Knowledge & Technology Transfer of Emerging Materials & Technologies through a Design-Driven Approach

Deliverable 3.1: Training Contents of the specific teaching methods for each EM&T

Author: **P1 – Politecnico di Milano - Polimi**

@datematseu #datematseu
www.datemats.eu

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Knowledge & Technology Transfer of Emerging Materials & Technologies through a Design-Driven Approach
www.datemats.eu

@datematseu
#datematseu

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EXECUTIVE SUMMARY

This document reports the task 3.1 Training Contents of the specific teaching methods for each EM&T. Each HEIs set up the teaching methods, addressed to Design students, related to its specific EM&T area after the transnational workshop [2.5]. The task took place between M8 and M10, led by Polimi, and involving KEA, Tecnun, Aalto, and FAD.

This task is part of Work package 3, aiming to define a Unique Design Teaching method for the 4 EM&Ts areas. Mainly based on the result of the discussion of the first transnational workshop [2.5], this phase aims at creating the contents of the unique design teaching method for students with a mixed background (design & engineering) in the field of EM&Ts.

According to the Project Description, Deliverable 3.1 consists of the production of Four Academic Syllabus, one for each EM&T containing: Objectives; The applied method (i.e., theoretical lectures, hands-on sessions, brainstorming, creative session, collaboration with companies, team building, etc.); References. It is the direct result of task 3.1 Setting up of the specific teaching methods for each EM&Ts area. It is informed by the output generated for the literature review about EM&Ts methods and knowledge transfers [2.2], the logical framework related to the different EM&Ts methods discussed during the transnational workshop [2.5].

This document introduces the context of Material Education for Design and describes the methodology for the setup of the training contents for the specific teaching methods for each EM&T. In particular, the template used for the Syllabus design is reported. The resulting four Academic Syllabuses are presented and discussed. Conclusions describe future implications of the task in the scope of the project and as a legacy after the completion of the project. The Syllabus template and the four Academic Syllabus are attached as annexes to the document.

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1 INTRODUCTION

Herewith described task 3.1 is based on the formulation of training contents of the specific teaching methods for each Emerging Materials & Technology (EM&T) area. The task uses the current context of Materials Education for Design – continually changing and updating due to the evolution of the discipline and the introduction of newly available materials, new approaches and new teaching methods – as a backdrop, and the Datemats Logical Framework for a unique teaching method [Deliverable 2.5] as a blueprint. The foundation and blueprint of four innovative courses on EM&Ts for Higher Education Institution (HEIs) with a design curriculum have been set and formalize in four Academic Syllabuses that are here presented. Each of the syllabuses focuses on a specific EM&Ts area and to be performed at the respective HEI.

1.1 THE CONTEXT: MATERIAL EDUCATION FOR DESIGN

Materials and Technologies are a vitally important subject in the Design Education curriculum. This area is known for being needed updates continuously (Rognoli and Zhou, 2019). Firstly, because materials ate not to consider as a static subject, in the sense that their attributed meanings, manufacturing processes, prices, availability change, and fluctuate over time. Secondly, new materials are continuously being developed and applied. Most of the time, such Emerging Materials and Technologies (EM&Ts) expose new and unique characteristics, qualities, behaviors, and processes, channelling a shift in paradigm and requiring new approaches to teaching and learning techniques. Design practitioners and students continuously need to gain updated materials knowledge, skills, and competences, not only to deliver designs that exploit available material possibilities but also to contribute to new materials innovation and development (Haug, 2018).

Conventionally, materials education for design has been based on the ‘hard’ profile of materials, i.e., their technical characteristics, complying with a ‘Science-led’ approach (Ashby et al., 2007), and ‘Top-down’ approach (Myerson Report, 1991), i.e., from the understanding of the fundamentals. On the contrary, in the last 20 years new approaches in teaching materials for design have been emerging, since the ‘soft’ profile of materials have been brought to light and embodied in research and practice by a whole body of research (Rognoli & Levi, 2004; Rognoli, 2010;Karana, et al., 2009; Zuo, 2010; Van Kesteren, 2010; Pedgley, Karana, and Rognoli, 2016), basing on notions from prior works by Mazini (1986), Cornish (1987), and Ashby and Johnson (2002). Therefore, a new didactic approach to materials based on ‘Design-led’ and (Ashby et al., 2007) and ‘Bottom-up’ approaches (Myerson Report, 1991), i.e., from the understanding of the needs. Many recently developed methods, tools, and procedures applied to education to design with and for materials are based on this (Karana, et al. 2015; Ferrara & Lecce, 2016). An extensive survey on these methods is reported in the Literature Review [Deliverable 2.2].

