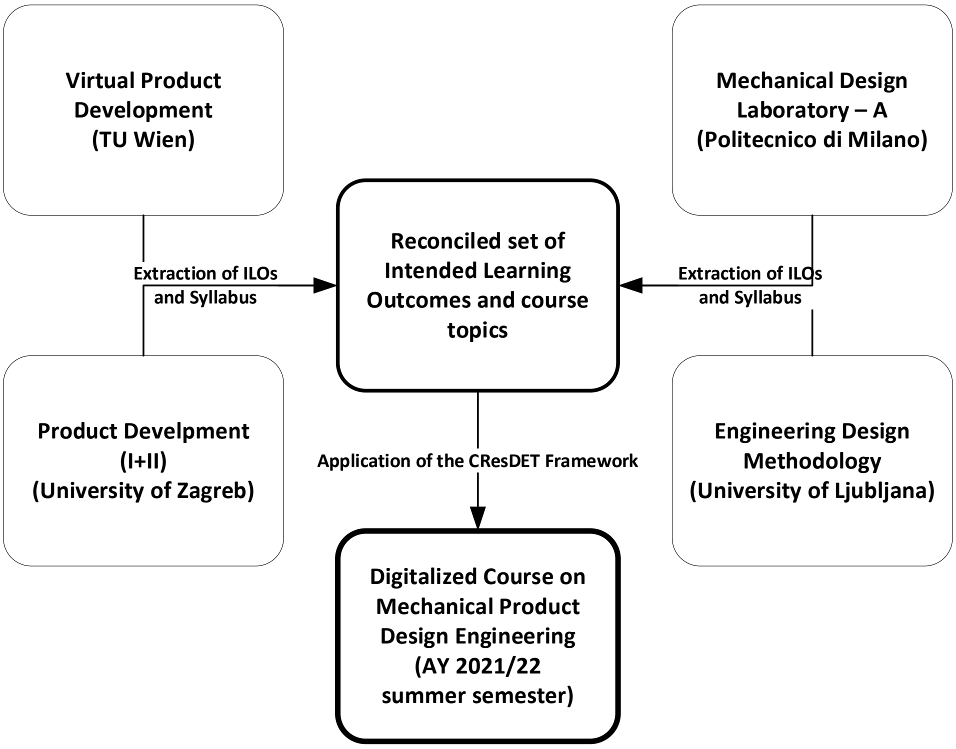

Figure 1: Visual summary of the proposed approach for the application of the CResDET framework in a real scenario

By aligning the intended learning outcomes and syllabi of these courses, the goal is to create a unified digital class on product design that can withstand future crises, while ensuring the active participation of 40 students (10 from each institution). Our analysis will involve a comprehensive examination of the existing practices, challenges encountered, and lessons learned during the transition to digital teaching methods. By assessing the suitability and effectiveness of these guidelines, we aim to develop recommendations for creating a resilient digital class that can withstand crises and maintain high-quality education in the domain of product design. Through a meticulous exploration of the intended learning outcomes and syllabi across the four institutions, we will identify common denominators that underpin crisis-resistant design education. This process will provide a foundation for aligning the curricula and fostering collaboration among the institutions, as this approach for a digital transition of engineering design education found real life in a digital mechanical engineering product design course held during the summer semester AY2021/22.

Implementing guidelines for crisis-resistant design education across four distinct academic institutions poses several challenges that need to be addressed. Firstly, the students attending these institutions may come from different mechanical engineering curricula, both within and between universities, leading to significant variations in their backgrounds and prior knowledge. Aligning the learning outcomes and bridging these disparities to create a cohesive digital class presents a substantial hurdle. Secondly, each institution likely employs diverse teaching and evaluation modalities, including varying levels of hands-on practical experiences, group projects, and assessments. Harmonizing these methodologies to ensure consistent learning experiences and fair evaluation methods is essential. Additionally, the duration and ECTS values of the courses offered by the institutions may differ, necessitating the development of a flexible framework that accommodates these variations without compromising the quality and depth of the educational content. Furthermore, logistical aspects, such as coordinating schedules, managing communication channels, and addressing potential language barriers, must be considered to foster effective collaboration among students and instructors from diverse backgrounds. Overcoming these challenges will require meticulous planning, collaboration, and a comprehensive approach to ensure the successful implementation of crisis-resistant design education across the participating institutions.

Therefore, the findings of this report will not only benefit the participating institutions but also contribute to the broader European educational community. The insights gained from our analysis will inform educational policymakers, institutions, and stakeholders seeking to enhance crisis-resistant design education in mechanical engineering. By identifying best practices and innovative strategies for digitalization, we can create an educational framework that prepares students for the challenges of the future and equips them with the skills necessary to thrive in crisis-prone environments. In the subsequent sections of this report, we will delve into the examination of intended learning outcomes and syllabi, focusing on the common elements shared among the four institutions. Building upon this foundation, we will then discuss the strategies and technologies required to digitalize the curriculum effectively, ensuring its resilience in the face of crises. The last section presents some general reflections on the usefulness of the framework and its suitability to contextualize the application of guidelines that might help the digital transition of product design education. Through these efforts, we aim to advance crisis-resistant design education, foster collaboration among academic institutions, and ultimately empower students to excel in an ever-changing educational landscape.

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2. ALIGNMENT OF TEACHING AT THE FOUR INSTITUTIONS

As mentioned this section aims at extracting the main common elements that characterize the classes held at the four institutions composing the consortium. To this purpose, this chapter is organized into subsections. The first one provides a schematic overview of the different classes by presenting their generalities. Then, the other subsections will deep dive, respectively, into the comparison of Intended Learning Outcomes and syllabi, in order to define objectives for knowledge, skills and competencies as well as the core thematic elements that are a must-have for a digital class that aims at those objectives.

2.1. OVERVIEW OF THE FOUR COURSES

Table 1 summarizes the four courses taken into consideration for the objectives mentioned in the introduction. The table collects different elements that enable the understanding of preliminary similarities and differences. This is also the key to run an anticipated estimation of potential challenges for the implementation of the CResDET framework and digitalization of the mechanical engineering product design education.

Table 1: General description of the courses

Course Title	University	ECTS	Semester/Year	Study Program
Virtual Product Development	TU Wien	5	No recommendation	Undergraduate
Mechanical design laboratory A	Politecnico di Milano	4	3rd year	Undergraduate
Product Development (I+II)	University of Zagreb	4+4	3rd year	Undergraduate
Engineering Design Methodology	University of Ljubljana	4	2nd year	Undergraduate

Despite their names might sound in most of the cases extremely different from each other, there are already some clear commonalities among the courses that are presented in Table 1 and that will be used to show how to create a unique (almost fully) digital course using the CResDET framework. Names, despite differences share some commonalities in couples: Zagreb's and Wien's courses' names differ only by one adjective. On the contrary, Milan's and Ljubljana's courses share the word "design".

All of these courses are held at the undergraduate level and, with the exception of Zagreb's course which is the combination of two courses covering the whole product development lifecycle, their associated ECTS number is similar and in between 4 and 5. This will require shrinking part of the contents that are typically proposed in those courses in order to align the commitment required of students to similar levels. The comparison among learning outcomes and among syllabi will clarify these differences further in the next subsections. However, an additional element that cannot emerge from Table 1 concerns the fact that all these classes are delivered together with some exercise hours on the theoretical topics presented during regular lectures. Most of these practical activities require students to work individually, but also in teams of different sizes. This aspect will require a dedicated reflection at the moment of setting the reconciled syllabus and the related intended learning outcomes (Section 2.4).

2.2. INTENDED LEARNING OUTCOMES (ILO)

The collection of Intended Learning Outcomes for the four classes is easy to make, however difficult to collapse into a single readable schema, given the amount of information these convey. For such a purpose, the ILOs from the four institutions are here presented briefly as bullet lists, which is also the way they are presented in the respective study program documentation.

TU Wien

- shape product development activities methodically and understand the functioning of corresponding IT systems
- assess the value of early involvement of IT-based methodologies in product development
- discuss the process of FE methods
- understand the need for neutral exchange formats
- explain VDI based models
- explain various CAx procedures
- evaluate and apply concepts and select appropriate IT procedures
- include other domains of product development such as electrical engineering or computer science (cross-sectional competence)
- apply product development methods
- use various CAx methods
- use neutral exchange formats
- develop simple products themselves
- incorporate product requirements into product development

Politecnico di Milano

- Knowledge and understanding
  - Phases and activities of the product development process
  - Functional approach to engineering design
  - Basic methods and tools for virtual prototyping
  - Systems and techniques for computer-based integrated design
  - Product hierarchy and product information management
  - Data exchange formats and their interoperability issues
- Application of knowledge and understanding
  - Parametric modelling of parts and assemblies
  - The production of technical drawings with annotations
  - Use of CAD libraries
  - Data exchange for CAD/CAE systems interoperability
  - Kinematic analysis of mechanical systems

University of Zagreb

Contribution to general/global ILOs (related to the study programme)

- Apply principles and fundamental knowledge of natural and technical sciences to identify and describe simple problems in the field of mechanical engineering.
- Decompose problems into simpler tasks and propose steps to solve them.