As Haug (2018) states different approaches and methods for teaching materials exist and are applied in design High Education Institutions (HEIs): these involves multiple and intertwined sources of learning, such as ‘Material-produced’ information (i.e., direct experimentation with materials), ‘Interpreter-produced’ ones (i.e., discussion and confrontation with instructors, experts, and peers), and ‘Representation-produced’ ones, i.e., texts, videos, and pictures. In this framework, Active leaning (Bonwell & Eison, 1991) and Experiential Learning (Kolb, 1984) are fundamental approaches to teaching and learning materials in a design context, in particular, engaging students in a design challenge with companies (Piselli, et al. 2018) and learning through making (Pedgley, 2010).

Schön and Bennet (1996), described how the design and creative practice itself could be observed as a conversation with materials, through which the practitioner gets to know materials. Teaching with physical materials and product samples emerges as an efficient method for gaining knowledge about materials and for stimulating the creative process though direct exploration (Haug, 2018; Rognoli, 2010; Van Kesteren, 2010; Pedgley, 2010; Ayala Garcia, Quijiano and Ruge, 2011).

1.2 THE SYLLABUS AS A PEDAGOGICAL TOOL

The tool used to formalize the training contents is one of the Academic Syllabus. A syllabus is a pedagogic tool, a teaching device, playing the crucial role of facilitating learning, providing a blueprint, a framework (Afros & Schryer, 2009). It is a tool for teachers to think systematically and coherently about what and how to teach, and a communication tool to provide relevant information to students, e.g., contents, structure, learning objectives, evaluation methods (Doolittle & Siudzinski, 2010). Syllabuses are the foundations that courses are built on: the resulting course can be considered the product of the syllabus applied, including both the blueprint as well as the materials to be learned/taught, together with guidance to the practitioner in terms of approach and implementation (Slattery & Carlson, 2005; Parkes, & Harris, 2002).

2 METHODOLOGY

2.1 ALLOCATION OF THE EM&TS AREAS

Four Academic syllabuses were expected as outcomes of the task, one for each EM&Ts area allocated to each HEIs, according to the following scheme based on the HEIs' individual expertise and contribution in the project:

- ICS Materials at Polimi, the Politecnico di Milano, School of Design, Italy
- Nanomaterials at Tecnun, the University of Navarra, School of Engineering, Spain.
- Experimental wood-based materials at Aalto, the Aalto University, Finland
- Advanced Growing materials at KEA, the Copenhagen School of Design, Material Design Lab, Denmark

2.2 PREPARATION OF A TEMPLATE

To obtain a coherent design for the four syllabuses, Polimi provided a template [Annex 7.1] to the Partners involved in the task, as described below. The structure of the template has been designed and shaped based on the format used into Academic teaching environment by taking into consideration the Descriptors of Learning Outcomes for Higher Education Qualification (Gudeva, et al., 2012), to have a universal, normed, and comprehensive document as a legacy of the project after its execution.

The template is divided into different sections:

1) Rationale: to explain the reason for the existence of the course and how it relates to the rest of the field or area's curriculum.
2) Course Aims and Outcomes: divided into aims, learning objectives, and outcomes. Emphasis is put on thinking from the students' perspective and how the course can contribute to them professionally. In this section, the modules, specific learning objectives for each module, and related outcomes (describing substance and form) are presented.
3) Format: to outline detailly and clearly the multiple formats used in the course, i.e., lecture & hands-on sessions, lab and discussion, group learning projects, and/or presentations.
4) Course requirements: to present the tasks and assignments aligned with the specified learning outcomes. Requirements include the description of class attendance and participation policy, course readings (required texts and background readings), assignments for each module.

5) Grading procedures: to explain how the grade is made of in each module, using percentage.
6) Tentative Course Schedule: a table listing lectures/modules, topics, methods/tools, and assignments.
7) References.

2.3 DATEMATS LOGICAL FRAMEWORK [D 2.5]: A BLUEPRINT FOR INNOVATIVE CONTENTS AND FORMATS

In the syllabus template, some information has been fixed in the syllabus according to the Logical Framework [Deliverable 2.5], e.g., the nature, structure, and titles of the modules, the areas of learning process method, the suggested methods, as follow. The Logical Framework serves as a blueprint for the contents and structure for the unique teaching method to be applied in the distinctive EM&Ts areas, basing on deliverable 2.2 Literature Review about EM&Ts methods and knowledge transfers and task 2.5 Interdisciplinary Knowledge sharing. The framework:

a) systemizes the common gaps and issues as well as the ones for the distinctive EM&Ts, e.g., the need to identify and provide facilities and knowledge pre-requisites, and in particular guarantee safety and use low-cost equipment for didactic;
b) proposes a survey on potential methods to inspire or integrate into Datemats unique teaching method, e.g., material-driven design, user-centered approaches, and speculative design.
c) articulate the cross-disciplinary nature of each EM&Ts areas, i.e., the intersection between Design, Materials and Manufacturing and complementing discipline (computer science, chemistry, biology or engineering) and presents approaches for teaching designing with the complexity, e.g., open-access learning and facilitation of co-labs;
d) outlines an original framework for teaching design with and for EM&Ts, by identifying the necessary element for the setup and formalizing a through-design learning process based on three blocks:
    1. Understanding
    2. Exploring/Shaping
    3. and Applying.

The main highlights from the framework having a direct impact on the formulation of training contents are summed up in this paragraph.

Indeed, in the Logical Framework, each EM&Ts is framed in its specific cross-disciplinary nature. This has practical implication into the teaching method definition for each EM&Ts defining the type of knowledge, skills, and competencies that are required, as well as the expertise of the teaching staff. Each EM&T stands at the intersection of three primary disciplines. Besides some minor distinctions and specification, Design and Materials & Manufacturing are common areas for each EM&Ts, while the third disciple is specific for each area:

- Computer Science field (e.g., digital technologies, electronics, Human-Computer Interaction) for ICS Materials. Other relevant disciplines and knowledge fields involved are Ergonomics, Psychology & Perception, and Sustainability & Circular Economy. The definition of the Application sector emerges as fundamental, e.g., Health, Sports, Military, but not limited to wearables, e.g., Automotive, Architecture, Furniture.
- 'Hardcore' Science (e.g., Material science, Chemistry, Physics) for Nanomaterials. Other relevant disciplines and knowledge fields involved in the area are Sustainability, Economics & Marketing, Psychology & Perception.
- Chemistry (e.g., chemical engineering, material sciences) for Experimental Wood-based materials. Other relevant disciplines and knowledge fields involved in the area are Biology, Engineering, Arts, Psychology & Perception, and Sustainability & Ecology. The interaction with

the Service sector emerges as fundamental, e.g., new businesses for recycling and reuse for composting.

- Biology (e.g., biotechnological Science) for Advanced Growing materials. Other relevant disciplines and knowledge fields involved in the area are Chemistry, Ethics, Communication, Psychology & Perception, and Sustainability (e.g., engineering for production processes and lifecycle).

Therefore, the course is expected to be structured on 12 credits, divided into three modules based on the intersection identified in the Logical Framework:

1) Materials and Manufacturing (3 credits),
2) Specific area per each EM&Ts, e.g., chemistry, biology (3 credits)
3) Design (3 credits).

Being the subject in the intersection of different disciplines, as identified in the Logical Framework, the modules can be carried out co-teaching, e.g., with experts in related disciplines. Therefore, the syllabus asks to specify the required profile of the teaching staff in each module. The three modules will cover three main areas of the course, represented by the three blocks of the learning process identified in the Logical Framework:

1) *Understanding'* is a block where the fundamental knowledge is given to students. It is based on a diverse body of knowledge (e.g., explicit, tacit, theoretical, procedural, empirical) and multiple sources for acquiring knowledge (e.g., interaction with material samples, discussion with instructors, experts, and peers, lectures, texts, videos, and interviews).

2) *'Exploring/Shaping'* is the connecting block between 'Understanding' and 'Applying.' This is the block where tacit knowledge is mainly acquired. In this block the material is experimented and shaped, by hands-on exploration and in-labs exercises. While Exploring emphasises the designer getting experience on the materials and processes by iterating, documenting, and evaluating, Shaping is focused on the material being manipulated and developed in many ways, e.g., tinkering and fabricating. The initial stages of this block move ahead from the Understanding phase by exploring all the different opportunities that the material can exploit, with trials and errors, obtaining successes and failures. Moving on to the 'Applying' block, only one direction for material development is selected, and a converging process is applied, approaching the definition of form and function.

3) *'Applying'* block represents the synthesis of the process when the material is embedded and encoded into a project. In this block, the leading strategies and approaches that are applied are creativity, metaphors, biomimicry, sustainability, systematic approach, user-centered design, materials experience, speculative design, etc.

It is agreed that the application context definition and materials identification are the starting point of the process. The teaching and learning process is both cognitive and physical and is based on the identification of three main didactic blocks: Understanding, Shaping/Experimenting, and Applying. Although the description of the process establishes a consequential succession of the three blocks for the sake of understanding, they are profoundly intertwined, iterating, and often simultaneous and overlapping in their definition. Regarding the format, the course can have multiple formats, e.g., lecture & hands-on sessions, lab and discussion, group learning projects, or presentations, taking inspiration from the methods identified in the Logical Framework.