- Identify impacts and describe interactions between elements of technical systems and processes.
- Apply appropriate mathematical and engineering methods for modelling basic technical systems and processes in order to solve simple problems in the field of mechanical engineering.
- Communicate engineering problems in speech and in writing and present the solutions and results publicly.
- Carry out engineering tasks independently or as a team member.
- Carry out engineering tasks independently or as a team member.
- Calculate and dimension basic elements of technical systems and processes.
- Apply appropriate materials and technologies to meet the requirements of technical systems taking the constraints related to quality and cost-effectiveness into consideration.
- Describe energy conversion in technical systems.
- Follow global trends in technology development and application in the field of mechanical engineering.

Specific to the course

- Analyse user needs for the development of the new technical system.
- Compare existing technical solutions and products on the market.
- Create functional decomposition of the technical system.
- Create technical specifications and the house of quality for the development of the technical system.
- Generate and select conceptual solutions for technical systems.
- Analyse costs of the product development project.
- Design innovative principles for fulfilling the required functionality of the technical system.
- Structure the goals for the embodiment and detail design.
- Create the embodiment and detailed design of components of the technical system.
- Analyse and implement design criteria from different product life-cycle phase - manufacturing.
- Analyse and implement design criteria from different product life-cycle phase - operation.
- Analyse and implement design criteria from different product life-cycle phase - disposal.

University of Ljubljana

- Understand the importance of products
- Know the development process
- Know the engineering design process and stakeholders in the process
- To understand the role of design ergonomics in the engineering design process

- Understand user needs and engineering specifications
- Learn basic creative design methods and techniques
- Learn the guidelines for embodiment of concepts
- Understand the role of prototyping in the engineering design process
- In-depth professional theoretical and practical knowledge of systematic product development, development and engineering design process supported by a broader theoretical and methodological basis.
- Knowledge of impacts on the development and engineering design process.
- Professional theoretical and practical knowledge of methods and techniques for finding opportunities for a new product.
- Professional theoretical and practical knowledge of concept synthesis, evaluation and concept selection, embodiment, prototyping and prototype analysis of the product.
- Ability to apply the steps of the development and engineering design process and synthesize different views on product generation.
- Ability to find basic user needs and synthesize engineering specifications.
- Ability to evaluate and select suitable concepts according to engineering specifications.
- Ability to use guidelines to embody concepts and to choose the appropriate prototyping method and perform prototype analysis.
- Ability to perform complex operational and professional tasks, including the use of methodological tools: Diagnosing and solving of user problems
- Master complex work processes with the independent use of knowledge in new work situations: The application of the proven design methods of synthesis and analysis and techniques for the development and design of new products

These bullet lists show that the number of ILOs is not the same through the 4 institutions and that some of them explicitly or implicitly differentiate between ILOs concerning knowledge acquisition, while others focus on the acquisition of competencies/skills.

However, with a deeper observation of their contents, it appears clear that these items are overlapping in most of the cases among the 4 universities or at least in some of them. This is a necessary requirement so that it is possible to define common ILOs for the development of the tailored digital version of the course on mechanical engineering product design and development.

To facilitate the matching, Table 2 summarizes, by columns, the four institutions and, by row, a more general description of ILOs that might entail more than one of the items presented in the list, collecting them by thematic affinity and disregarding their merely textual denomination.

Table 2: Summary of the Intended Learning Outcomes that the different Universities share among their courses. The list in column 1 reports a list of generalized outcomes as for their meaning. (x = explicitly mentioned, o = derived from the meaning).

Generalized Intended Learning Outcome (ILOs)	Wien	Ljubljana	Zagreb	Milano
Understanding the importance and the process of product development	x	x	x	x
Knowledge of the engineering design process	x	x	x	x
Getting familiar (know or use) design methods and techniques	x	x	x	x
Understanding user needs and engineering specifications	o	x	x	o
Understand the role of prototyping	x	x	x	x
Use of CAD/CAE systems and data exchange formats	x	o	o	x
Practical application of learned concepts	x	x	x	x
Problem-solving skills in the field of mechanical engineering	o	x	x	o

At a first glance, Table 2 shows that all the universities aim to equip students with a firm grasp of why product development is important and the steps involved in the process (row 1). Moreover, the universities emphasize understanding the engineering design process, its stakeholders, and different stages like concept synthesis, selection, embodiment, prototyping, and prototype analysis (row 2). These courses also involve learning creative design methods, techniques, virtual prototyping, and IT-based methodologies in product development (row3), also beyond the skills to use various CAx methods, neutral exchange formats, and the interoperability issues associated with them (row 6). Understanding user needs is a common objective, focusing on incorporating product requirements into product development (row 4). All the universities, in addition, highlight the importance of prototyping in the engineering design process, even if it is not necessarily specified if the prototype is to be developed physically or digitally (row 5). Furthermore, all courses have a strong focus on applying the learned concepts in real-world scenarios, whether it's in developing simple products themselves or managing product development projects (row 7). Many of the courses involve training in identifying and solving problems, either independently or as part of a team (row 8), whether they are presented explicitly or not (additional details will appear in the next section about the courses’ list of contents.

2.3. COURSES' SYLLABI

Similarly to what was presented in the previous chapter, also the list of contents presented in the courses is extremely easy to retrieve, but quite complicate to organize into a single schema. Then, the following 4 bullet lists are meant to display these contents, organized according to each institution that delivers the course.

TU Wien

- Development process and process control
- Modeling of functional and active structures
- Methods of Systems Engineering
- Product configuration and rule-based mapping of product knowledge
- IT process for the early stages of product development
- Techniques and tools of virtual product development (calculation, simulation, DMU, FMU)
- Illustration of process chains (CAD / CAE, CAD / CAM)
- High end visualization, virtual and augmented reality in product development (kinematic analysis, tolerance analysis, collision analysis)

Politecnico di Milano

- Product development process and related tools.
- Phases of product development.
- Engineering design methods.
- Computer-aided tools supporting engineering design activities.
- Industrial applications.
- Engineering design process.
- From customer requirements to design specification.
- Planning of design activities. Gantt charts. Management of the design process.
- Introduction to Computer-Aided Design systems: Physical objects, digital models, design representations. Product documentation (3D models, technical drawings, reports...). Application examples.
- Geometrical modelling of mechanical systems.
- Feature-based modelling.
- Top-down and bottom-up approaches.
- Machine elements modelling approaches..
- Parametric modelling and applications.
- Part families.
- Criteria for defining the preferred modelling approach and related parametrization.
- Methods and tools for Virtual Prototyping.
- Integrated modelling and simulation for Virtual prototyping.
- Classification of approaches and technologies.

- Kinematic simulations of mechanical systems. Integrated virtual prototyping platforms.
- Product Lifecycle Management.
- Evolution of Computer-Aided technologies for mechanical design, Knowledge-based systems, Reverse Engineering and Virtual and Augmented Reality also within Industry 4.0.
- Product information management.
- Product data formats (IGES, STEP, DXF, STL, VRML) for geometric modelling, simulation, visualization systems.
- Types of data and information handled in industrial processes and related management tools.
- PDM and PLM systems.

University of Zagreb

- Introduction to product development.
- Product development process, organizational aspects, and opportunity identification.
- Product development planning and identifying customer needs.
- Product teardown and reversible engineering.
- Functional modelling.
- Product architecture and platform planning.
- Technical specifications and house of quality.
- Concept generation.
- Concept selection.
- Concept testing.
- Product development project management.
- Product development economics.
- Intellectual property and patents.
- Introduction to engineering design in product development.
- Design goals structuring and problem-solving.
- Resolving design goals' contradictions.
- Product life-cycle management.
- Principles and guidelines embodiment design.
- Principles and guidelines parametric design.
- Principles and guidelines for detail design.
- Design for X – environment and circular economy.
- Design for X – manufacturing and assembling.
- Design for X – additive manufacturing.
- Design for X – reliability and safety.
- Design for X – ergonomics.
- Design for X – robustness and maintenance.

University of Ljubljana

- Introduction to methodology of engineering design
- Engineering design requirements
- Engineering design Steps
- Concurrent engineering
- Technical system and functional structure
- Finding solutions to partial functions
- Generating of solutions
- Generating concepts
- Methods for stimulating creativity
- Evaluation and selection of the best concepts
- Design and detailing
- Embodiment design and detailing
- Ergonomics
- Prototyping

It is evident, from the observation of the abovementioned list of topics, that the four courses are different from each other, especially considering the differences for ECTS that were presented in Table 1. Zagreb's course, indeed, is significantly wider than the others as it combines two modules that address two of the product development process each (Product Planning and Conceptual Design – Module I – and Embodiment and Detailed design – Module 2). This said, it is equally clear that there are significant overlapping topics in most of the cases among the 4 universities, while in some cases the commonalities are just for some. Matching the topics among the partners is the key to define how to organize the syllabus of the tailored digital version of the course on mechanical engineering product design and development.