2.4 WRITING AND DELIVERY OF THE SYLLABUSES

The four HEIs partners have been asked to fill the template. Methodologically, the contents of each syllabus have been informed by the literature review about existing methods for innovative teaching applied in design curricula, in combination with the Logical Framework, and the expertise and know-how of the individual partners. Moreover, a crucial and determining aspect of the definition of the syllabus is the contextualization of each tentative course in the curriculum of the distinctive HEIs. Feedback by the Leader of the Task (Polimi) has been provided by notes by e-mails and comments on the document.

The quality of the phase was guaranteed by the high quality and experience in the field of the partners involved. A continuous share of information and comments (e-mail, shared documents on Google Drive, and virtual meetings) guarantee quality in the management of this task.

3 RESULTS: 4 EM&TS-SPECIFIC SYLLABUSES

Using the provided template and related instructions, each HEI partner provided a syllabus specifically made based on the related EM&Ts area. In this section, a concise and consistent overview of the syllabuses is provided by reporting, editing, and summing up the original text of the syllabuses. All the relevant information on contents, methods, and formats of the courses are reported. Their original and extensive version, as provided by partners, is attached as an annex to the document.

3.1 SYLLABUS BY POLIMI, DESIGN DEPARTMENT: 'DESIGNING WITH ICS MATERIALS – WEARABLE BASED'

The syllabus [Annex 7.2] outlines the tentative course 'Designing with ICS Materials – Wearable based' at the Politecnico di Milano, School of Design, Italy. This course teaches students with mixed background (design and engineering fields) to design *with* Interactive Connected Smart (ICS) materials in the wearable system domain (i.e., health, sports, well-being). The course aims:

a) To provide a body of knowledge: regarding ICS Materials – including Smart Materials and E-textiles – and their meaning, potentials, and critical issues concerning the Wearable domain; knowledge on related subjects, e.g., basic knowledge about the user-centered approach in HCI and sustainability.
b) To introduce students to new skills: "tinkering" and experimenting in a cross-disciplinary environment, e.g., in a FabLab or a maker space with experts from different fields.
c) To practice students' design capabilities: in transferring and applying knowledge from material research and exploration in the design concept and prototyping; managing the complexity and designing new interactive systems leveraging ICS Materials properties and qualities, considering the context of applications, e.g., wearable.

The area is mainly based on the cross-disciplinary area between design, materials and manufacturing, and computer science, and requires a teaching staff with expertise on these subjects. The course is divided into three modules:

1) Understanding (3 credits): the module uses theoretical lectures and online interviews with experts covering different subjects, e.g., Materials experience, Dynamism, Smart materials technicalities, to frame materials-related aspects such as historical use, cultural meaning, chemical composition, and technical qualities. The module includes the use of physical samples (with materials and technology embedded or separated). In alternative, teachers provide cards or other tools representing the EM&T. Students are assessed by the production of a scholarship paper to be presented to the rest of the class, developed doing desk research, field

research, and group discussions. The teachers' profile is based on design and material engineering.

2) Exploring and shaping (3 credits): the module focuses on hands-on experimentation with ICS materials leveraging technical knowledge (i.e., basics of coding, electronics, and Human-Computer Interaction provided through theoretical lectures, tutorials, and exercises) and design approach in computational/material tinkering, i.e., creative experimentation with physical and digital. Through this process, students will produce samples and process documentation on which they will be given assessment. The module involves teachers from the design area and teachers from computer science.

3) Applying and Designing (6 credits): the module consists of the execution of a design project with a brief launched by a company. The project work is realized by developing design and prototype(s) based on the output derived and the skills acquired from the previous modules. The design techniques used are drawing, concept development, and prototyping, supported by demonstrations of making techniques and combined with group discussions. The design method is based on the combination of speculative design and a holistic and hybrid approach to design considering different layers of the artefact (e.g., digital and physical, product and experience, static and temporal). The expected deliverables on which students will be assessed are prototypes, samples and demonstrators, videos, presentations, and documentation of the process. The teaching staff involved has expertise in design, manufacturing, and computer science.

3.2 SYLLABUS BY TECNUN: 'DESIGN WITH NANOMATERIALS'

The syllabus [Annex 7.3] outlines the tentative course 'Design with Nanomaterial' at the University of Navarra, School of Engineering, Spain. This course teaches industrial design and engineering students the role of available nanomaterials in design - e.g., nano-cellulose, nano-clay, smart nanomaterials. It shows how their properties, processing, and attributes - e.g., technical, performance, aesthetic, and consumer functions - will have deep impacts on the design, production, and use of many components and products in different fields of application: sports, interactive products, prosthetics, fabrics, etc. The course aims:

a) to provide knowledge: about Finnish biomaterials – e.g., cellulose fibers, fibrils (micro- or nano-structured) and derivatives, lignin, bark extractives and novel combinations of these –, and in-depth knowledge of a selection of 1-2 materials, combined with the basics of material sustainability and scaling up bio-based material ideas towards innovations and even commercialization.
b) to transfer skills about: basic working methods and safety rules; how to plan, execute, document, communicate and present the experimental working process and results in a professional way; how to apply the knowledge from material research and exploration in design concept and prototyping.
c) to practice students' competences: to conduct practice-based material research; to discuss and to apply the gained knowledge in material experiments; to work in an interdisciplinary environment in practice and be aware of its strengths and challenges; to develop innovative ideas through a holistic approach and by hands-on prototyping and experimenting with materials; to envision how advanced bio-based materials could make life comfortable and more sustainable in the future.

This course wants to give students not only a piece of theoretical knowledge about nanomaterials but also wants to focus on a more practical approach as the starting point for innovation. The teaching staff involves experts in nanomaterials theory and practice, prevention of occupations risk, teamwork and dynamization process, and persons with contacts with Industry. The course is divided into three modules using both traditional face-to-face lectures and flipped learning methodology / on-line sessions in the form of Videos/Audios/Readings/Questionnaires.

1) Understanding (3 credits): the module explains the basics of nanomaterials (i.e., Definition, History and evolution, Classification) and their enhancing properties (or "superpowers," i.e., Properties in the Physic, Chemical, Electric, Magnetic fields) using on-line material; the module also introduces students to the subjects related of safety when working with nanomaterial (i.e., Health, Environment and waste management, Legislation) through in-person lectures. Students are assessed through theory and assignment.

2) Exploring (3 credits): the module presents application examples of nanomaterial in several fields, i.e., Aerospace, Environment, Water, Chemistry, Construction, Fabrics, Food, Industry, Health, Packaging, using on-line materials to emphasize the success stories of companies; the module also introduce students to experiencing and playing with nanomaterials using samples, laboratory experiments, and in-person lectures. Students are assessed through theory and assignment.

3) Applying and Designing (6 credits): the module is entirely face-to-face and focuses on individual or team works where students will face two different challenges: 1) developing a new product starting from a selected nanomaterial; 2) redesigning an existing product identifying a nanomaterial to identifying the properties to improve. Students are entirely assessed through the assignment.

3.3 SYLLABUS BY AALTO: 'DESIGNING FOR AND WITH WOOD-BASED MATERIALS'

The syllabus [Annex 7.4] outlines the tentative course 'Designing for and with wood-based materials' at the Aalto University, Finland. This course teaches students with varying backgrounds (design, architecture, science, engineering, business) to combine design with material research. It introduces a broad spectrum of biomaterials, especially wood-and plant-based, offering one possible pathway towards a more sustainable material world. The course aims:

d) to provide knowledge: about Finnish biomaterials – e.g., cellulose fibers, fibrils (micro- or nano-structured) and derivatives, lignin, bark extractives and novel combinations of these –, and in-depth knowledge of a selection of 1-2 materials, combined with the basics of material sustainability and scaling up bio-based material ideas towards innovations and even commercialization.
e) to transfer skills about: basic working methods and safety rules; how to plan, execute, document, communicate and present the experimental working process and results in a professional way; how to apply the knowledge from material research and exploration in design concept and prototyping.
f) to practice students' competences: to conduct practice-based material research; to discuss and to apply the gained knowledge in material experiments; to work in an interdisciplinary environment in practice and be aware of its strengths and challenges; to develop innovative ideas through a holistic approach and by hands-on prototyping and experimenting with materials; to envision how advanced bio-based materials could make life comfortable and more sustainable in the future.

This course is composed of three modules. The course is situated in the cross-disciplinary area between design, material engineering, and chemistry (first and second module), and business (third module). Therefore, the teaching staff requires such type of expertise.

1) Introduction: Design meets Biomaterials (3 credits): the module is about understanding, an introduction to the topic, and working methods, including design process and scientific research. Students will get to know and will be inspired by Finnish bio-based materials; they will understand the basics of material sustainability and know basic working methods and safety rules, through thematic lectures and presentations (classroom or virtual), watching online videos with experts, desk research, group work, and most importantly materials explorations in laboratories or workshops. In this module, students are assessed on their participation, completion of 2-3 assignment (Safety rules test and task related to materials experimentations and recipes) in teams or individually, production, and presentation of tangible samples. The profiles of teachers involved in the module are focused on design, chemistry, and material engineering.