Similarly to what was done for ILOs, in order to facilitate the matching, Table 3 summarizes, by columns, the four institutions and, by row, a general description of thematic contents that are delivered according to what is presented in the above four bullet lists. The items presented by rows might be in essence more general as here the purpose is to define an overarching structure of themes, collecting them by thematic affinity and disregarding their merely textual denomination.

Table 3: Summary of the topics that the different Universities share among their courses. The list in column 1 repots a list of generalized thematic contents as for their meaning. (x = explicitly mentioned, o = derived from the meaning).

General topic/theme in the syllabus	Wien	Ljubljana	Zagreb	Milano
Understanding of the Product Development Process	x	x	x	x
Engineering Design Methods	x	x	x	x
Project Management	x	x	x	x
Intellectual Property & Patents			x	

Understanding User/Customer Requirements	x	x	x	x
Product Lifecycle Management and Product Data Management	x	x	x	x
Computer-aided Tools & Virtual Prototyping	x	x	x	x
Creativity in Solution Generation		x	x	
Ergonomics		x	x	
Design for X			x	x
Detailing & Embodiment Design	x	x	x	x
Prototyping			x	

From a quick-view analysis of Table 3 the degree of overlapping among the courses appear to be higher than by looking at the four syllabi. Moreover, an in-depth examination of this table highlights that all the universities include the introduction to product development, the different stages involved, planning, management, and the organizational aspects (row 1). Moreover, all the universities also present various methods used in engineering design as well as in concurrent engineering (row 2). All the partners also provide some elements to control the product development process in terms of tasks and organization by means of contents focusing on project management (row 3). As well, the process of identifying customer needs and translating them into design specifications is common across all universities (row 5). For what concerns the tools and the approaches used to manage the product design process, all the above classes held at the partners' institutions focus on PLM/PDM systems for data management and on CAD modeling tools to cover the essential part of creating solutions models via design representations that might convey project-related contents (rows 6 and 7). All the courses address the generation of solutions in different ways, as for these topics the commonalities are less marked. Ljubljana and Zagreb proposes design creativity methods and approaches, while the other two partners don't, at least for what concerns the courses presented in Table 1 (row 8). More targeted approaches to the generation of solution cover specific design objectives. On the ne hand, with techniques that might made explicit the problems of usability and estimate the generated solution, such as ergonomics (row 9). On the other hand, with design guidelines that are meant to support the design team to focus on specific objectives during the product life-cycle, like environment, manufacturing, reliability, safety, ergonomics, robustness, and maintenance (row 10). Additionally, embodiment design, detailed design and application of design principles are emphasized across the universities (row 11).

It is also worth mentioning that some topics are presented just by one of the partners, as in the case of prototyping (row 12), here to be meant as physical or hybrid prototyping; to be strictly distinguished from Virtual Prototyping, which is here considered as part of the topics addressed by lectures on Computer-Aided tools. Intellectual property and patents, as a teaching topic, is also delivered by the University of Zagreb only (row 4), while it is known that other partners address the same topic in different courses that are not considered here.

This analysis, together with the one presented in Table 2, makes it possible to figure out how the 4-partner-shared digital class on mechanical engineering product development should be planned and structured. This planning is detailed in the next subsection and it will serve as the necessary input to use the CResDET framework, as it will be presented in Section 3 of this document.

2.4. DEFINITION OF COMMON TOPICS AND LEARNING OUTCOMES

Beyond what is presented in Table 2 and Table 3, the definition of ILOs and the related topics cannot be done simply by selecting the common elements between the four institutions as each of them could decide to invest more on some themes and less on other ones. That simply represents the starting point for planning objectives and topics with a more comprehensive definition of the digital course, as this could potentially require some crucial elements that initially did not appear among the ones on which the partners converge, but that, in the end, is essential for a complete overview of the mechanical engineering design process.

With reference to the (revised) Bloom's Taxonomy (Figure 2) that is explicitly mentioned in the CResDET framework, it is possible to restate the shared Intended Learning Outcomes explored in Table 2 in a more structured and repeatable way. Some of the ILOs belong to the lower part of the pyramid of the Bloom's taxonomy as these are the elements that all the other skills are built on. As a consequence, the higher levels of the pyramid entail with skills and competencies that are based on the interiorization of the theoretical concepts that are characteristics of the pyramid basis.

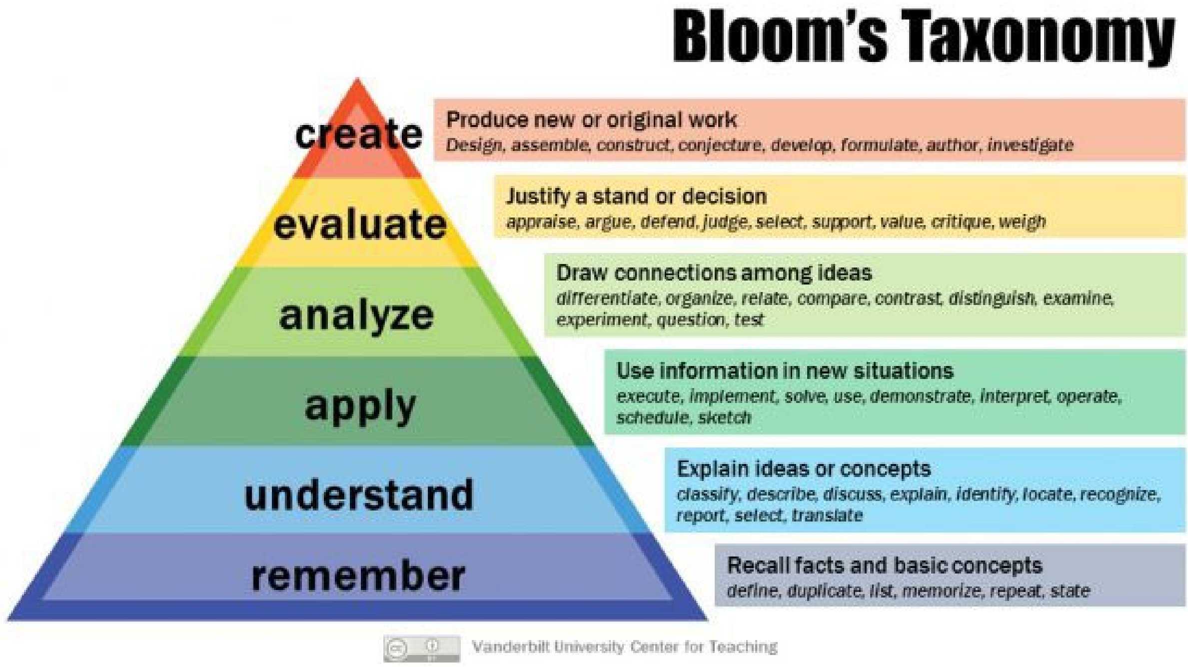

Figure 2: The revised Bloom's Taxonomy that can be conveniently used in order to define the Intended Learning Outcomes

To this purpose the list of ILOs collected in Table 2 can be conveniently reorganized as a set of specific ILOs for the digitalized edition of the reconciled course on Mechanical Product (Engineering) Design. Table 4 presents a schema that aims at clarifying this connection (some of the generealized ILOs in the first column have been grouped together because they both contribute to the redefinition of multiple ILOs). Still on the link between the right and the left columns, it is worth noticing that the same generalized ILO on the left might generate one or more specific ILOs for the unified course. For the sake of completeness, the meta-ILO about the "Practical application of learned concept" is not reported in Table 4 – left column, differently from Table 2. The reason is that this meta-ILO describes that all the courses require their students not just to remember ad understand the main concepts they are exposed to, but also to learn how to put that knowledge into practice. This is, therefore, potentially applicable to all the other generalized ILOs, therefore these ILOs abut knowledge applications are already embedded in the right column of Table 4.

Table 4: Summary of the "high level/generalized" ILOs shared by (most of) the four institutions and a list of specific ILOs to be used in the digitalized version of the course on Mechanical Product (Engineering) design.

Generalized ILOs	Redefined Learning outcomes (Bloom-based)
• Understanding the importance and the process of product development	• Remember and understand the structure, the phases and the impact of the product development process
• Knowledge of the engineering design process	• Remember and understand the basic concepts behind the engineering design process (i.e. analysis, synthesis, evaluation)
• Getting familiar (know or use) design methods and techniques • Problem-solving skills in the field of mechanical engineering	• Remember and understand design methods and tools for problem analysis, idea generation, combination and evaluation • Apply design methods to generate ideas • Apply design methods to create product concepts by combining them together, • Apply design methods to evaluate, compare and select product concepts
• Understanding user needs and engineering specifications	• Analyze the context of application for a solution and the characteristics of potential users • Create a list of engineering requirements that aims at fulfilling the needs emerged in the context of application
• Use of CAD/CAE systems and data exchange formats • Role of prototyping	• Remember and understand the CAD modeling approaches and the criteria to set, run and interpret CAE analyses • Create parametric 3D CAD models of parts and assemblies • Analyze 3D CAD models to anticipate potential design problems to address

In addition to this, there are additional ILOs that one should consider also with reference to the typical dynamics that every course set between the teacher and the students and within the students themselves. These elements are not yet fully integrated within the list of ILOs provided by each institution, but at the same time the introduction of group work and team-based exercise lead to a completely new class of ILOs.

Therefore, "Remember and Understand the challenges of the product development process, its methods and tools as well as of team work and team dynamics" has to be included in the list of ILOs for what concerns the ones belonging to the categories of "knowledge and understanding" (remember/understand). At the same time, this acquisition of knowledge needs to be also practiced by means of occasions to "Apply techniques for ensuring appropriate relationship between team members and efficient delivery of tasks".

The same logic is applicable for the definition of the contents of the course, i.e. its syllabus. From this perspective, it is possible to use the reconciled list of topics presented in Table 3. However, it is also possible to proceed in a more traditional way, so that it is on the educator to choose the appropriate contents for the topic of the course, given the set of ILOs defined for the learners.

Table 5: List of topics to include in the syllabus for the digitalized course across the four universities. Left column: generalized topics/thematic items belonging to the four courses; right column: specific topics to present in the unified digital version to propose.

General topic/theme in the syllabus	Topics to be included in the new syllabus
Understanding of the Product Development Process	• Product development process: sequence and goal of phases, type of information to process
Engineering Design Methods (including Design for X, Creativity for Solution Generation and user/customer requirements)	• Approaches to goal/objective/requirements definition (e.g. Persona method) • Design Concept Mapping (OTSM-TRIZ Network of Problems) • Idea Generation techniques (Design-by-Analogy, bio-inspiration)
Project Management	• Project Management: organization in WP, tasks, human resource allocation and timing, responsibilities
Intellectual Property & Patents	• Market Analysis • Competitor Analysis • Patent search, patent landscaping, patent inspiration
Product Lifecycle Management and Product Data Management	• Data and Information processing in the Product Lifecycle;
Computer-aided Tools & (Virtual) Prototyping + Ergonomics	• Parametric CAD Modeling • Modeling for CAE and FEM simulation logic • Virtual Mannequins
Detailing & Embodiment Design	• Product Layout • Parts interfaces and related characteristics for product functionalities

The defined course topics cover effectively all the shared topics that the four universities respectively present in their own courses and, from a comprehensive perspective, they also equip learners with the necessary toolkit of methods and tools, beyond knowledge and skills, to cover the whole product development process.

In fact, these enable students to tackle an ill-defined design problem, provide a more appropriate formulation for it and characterize design goals and objectives in terms of user demands ad engineering requirements by means of a comprehensive exploration of the market, including the competitors and the solutions that IP rights protect. The syllabus also include topics, methods and tools that enable the generation and the mapping of design concept as they evolve during the project, so to support both the conceptual design stage as well as the subsequent steps of the product development process. Design issues, furthermore, can be foreseen by means of virtual prototyping: the course equip students with knowledge and skills about CAD modeling (and related tools) and as well as the different opportunities offered by CAE systems, thus including the ones that produce finite element simulations as well as for the interaction with humans for understanding problems of ergonomics, where relevant.

The topics mentioned in the right column of Table 5, together with the ILOs presented in the right column of Table 4, thus represent the core elements that characterize the digital course on Innovative (Mechanical) Product Design Engineering. Essentially, it is a course for mechanical engineers of an undergraduate study program, coherently with the four classes that the different institutions carry out independently. At the same time, the general structure of the same and its capabilities to cover a complete, or almost complete, product development process makes it also suitable to be delivered for students of a graduate study program that haven't been exposed to these concepts or would like to reinforce/consolidate its knowledge and skills.

Furthermore, these are also the necessary entry points to fully leverage the CResDET framework for the digitalization of courses (in the event of a crisis). The next section aims at clarify how the current set of ILOs and topics should be considered when designing a class that will be delivered at least partially by means of digital means. This example will also serve as a test bench as it will face direct application during the project execution (and beyond).

3. APPLICATION OF THE FRAMEWORK

The application of the framework in this section is divided into three main subsections, coherently with the framework structure which is, indeed, organized into three main phases as depicted in Figure 3. The first one aims at defining the characteristics of the crisis scenario, such as the specific conditions that educators and learners should comply with for accessing knowledge, materials and infrastructures. The second one corresponds to the investigation of the content domain, as it considers both the limitations imposed by the crisis and the constraints that the course topic define for its implementation. During this stage the educator aims at checking how to best implement all the contents given that the class will be composed, most probably, by different profiles of learners (despite their background can present strong similarities on the core topics of mechanical engineering). This will make it possible to structure the layout of contents and the specific way of delivering them in order to maximize the achievement of the Intended Learning Outcomes.

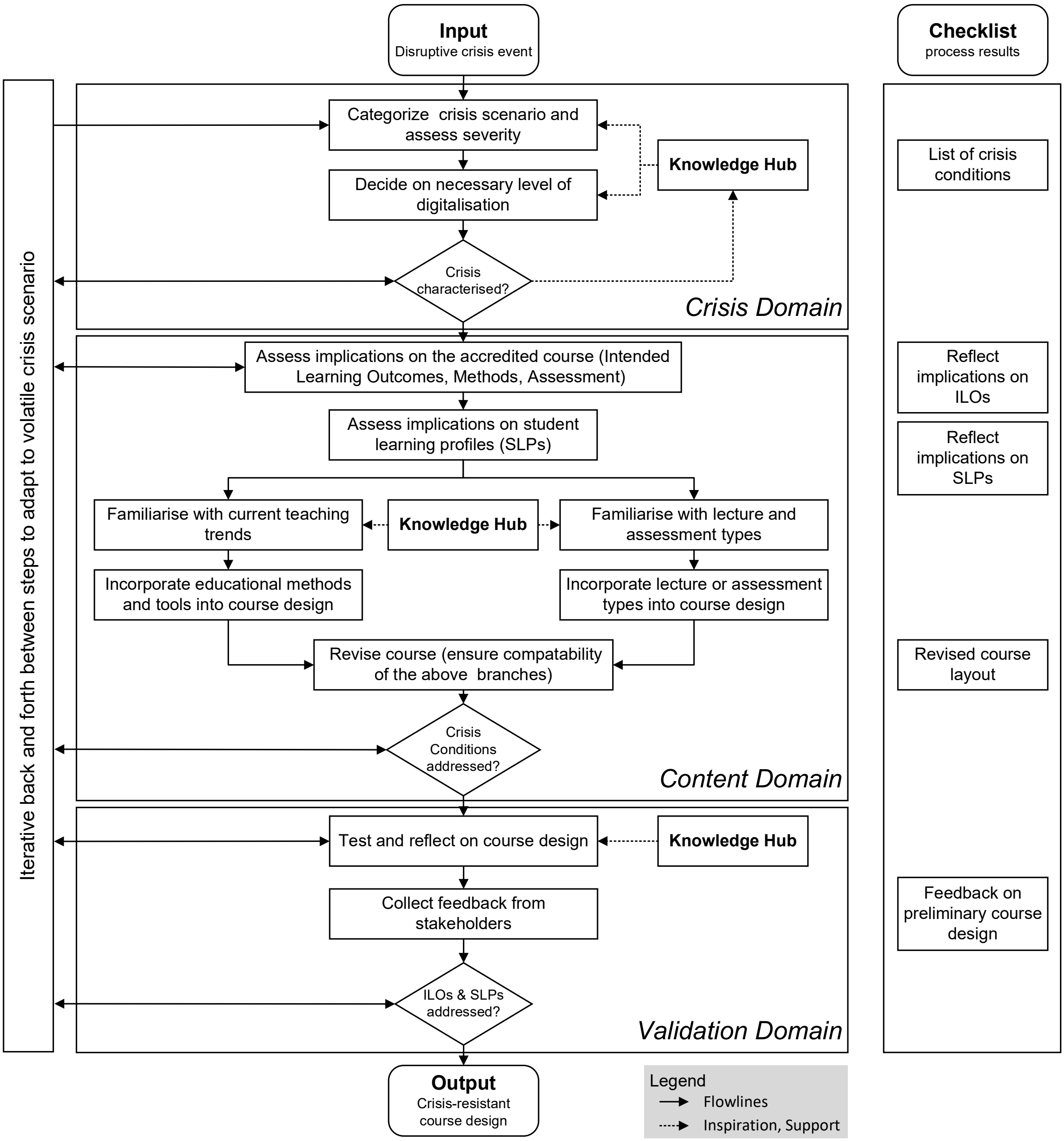

Table 6: The CResDET framework and its three main steps for the digitalization of courses in crisis scenarios.

The third and last stage of the framework concerns the evaluation/validation of the newly designed course. This can take place both before or after the course implementation. In the first case it will be a qualitative evaluation that educators can typically carry out by means of expert colleagues' opinion that already faced similar challenges in previous experiences, so that they can check the soundness of the course structure with reference to topics and ILOs. In the second case, the overall validation of the class can be carried out by a wider set of stakeholders, depending on the way the course will be delivered. These will provide an ex-post evaluation on the real implementation of the course according to a multitude of perspectives (e.g. adequacy of ECTS with reference to the required workload; adequacy of teaching methods and tools; capability of learners to reach the ILOs, etc.).