2) Experimental material project (6 credits): this module is about exploring and on developing innovative ideas and materials experiments related to biomaterials with a holistic approach. It is based on a practice-based research project on a selection of 1-2 materials in interdisciplinary teams or individually. Material exploration and hands-on experimentation in laboratories or workshops are combined with thematic lectures and presentations (classroom or virtual), readings, desk research. In this module, students are assessed on their participation, project design, documentation of the working process (learning diary), and production and presentation of tangible material samples or/and prototypes. The profiles of teachers involved in the module are focused on design, chemistry, and material engineering.

3) Applications: Scaling up (3 credits): this module focuses on applying the gained knowledge from the material research and exploration in realizing concepts and prototyping and on scaling up bio-based materials ideas and innovation into products, services, systems, or developing business seeds in the context of the circular economy. The project work, in teams or individually, is combined with lectures and desk research, including company visits or stakeholder lectures and presentations. In this module, students are assessed on their active participation, documentation of the concept development and realistic projections, and final presentation to the results. The profiles of teachers involved in the module are focused on design, material engineering, and business.

3.4 SYLLABUS BY KEA, MATERIAL DESIGN LAB: DESIGNING WITH ADVANCED GROWING MATERIALS

The syllabus [Annex 7.5] outlines the tentative course 'Designing with Advance Growing Materials" at the Copenhagen School of Design, Material Design Lab, Denmark. This course teaches design students to design with materials, introducing an approach to design that can be used with many materials, but with a specific focus on advanced grown materials as a natural and renewable resource for the future. The course aims:

a) to provide knowledge about: the foundation of material research; basics of material technology; the categories of advanced grown materials; basics of chemical composition, the growing conditions and the compatibility with other materials - and how this is related to sustainability; prospects and potentials related to using advanced grown materials.
b) Transfer skills about: how to explore a material in the lab, using the different equipment provided; how to set up and document both phenomenological and scientific material experiments.

c) Practice the students' competencies and ability: to design with materials; to do research into - and apply - new emerging materials in their design projects; to design in a cross-disciplinary field between art, technology, and natural science; to apply the knowledge from the material research and exploration in the design concept and prototyping.

This course is composed of three different modules, with multiple formats based on the combination of reading and lectures, and active exploration and experimentation. The subject of the course is situated in the cross-disciplinary area between design, chemistry, biology, material engineering, and manufacturing technology. Therefore, teaching staff requires such type of expertise.

1) Material Research (2 credits): the module is focused on research into the quality of the material framed by aspects such as technical and experiential qualities, source, chemical composition, growing conditions, historical use, cultural meaning, sustainability parameters, etc. The module is composed of individual desk and field research on these subjects, on which students are assessed with a written and oral presentation, supported by material samples, visuals, drawings, etc. This is combined with lectures, online interviews with experts, and group discussions. The profiles of teachers are based on design, chemistry, biology, and material engineering.

2) Material exploration (5 credits): the module is based on the exploration and development of the materials, using hands-on experimentation with the material following both a phenomenological and a scientific approach. The material exploration takes place in the lab, based on individual material experimentation, and potentially involving co-creation with external experts. It is introduced with the means of demonstrations and combined with lectures, readings, and group discussions. Students are assessed on their ability to use the material research and learn from the material and experimentation, by an oral presentation of the material exploration and by its documentation and exhibition of the material samples. The profiles of teachers are based on design, chemistry, and material engineering.

3) Design (5 credits): the module focuses on developing design and prototype(s) based on material research and exploration. The design development takes place in the lab, and potentially also in other suitable workshops. Concept development is done by drawing, prototyping, and supported by demonstrations of making techniques and combined with group discussions. Students are assessed by an oral presentation of the design and exhibition of prototypes, drawings, and other visual support. The profiles of teachers cover design and manufacturing technology.

4 DISCUSSION: A COMPARISON OF THE 4 SYLLABUSES

The discussion is based on the comparison of the four syllabuses, to identify common and distinctive characteristics. The results are formally and contently consistent with the template and comparing each other. However, the template was used as a flexible tool to adapt to each HEIs needs. The most evident examples are the management of the Specific Learning Objectives paragraph in section (2) Course Aims and Outcomes, and the combination of section (6) Tentative Course Schedule with sections (3) Format and (4) Course requirements, as in the Nanomaterials syllabus. Another example is the management of the section (7) References, which is matching with (4) Course requirements: Course readings.

Formally, each document is made of 4 to 6 unformatted pages, 3-4 pages formatted, from 960 to 1300 words, from 6800 to 9600 characters. Graphical elements, fonts, bullet points have been generally modified by partners. In two cases, a subtitle/inspiring sentence has been inserted below the title to emphasize the peculiar aspects of the course, contextualize it, and trigger students' attention and motivation.