3.1. CRISIS DOMAIN

As briefly mentioned above, this part aims at characterizing the crisis scenario, which means that the different conditions creating constraints for the education "as planned" have to be defined according to the guidelines/categories provided at CResDET Framework webpage about crisis scenarios.

As mentioned in the introduction, the progressive release of COVID restrictions in the beginning of 2022 (second semester of AY 2021/2022) for most of the teaching activities significantly reduced the opportunities of showing a meaningful application of the CResDET framework to a real crisis scenario. However, what shown in the Section 2 of this document creates the opportunity for a real implementation of a digital class that links learners from four different institutions in an almost completely digital environment.

The nature of this class has to be compulsory digital as there are no opportunities to allow learners from sufficiently distant institutions to interact live in the same physical space continuously over a whole semester. This crisis-like scenario has specific conditions that might be relevant to consider when planning the expected degree of digitalization of the course. The following items in Table 6 characterize such crisis-like scenario that joins four academic institutions from four different countries to deliver a single digital class on Mechanical Product Design suitable for an undergraduate Mechanical Engineering study program.

Table 6: Categorization of the crisis-like scenario

Category	Subcategory	Condition/description, impact and explanation
Freedom of Movement	**Not applicable**	**Condition:** "Restriction of international movement" **Impacts and consequences:** Educational activities that require international movement are only possible with restrictions. If these restrictions cannot be met in an appropriate manner, education needs to take place on a national or digital level. **Explanation:** This digital course enables the international mobility of students for a few days (4 to 6) in a semester. The remaining part of the semester the students are typically set at their own institutions for regular classes, each of them with potentially different timetables.
Power	**Availability**	**Condition** "No issues"

		Impacts and consequences: No impact **Explanation:** The general freedom of movement for students enables them to easily relocate to different buildings equipped with workstations or where they can power up personal laptops to work with tools for many different purposes (e.g.: communication, concept mapping, CAD modelling, etc). Other equipment, such has machining tools are not necessary, nor the ones for tangible prototyping (e.g. 3D printing).
Connectivity	**Telephone connection**	**Condition** "No issues" **Impacts and consequences:** No impact **Explanation:** There will be no problems with the telephone or mobile phone connection, beyond reasonable expectations. This means that voice communication will be possible for all the stakeholders without particular limitations.
	Internet connection	**Condition** "No issues" **Impacts and consequences:** No impact **Explanation:** Students will experience no specific limitations in accessing the internet and its contents, services, etc. The concurrent availability of rooms equipped with cabled connection at the different institutions as well as the general availability of the universities' wireless network(s), makes the scenario of prolonged internet connection issues unreal. Backup solutions, beyond what mentioned, include also mobile-based connection.
Institution	**Physical access**	**Condition** Partial access **Impacts and consequences:** Students from foreign institutions cannot attend the lecture carried out by staff physically based in one of the four locations **Explanation:** Learners will have physical access to their institutions, locally. However, professors/educators will deliver in person lectures just to those students physically based in the same institution (nation). Students from the other three institutions cannot participate in real life.
	Online access	**Condition** "No issues"

		Impacts and consequences: No impact **Explanation:** All the four institutions kept the ICT infrastructure that they implemented to face the COVID19 pandemics. Virtual rooms are made available to all students also between different institutions. Some potential risks might be considered for accessing servers for CAD tools licenses.
Learning resources	**Physical availability**	**Condition** "No issues" **Impacts and consequences:** Small needs to adjust the choice of learning resources due to different conditions at the four universities. **Explanation:** The physical learning resources in this case are books and manuals that students might find at their own libraries ("shared" book titles take priority) as well as the workstations that will make it possible for them to interact with CAD tools (same or similar CAD tools should be chosen to minimize issues due to compatibility – except where explicitly required).
	Online availability	**Condition** "No issues" **Impacts and consequences:** No impact **Explanation:** As for the online access, the infrastructure for remote communication is still in place in all the universities and all of these also include multiples services, such as file sharing systems, etc. These ones in most of the cases already store many contents that can be used for teaching/learning (e.g. slides, short books excerpts, schemas, templates), but can also host new and adapted versions tailored for this course specifically.
	Physical access	**Condition** "No issues" **Impacts and consequences:** No impact **Explanation:** As for the access to the institution, also the physical access to learning materials can be restricted due to the four different locations the course attendants might be at. As per the availability, learning materials should be accessible indistinctly to each student and therefore suggested readings just available as hard copies (typically books) will be suggested among university shared book titles

		or among books whose contents are quasi-equivalent. No issues are foreseen for the accessibility to CAD rooms for 3D modelling and simulations.
	Online access	**Condition** “No issues” **Impacts and consequences:** No significant impact **Explanation:** Most of the hard copies of learning materials are often made available and accessible to all the students via university learning platforms or university library online service. With available network connection and physical access to systems to navigate the internet, there are no limitations. Similarly for what concerns other learning materials/sources.
Personnel	**Availability**	**Condition** “No issues” **Impacts and consequences:** no impact **Explanation:** There is no specific lower limitations regarding the availability of educators. In fact, the course require the involvement of teaching and training staff to support the students’ activities during the whole semester. The limitations concern the upper limit, which is comprised between 1 and 2 staff members per institutions
Equipment	**Availability**	**Condition** “No issues” **Impacts and consequences:** Small needs to adjust the choice of rooms to host all the students and their equipment. **Explanation:** The fact that the four institutions are geographically distributed might potentially affect the execution of some activities. While these issues are negligible for standard classes, this could be harsher to face with CAD equipment. However, the four partners have similar CAD labs equipped with CAD modeling tools and CAE systems to run basics simulations. The issue to consider here, as mentioned for the physical availability of learning resources, will be the availability of licenses for the same computer-aided tool among the four institutions.
	Suitability	**Condition** “No issues” **Impacts and consequences:** No impact

		Explanation: As this class derives from a meaningful and comprehensive subsets of ILOs and thematical contents of courses delivered by the four institutions, there are no issues with the suitability of the equipment, both for shared physical spaces and virtual ones.

As a partial conclusion, it appears that the framework helped in spotting potential organizational issues due to the geographical distribution of course participants across the four countries composing the consortium. The potential impact of these crisis-like restrictions will help defining the next step, which concerns the level of digitalization as available on the related CResDET Framework webpage.

Table 7 reports the information concerning the different levels of digitalization that an educator should consider, given the crisis induced restrictions, in order to carry out proficiently what is planned, in general terms, for the ILOs and syllabus of the course. The specific characteristics of the digitalized version of the course on innovative mechanical product design for engineering designers (Mech Eng undergraduate level or more) include a short term mobility that makes it possible for participants to gather in the same location and participate in course activities. Therefore, the course cannot be considered completely held in a virtual classroom, but it is surely carried out for more than three-quarters of the time online.

Table 7: Level of digitalization

Name	Description
No technical support	Classic lessons without technical support.
Technology-enhanced learning (< 25% online)	Classic lessons with minor technical support (e.g. PowerPoint). The lesson is not changed at its core, and there is no reduction in the required presence.
Blended learning (25% to 75% online)	Combination of classic lessons with computer-aided learning and teaching (e.g. via the Internet). Presence phases and e-learning phases alternate and complement each other.
Online learning (> 75% online)	Mostly computer-aided learning without physical presence. The online lessons are supported with sporadic physical lessons (e.g. assessment periods).
Fully virtual Classrooms (100% online)	The educators and students are only connected via digital media. The processing of the contents takes place exclusively via electronic means.

In summary, the framework helped to spot the following elements that the consortium should consider during the design of the digital course:

- Students/course participants and course stakeholders more in general, mostly cannot move, except locally. The only chance to share a common physical location takes place during the short-term mobility of the Erasmus+ project course.
- Differences in "standard" university course timetables at the different locations might trigger frequent overlaps with the timing of the activities of this digitalized course.
- Rooms for the course activities should be chosen in order to host all the "resident" participants with sufficient space, seats and equipment when there is no short-mobility in place.
- Rooms for the course activities should be chosen to host all the course participants with sufficient space, seats and equipment when short-mobility is in place.
- Learning materials should be made available mostly as online resources in order to facilitate the accessibility and the harmonization of knowledge among the four institutions. Hard copies of learning materials should be selected by giving priorities to books (or else) that each single institution owns.
- CAD/CAE tools, as well as other online tools or services, should be chosen so that they facilitate online interaction among participants and minimize issues due to communication barriers (e.g. same or compatible CAD tools among the four institutions).

With this preliminary set of requirements to satisfy, which are the implications due to the crisis-like scenario just characterized, and the above presented sets of ILOs and course contents (section 2), it is possible to address the content domain.

3.2. CONTENT DOMAIN

This part of the framework aims at supporting the design of the course contents and organization during the semester in order to facilitate the participants to achieve their ILOs. Moreover, it targets also the different learning profiles of the participants, by categorizing them into four main categories as for Mumford and Honey. This step about Students' Learning Profiles (SLPs) is essential as it progressively steers the selection of the most appropriate approaches, methodologies/methods and tools, also with reference to the limitations emerged during the characterization of the crisis scenario.

The list of educational items (which is here used as an umbrella term for approaches, methodologies, methods and tools, as the same item is identified in different ways depending on the source) provided on the CResDET webpage can support the abovementioned selection. For instance, it helps learning some useful details about these items and screening which of them are suitable for a physical and for a blended/online/virtual environment (and which ones for both). It is complemented by the matching of educational items with the most suitable learning style these facilitates, which kind of lecture type this is suitable for and the expected/possible degree of digital implementation in case of crisis scenario induced limitations. Through such characteristics, it is then possible to define the course implementation plan (details in subsection 3.2.1).

The unified ILOs and the related course contents have been already presented in section 2. At that time, the connections between ILOs and course content was not made explicit. It is done here below, in Table 8, to visualize how these are linked to each other, in order to facilitate the selection of suitable education items to address them.

Table 8: ILOs and Syllabus topics. ILOs and topics in the same row are linked.

Redefined Learning outcomes	Topics to be included in the new syllabus
• Remember and understand the structure, the phases and the impact of the product development process • Remember and understand the basic concepts behind the engineering design process (i.e. analysis, synthesis, evaluation)	• Product development process: sequence and goal of phases, type of information to process
• Analyze the context of application for a solution and the characteristics of potential users • Create a list of engineering requirements that aims at fulfilling the needs emerged in the context of application	• Approaches to goal/objective/requirements definition (e.g. Persona method) • Market Analysis • Competitor Analysis • Patent search, patent landscaping, patent inspiration
• Remember and understand design methods and tools for problem analysis, idea generation, combination and evaluation • Apply design methods to generate ideas • Apply design methods to create product concepts by combining them together, • Apply design methods to evaluate, compare and select product concepts	• Design Concept Mapping (OTSM-TRIZ Network of Problems) • Idea Generation techniques (Design-by-Analogy, bio-inspiration)Project Management: organization in WP, tasks, human resource allocation and timing, responsibilities
• Remember and understand the CAD modeling approaches and the criteria to set, run and interpret CAE analyses • Create parametric 3D CAD models of parts and assemblies • Analyze 3D CAD models to anticipate potential design problems to address	• Parametric CAD Modeling • Product Layout • Parts interfaces and related characteristics for product functionalities • Modeling for CAE and FEM simulation logic • Virtual Mannequins • Data and Information processing in the Product Lifecycle;

This set of learning objectives and topics represent the entry point to address all four different learning styles as for Mumford and Honey, coherently with Kolb's cycle. These are associated with 4 learning styles depending on the specific kind of activities each individual is familiar with. Figure 4 presents a graphical summary of these learning styles, as available at the related CResDET webpage.

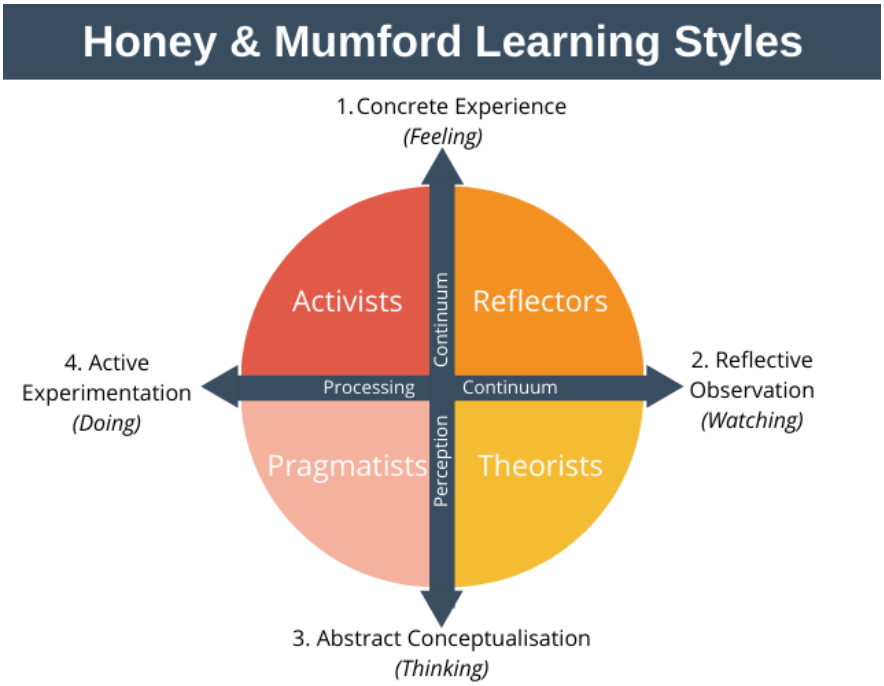

Figure 3: The learning styles by Mumford and Honey (learning profiles in the four quarters)

The brief description of the four learning pofiles is here reported for sake of completeness.

- **Activist learners** mostly acquire knowledge and skills through a learning by doing approach, with an active engagement in new activities and experiences, despite they get bored with implementation and longer-term consolidation.
- **Reflector learners** need to elaborate on what they observe which means that they do not necessarily need to experience in first person new situations and that potentially they mostly benefit from comparing different experiences before they draw definitive conclusions.
- **Theorist learners** have a natural preference towards more abstract concepts that describe the contents they need to learn, which they assemble into a rational pattern (e.g. a model) that they build with analysis and synthesis.
- **Pragmatist learners** mostly tend to acquire knowledge and skills if these have a direct and usable implication in the real world and in their own life: they want to check experimentally their applicability and their usefulness through direct practice.

Therefore, in order to facilitate the learning of all the possible profiles participating in the digital edition of the mechanical product design, the activities should be organized according to a blend that mixes purely theoretical moments (such as traditional ex-cathedra lectures) with more student-centered methods that leverage active learning and that the framework should help to select/define.

The list of educational items provided on the CResDET website is too wide for being reported here completely, therefore this document here below simply summarizes what are the main criteria used for the selection of the educational items and the rationale that facilitated linking them to specific learning styles.

The course should be designed so that it includes traditional learning activities for the introduction of new concepts that the learners are not yet aware of, in order to satisfy the theorists and stimulate other learning profiles to familiarize with different learning styles.

The pragmatists should be also left sufficiently free to benefit from theoretical concepts proposed in ready-to-use formats that enables their direct application in context and with their peers. Likewise, theorists as well as other learners will become closer to learning style they are not so used to.

The introduction of concrete experiences in the mix of project activities will, in turn facilitate both the activists and the reflectors to learn more quickly, especially for what concerns their interaction with peers, in a real-like operational context. Of these mutual interactions could also benefit theorists and pragmatists, who can share their partially consolidated learning. These practical activities also provide room for ex-post reflections that help interiorizing concepts via first hand observation and conceptualize the learning at a more abstract (and thus more flexibly usable) level.

The course to digitalize, then, should be promisingly organized as a Project-Based Learning educational initiative for several good reasons:

- The course is about product development and the related activities typically takes place in project-based context also in real life scenarios;
- Some specific profiles of learners mostly benefit from concrete experiences as a design project could provide;
- Learners from four different institutions should participate in the course and the ILOs also include the acquisition of design skills in teams;
- Design projects enable the administration of work and enable practicing project management, together with the distribution of responsibilities.
- Design projects will provide students/participant with real constraints to the exectution of the activities (e.g. un/availability of information, industrial secrets, confidentiality, hard deadlines, etc.)

Then, all the course topics, as mentioned above, are to be presented as ex-cathedra lectures before the learners are required to apply such knowledge in simple examples/exercises or project task. The planning of the topics should coherently follow the typical sequence of phases of a product development process in order to adhere as much as possible to a real-like product development scenario.

Some of the lectures or part of their contents should be framed in the form of tutorials or commented examples that pragmatists might try to adapt to the project at hand, for the specific goals it has to attain.

Participants should also have the chance to deep dive in real-like activities, which means that beyond sharing similarities with regular industrial projects for technical goals, they can also experience similar working conditions, e.g. time pressure or endless design sessions to solve urgently some problem. From this perspective, the real-like experiences should also be capable of reflecting the main characteristics of the stages of a product development process, so that learners become aware of their peculiarities, coherently with the ILOs mentioned in Table 8.

As the work proceeds during the project by means of the students' teamwork, it will be necessary to also introduce some guided activities that enable the participants to critically reconsider what they did. This should facilitate to check how well the participants performed individually and as a team. Moreover, this makes it possible to verify if the participants' expectations about their work is aligned or matches the expectations of the people who set the project goals (educators and other stakeholders, e.g. a company providing a case study/design challenge for the project).

Among the 70+ educational items mentioned in the table linked at the beginning of previous page, therefore, the consortium picked the following approaches/methods and tools to deliver the course contents, organize its activities and address the needs of different learners, by type. The link is made explicit in the following list, which so far presents the selected educational items in alphabetical order as their appropriate sequence will be defined in the implementation plan.