Regarding the contents, overall, the courses are consistent and emphasize the specific competencies and approaches required by the EM&Ts ad the HEIs background. The suggested subdivision in three modules has been kept. In all cases, instead of using the suggested subdivision in 1) Materials and Manufacturing, 2) Specific related discipline, and 3) Design, the modules have been conceptualized on the three blocks 1) Understanding, 2) Exploring/Shaping, and 3) Applying. In some cases, the modules have been renamed, adapting and complying to HEIs' individual nomenclatures and approaches, e.g., KEA named the modules 'Material Research', 'Material Exploration,' and 'Design,' and Aalto called them 'Introduction:,' 'Experimental Material project' and 'Application and Scaling up'. The three knowledge fields, i.e., 1) Materials and Manufacturing, 2) the specific EM&Ts complementing area, and 3) Design, are assumed as transversal in the three modules in all syllabuses and provided as combined in all modules, except for Polimi's one. In Polimi's syllabus, there is a matching between the modules and the knowledge fields. Therefore module (1) Understanding is mainly based on Materials and Manufacturing, module (2) Exploring and Shaping is mainly based on the specific EM&Ts complementing area (i.e., computer science, electronics, and Human-Computer Interaction), module (3) Applying & Designing is mainly based on Design notions and approaches, e.g. speculative design, holistic design, and user-centred design.

With the exception of some distinctions caused by the type of didactic approach established in each HEIs and related curricula, the learning objectives and aims of the courses are consistent. They are framed into a) knowledge to provide, b) skills to transfer, and c) competences to practice. These goals' categories are distributed in the three modules, as is evident in Aalto's syllabus, or are allocated to specific modules, as is evident in Polimi's and KEA's syllabuses.

These reflect on the definition of modules' procedures, format, and contents. Tasks and assignments are required for each module, as individual or team works. Typology of requirements and assessment criteria are generally consistent in all the syllabuses. Generally, Module 1 is mainly based on transferring the explicit knowledge on the area basing on a theoretical approach, using texts, lectures, videos, interviews. It is mainly characterized by the fulfillment and presentation of theoretical assignments and tasks, e.g., desk and field research, scholarly paper writing, with the exception of Aalto requiring, in addition, the production and presentation of tangible samples from materials explorations in laboratories or workshops.

Module 2 is mainly focused on gaining tacit knowledge on the area using a pragmatic and procedural approach: hands-on experimentation and lab exercises are used as a device for learning. Students are assessed basing on the experimentation process' documentation (e.g., Aalto's learning diary), the quality resulting samples and demonstrators, and the way they are communicated and exhibited. KEA and Polimi make explicit that part of the evaluation is based on the proven student's ability to use the knowledge acquired in materials research (KEA) and theory (Polimi) into materials exploration. Only Tecnun's syllabus requires the integration of theory-based assessment.

Module 3 is mainly based on the synthesis of the previous modules and with the execution of one or more design briefs/challenges/assignments, i.e., a final project. Students are assessed on the quality of the final design, the quality of the prototypes and supporting material (documentation, samples, demonstrators, videos, etc.), the oral presentation and exhibition of the work (Aalto, KEA and Polimi) or more generally by the fulfillment of the assignment, i.e., the design challenges (Tecnun). Aalto's specify that one element of assessment is the design's realistic projections (e.g., practical next steps). In each module, Aalto considers students' active participation as an element of the grading system.

In two cases, the module credits have been re-shaped according to the HEIs' own systems and approaches. For instance, KEA and Aalto modified the allocation of the credits to emphasize the pragmatic approach of the second module on Exploration and to reduce the amount hours and credits for the first module, which is mainly introductory and theoretical.

In all syllabuses, the learning process is based on multiple formats and is supported not only by reading and lectures but by actively exploring and experimenting. A combination of face-to-face / in-person teaching methods and online teaching methods is used in all syllabus. Blended teaching methods are particularly emphasized in Tecnun's syllabus, where online methods (Videos/Audios/Readings/Questionnaires) cover 30% of the entire course, and 50% of the first and second modules, while the third module based on a design challenge, is entirely physical. The other HEIs mentions online videos and interviews with experts (KEA, Polimi, and Aalto) and virtual thematic lectures and presentations (Aalto).

The intervention of experts and companies is expected by all HEIs, in particular by means of online interviews (Polimi, and KEA), online videos (Aalto) co-creation experimentations (KEA), presentation of success stories as best practices (Tecnun), project briefing by a company (Polimi) and company visits or stakeholder lectures and presentations (Aalto).