- Appointment with students (Reflectors/Theorists)
- Brainstormings (Pragmatists/Activists)
- Collaborative learning spaces (Pragmatists/Activists)
- Field trips (Activists/Reflectors)
- Group discussions (Reflectors/Theorists)
- Hackathons (Pragmatists/Activists)
- Market research (Pragmatists/Activists)
- Network of problems (Pragmatists/Activists)
- Peer-partner learning (Activists/Reflectors)
- Problem solving activities (Pragmatists/Activists)
- Reflective discussions (Reflectors/Theorists)
- Team projects (Pragmatists/Activists)
- Technical drawings (Activists/Reflectors)
- Video lessons (Theorists/Pragmatists)
- Video creation (Pragmatists/Activists)
- Virtual prototypes (Pragmatists/Activists)

This list clearly shows that every educational item is suitable for two type of learners as they mostly entail activities that span more profiles. These also have different complexity level (for a short description please refer to the table available on the CResDET website) and therefore the ones which enable the flexible introduction of sub activities enables a wider set of learning styles to be covered.

Figure 4 provides a graphical overview of the main elements selected with some options for the implementations within the overarching structure of the Kolb's cycle and the learning styles by Mumford and Honey.

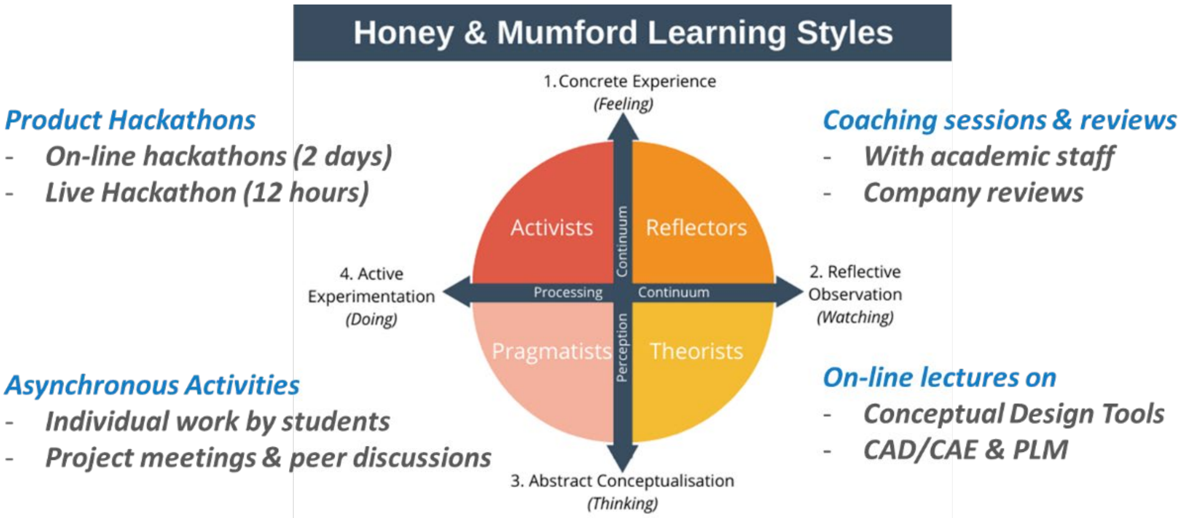

Figure 4: Allocation of educational items with reference to learning styles and Kolb's cycle stages.

These ones have now to be organized into a coherent structure of contents and activities that enables the students to learn progressively and implement in practice what they learn, with the pace set by the phases of the product development process and its stages. This is described in the next subsection.

3.2.1. COURSE IMPLEMENTATION PLAN

The course needs to be implemented so that the students are progressively exposed to contents and topics that are relevant for the specific stage of the product development process they are facing. At the same time, the implementation of the course should also provide every learner with opportunities to face activities that are both familiar and unfamiliar with its preferred learning style. To do so, the course is organized so that every stage or phase of the product design process (here organized in its three first phases: fuzzy front-end, conceptual design, embodiment design) includes:

- theoretical lectures;
- individual work to carry out, present and discuss with peers;
- active learning activities as product design hackathons; and
- moments of reflection with supervisors/coaches and field experts for the product design project they are facing.

The course span a whole semester of activity, during the teaching period of the same (approximately 3/3.5 months ➔ 13/14 weeks of activities, excluding breaks for holidays). Within this period, the whole course should be completed together with all the activities related to the design project.

The following bullet list describes the implementation plan for the course, organized coherently with the above presented rationale.

1. General introduction (Kick-off of the course - remotely)
    a. Presentation of the course goals
    b. Presentation of the design project theme and the partner company business domain
    c. Presentation of the engineering design process methodology and its articulation throughout the course
    d. Presentation of design teams (5 x 8pp or 4 x 10pp with 40 attendants and 6 to 8 coaches assigned to specific teams)
    e. Presentation of the course implementation and project phases
2. Fuzzy front-end (4 weeks approximately – fully remotely)
    a. Lectures/Tutorials (2h max each, multiple contents can be delivered in the same lecture/tutorial) on
        i. Project Planning and Management
        ii. Market Analysis
        iii. Patent search and patent landscaping
        iv. Competitor analysis
        v. Persona Method
        vi. Product Vision definition
    b. Individual application of concepts in asynchronous activities and peer discussion on interim findings (weekly based)
        i. Project workplan
        ii. Extrapolation of market alternatives, trends and arena of players
        iii. Identification of existing opportunities for patenting
        iv. Identification of target patents to be used as inspiration
    c. Product Design Hackathon (2 days, 4 hours each)
        i. Identification of market opportunities
        ii. Definition of relevant user profiles to match those opportunities
        iii. Identification of promising directions for product development (in terms of its elementary characteristics
    d. Reflective observation activities
        i. Meeting with coaches (weekly based, in collective gatherings)
        ii. Design review with field experts from the company (after the end of the design hackathon)
        iii. Reflection on the whole stage and its implementation to extract the lessons learned (after the design review meeting, with coaches)
        iv. Consolidation of the product characteristics to steer the conceptual design stage (after the design review meeting)
3. Conceptual Design (4 weeks approximately)
    a. Lectures/Tutorials (2h max each, multiple contents can be delivered in the same lecture/tutorial) on

        i. Functional modeling
        ii. Requirements formalization
        iii. Concept Mapping and Network of Problems
        iv. Design by analogy and bio-inspiration
        v. Problem solving techniques and design conflict resolution heuristics
        vi. Concept combination via morphological matrix/table
        vii. Concept evaluation
    b. Individual application of concepts in asynchronous activities and peer discussion on interim findings or brainstorming work for idea generation (weekly based)
        i. Project workplan
        ii. Transformation of user requirements into product requirements (engineering, (non-)functional, etc.)
        iii. Definition of product functions
        iv. Identification of alternative solutions to address those functions
        v. Organization of concepts into an ordered and coherent map (Network of Problems)
    c. Product Design Hackathon (2 days, 4 hours each)
        i. Identification of opportunities for partial solutions combination
        ii. Generation of multiple product alternatives
        iii. Selection of the n (4) best alternatives among the identified product profiles for development
    d. Reflective observation activities
        i. Meeting with coaches (weekly based, in collective gatherings)
        ii. Design review with field experts from the company (after the end of the design hackathon)
        iii. Reflection on the whole stage and its implementation to extract the lessons learned (after the design review meeting, with coaches)
        iv. Selection of the best product design to further develop coherently with the experts' review outcome to proceed with the embodiment design stage (after the design review meeting)
4. Embodiment Design (4 weeks approximately)
    a. Lectures/Tutorials (2h max each, multiple contents can be delivered in the same lecture/tutorial) on
        i. 3D modeling generalities
        ii. 3D parametric CAD modeling for parts and assemblies
        iii. 3D parametric CAD modeling best practices
        iv. CAE tools and parametric CAD modeling for the same
        v. Opportunities offered by module for Ergonomics
    b. Individual application of concepts in asynchronous activities and peer discussion on interim findings (weekly based)
        i. Project workplan

        ii. Organization of the product hierarchy of parts and preliminary Bill of Materials
        iii. Definition of main parts dimensions and interfaces/assembly sequence
        iv. Development of preliminary 3D models for product parts
        v. Creation of elementary sub-groups/sub-assemblies
        vi. Identification of already marketed components to embed in the solution
    c. Product Design Hackathon (12h continuously in a equipped room at one of the consortium partner university)
        i. Team refinement of product parts in 3D models
        ii. Team design and 3D modeling of new product parts
        iii. Team creation of 3D assemblies in a shared environment
        iv. Setting CAE simulations (or its main parameters), depending on the specificity of the proposed project
        v. Preparation of preliminary product documentation
    d. Reflective observation activities
        i. Meeting with coaches (weekly based, in collective gatherings)
        ii. Design review with field experts from the company (after the end of the design hackathon)
        iii. Reflection on the whole stage and its implementation to extract the lessons learned (after the design review meeting, with coaches)
        iv. Definition of the last steps to refine the solution and present the project results (after the design review meeting)
5. Final presentation of the project results (1 week)

The last stage does not have any frontal lecture and the constructive feedback about the last steps of the project are carried out by coaches in frequent but short review and alignment meeting before the final presentation of the generated solutions, together with the partner company representatives that also contribute to the evaluation of the team work. The final presentation, as well as the other events are carried out remotely by means of ICT tools for communication.