Regarding the definition of the EM&Ts, all the syllabuses mention a selection of materials the course would focus on, with different levels of granularity and definition. While Aalto's syllabus provides a detailed definition of (especially Finnish) wood-and plant-based, e.g., cellulose fibers, fibrils (micro- or nano-structured), and derivatives, lignin, bark extractives and novel combinations of these, KEA's syllabus provide a broader definition of advanced grown materials. Tecnun's s syllabus mentions examples of materials the course would focus on, i.e., as nano-cellulose, nano-clay, smart nanomaterials. Another consideration can be done on the definition of the context of the application. Polimi's syllabus is mainly based on materials for the wearable domain, i.e., primarily smart textiles but not limited to them.

Regarding the context of applications, Polimi's syllabus defines the starting point in the domain of wearables, e.g., health, sports, well-being. Tecnun's syllabus mention a broader spectrum of potential fields of application, i.e., sports, interactive products, prosthetics, fabrics, but also Aerospace, Environment, Water, Chemistry, Construction, Food, Industry, Health, Packaging, etc. Aalto's and KEA's syllabuses do not mention any specific field of application, excepting for Aalto's syllabus to refer to products, services, systems, or developing business seeds in the context of the circular economy.

Cross-disciplinarity is integrated into all the syllabuses with co-teaching, engaging experts, and creating a teaching staff involving different profiles covering more disciplines. The principal complementing disciplines to design and materials and manufacturing are identified in Computer Science, Human-Computer Interaction and Electronics for ICS Materials (Polimi), Biology, Chemistry and Material Engineering for Experimental wood-based Materials (Aalto) and Advanced Growing Materials (KEA), different areas of Engineering for Nanomaterials (Tecnun). Sustainability and Environment appear as transversal disciplines in all syllabuses (in particular Aalto's and KEA's ones), while Legislation is mentioned only in Tecnun's syllabus, and Management is mentioned only is Aalto's one. Indeed, Aalto's syllabus expects to devote one module to scaling up ideas into innovation and envisioning business seeds. The subject of safety is explicitly mentioned by Tecnun and Aalto.

Further differences and similarities emerge by the direct comparison between the syllabuses that are extensively reported and described in the following sections.

5 CONCLUSION: NEXT STEPS AND OPPORTUNITIES

The contents described in the syllabuses will be gradually tested and implemented in different actions of the projects.

First, they will be tested in the pre-mobility action [Task 3.2]. Specifically, the identified teaching contents and formats will be partially implemented in the production of online resources for in-house and international students, including video lessons, tutorials, and discussion in virtual classrooms. Each HEIs involved will be responsible for the creation of one training module related to its EM&T area addressed to students for the pre-mobility. These contents will be upload on a platform (e.g., Youtube or Vimeo) and shared with a total of 120 students, i.e., 30- 32 students for HEIs, with almost an equal distribution of 8 students for each EM&Ts. Feedback from students will be collected to make a preliminary assessment of the contents.

Second, the training contents will be tested during the mobility with Interdisciplinary EMT&s challenges [Task 5.3], i.e., Design challenges based on EM&Ts involving the mobility of students from and to the HEIs involved in the project. The task is based on the organization and execution of four experimental creative workshops, each focusing on one of the four specific EM&Ts areas. The four workshops will involve in total: at least: 20 companies, 80 in-house students, 60 students in mobility, 20 staff/faculty.

Finally, the syllabus will last as a legacy of the project after its completion and may be applied in future courses to be added in the HEIs' curricula.

Two further tasks of the project included the development of deliverables that can support the training contents for each EM&Ts. The first one is [Deliverable 3.3] Training contents and exercises about entrepreneurship related to EM&Ts, i.e., an Academic Syllabus for entrepreneurship teaching methods following a similar outline to this deliverable. The second one is [Deliverable 3.4] EM&T transfer toolkits version 1, i.e., a collection of tangible samples showing the emerging materials and technologies, in the shape of four materials box. The toolkit also includes datasheets to interpret the samples and links to multimedia contents, such as descriptive videos and tutorials. Those will be part of our unique design method as an appropriate medium to be used in order to facilitate the knowledge transfer activities with companies and students.

Still respecting and being inspired by the Logical Framework (Deliverable 2.5), using it as a blueprint, the resulting syllabuses allow potentially to reframe the Logical Framework validating, enhancing, and completing different aspects, considering the contents, methods, and formats expressed in the syllabuses.

Concluding, one opportunity for the future development of the syllabus is exploiting the potential of a web-based syllabus (Afros & Schryer, 2009), which expands the navigation, communication, and interactivity possibilities (e.g., link to bibliography, digital contents, calendar).

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7 ANNEXES

7.1 Syllabus template, by Polimi

7.2 ICS Materials syllabus, by Polimi

7.3 Nanomaterials syllabus, by Tecnun

7.4 Experimental Wood-based materials syllabus, by Aalto

7.5 Advanced Growing materials syllabus, by KEA

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