On the contrary, one additional event takes place during the semester within the timeframe of the Erasmus+ short-term mobility. The students have the chance to visit the factory/company building/offices of the partner company that provides the design project theme for the semester work in real life. The selection of the industrial partner, from this perspective, should be conveniently done in the same country where the hosting HEI is located.

ICT tools also facilitate the implementation of the course. A shared working space that effectively demonstrated to allow students to

- flexibly note ideas and concepts;
- create maps;
- organize hierarchies of information with original organization of the same; and

- generate meaningful schemes;

to help design activities in earliest stages of the product design process is MIRO. However, other commercial alternatives are available to offer a blank space to populate with templates and standard concept holders.

For what concerns the CAD tools, OnShape by PTC flexibly enables multiple users to work on the same file at the same time, thus bypassing many check-in/check.-out limitations of many PLM software. Other options by different CAD manufacturers are also available and the choice should favor the flexibility of use in collaborative contexts. Specific CAE applications might not be available in online collaborative CAD tools. In such cases it is advised to rely on locally available resources. This also offer the opportunities to highlight to learners the importance of neutral file formats for data interoperability among different CAD tools.

3.3. VALIDATION DOMAIN

The third and last step of the CResDET framework brings the design of the digitalized education to its evaluation stage. This evaluation can take place in two different instants. Before and after the implementation of the course. Depending on the available knowledge to do this beforehand (expert design educators should be available for a third party assessment and suggest correction), it is always advisable to run the validation of the course during or at least at the end of the implementation.

The specific case presented in this document would obviously benefit from a third party evaluation as every design course. However, this step has been skipped as the design of the same involved at least 2 to 5 people from the different partner institutions. This means that this is the result of the harmonization of knowledge and perspectives by a large panel of experts, which should reduce the chances of potential thematic or organizational flaws.

The in-vivo or ex-post validation has been carried out with reference to the real possibility to collect the data about the students activities during the project, which can be significantly different from each other, depending on the specific vision each team of student decides to work on. Moreover, the nature of this course, which is almost completely carried out virtually via remote communication and collaboration systems does not facilitates the monitoring of students involvement, engagement and contribution.

However, OnShape provides a sort of log files of user activities during their interaction with the CAD tool. Therefore, these data have been captured during the live hackathon, carried out during the third phase of the project (Embodiment design).

As a general example of how the collected data can support the validation of the class, Figure 5 presents diagrams describing the degree of interaction the students had with OnShape during the third Hackathon in Vienna, where they worked all together, in teams, to define a draft assembly of their solution in a CAD environment. It represents the situation for the five teams, composed by 8 students each, that participated in the course and specifically in the third hackathon.

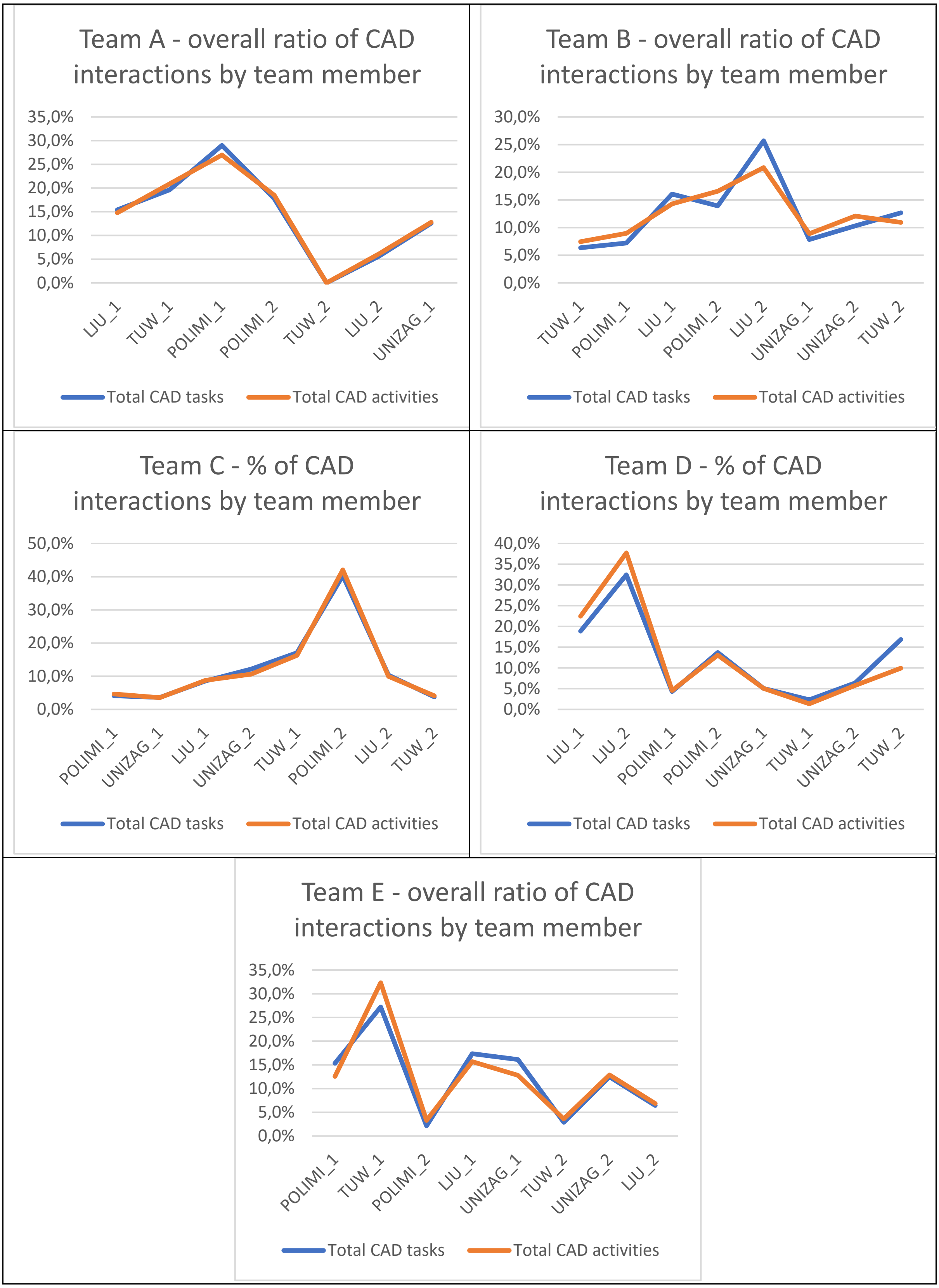

Figure 5: Diagrams of interactions for the 5 teams participating in the design project/course

All the participants, at the end of the course expressed great appreciation both for the topics of the course as well as for its mix of educational activities, which are uncommon in traditional courses. A plus for them is surely the short-term mobility, which also recalls the importance of physical interactions whenever constrained to interact just remotely.

4. REFLECTION ON THE APPLICABILITY OF THE PROPOSED FRAMEWORK

This document presents an example of application of the CResDET framework, for the digitalization of courses in the event of a crisis outbreak. This application specifically focused on the digitalization of a course for (Innovative) Mechanical Product Design for undergraduate students in mechanical engineering.

This choice is due to the need of checking the applicability of the CResDET framework steps and guidelines in a real-like scenario that might present some characteristics of a crisis, due to its innovative nature. The course combines four different universities geographically distributed in four different countries (Italy, Slovenia, Croatia, Austria). These have to create and implement a unique course on the abovementioned topic that is suitable for being participated by students from the four HEIs indistinctly and, by geographical constraints, in a virtual environment due to their distances. After the harmonization of ILOs and course contents across the four HEIs (Section 2), the CResDET framework started providing its benefits.

In section 3 the whole framework is applied by using those harmonized ILOs and course syllabi. The first part of the methodology provides support to frame the crisis(-like) characteristics and fully describe the scenario. These characteristics sometimes appear to be not relevant or poorly applicable to the case at hand. This is an unfortunate, but at the same time inevitable, side effect that enables the framework to be used flexibly in a wider variety of situations. Nevertheless, whenever relevant, the characterization of crisis conditions triggered some non-obvious reflections about space and resource availability for participants. These come particularly in handy when it is time to design the course implementation. Furthermore, the step concerning the definition of the level of digitalization of the course activities will also help to finally check a general compatibility with the crisis-induced restrictions/limitations and impacts and the actual possibility to pick specific educational items in the next stage of the framework.

The content domain is probably the most effective part of the framework to provide support for course design and its digitalization. On the one hand, the previous phase helped the design by setting requirements and constraints for the implementation of the course in a digital environment. On the other hand, the content domain stage enables the education designers to match objectives with education opportunities to synthesize a digital course. Educators can use the content and the related ILOs of the course they want to turn digital and match them with a series of educational items that are potentially suitable to enable different students, characterized by different learning profiles, to get the maximum benefits from the activities it is involved in.

Obviously, the framework suggests opportunities to the designer of the courses, but the explicit mentions to the suitability of educational items for specific activities and learners provide adequate support for the definition of the implementation plan.

The effective applicability of the framework to those that are poorly familiar with the specific characteristics of each educational item included in the CResDET table remains questionable. However, this flaw can be compensated by deepening the knowledge on approaches, methods and tools that appear more promising for the specific course at hand and its ILOs.