2018

Overview of existing studies related to Smart Product Development

TECHNICAL REPORT

CASPROD CONSORTIUM

Contents

1. Introduction

The key transformation within the concept of Industry 4.0 is from traditional mechatronic products towards smart products. Of course, this transformation implies that fundamental changes are needed within engineering education and practice. Besides technological topics like big-data or IT-infrastructure, one of the most prominent and emerging topics are human factors (Herzog and Bender, 2017).
Based on the needs analysis of the existing and future engineering educational and industrial environment, Jeschke et al. (2015) suggested implications for future engineering education:

- Excellence through Interdisciplinarity
    - Development of highly complex, socio-technical systems requires the collaboration of various academic disciplines
- Adaptability to rapid innovation cycles
    - Less detailed specialized content, but the ability of life-long learning
- Survival in Industry 4.0 requires IT skills
    - Engineers need to have basic knowledge and understanding of other disciplines
- New Business Thinking
    - New skills in leadership, decision making, collaboration etc.
- Dealing with uncertainty and fostering creativity

Therefore, for the preparation of relevant and contemporary smart product development curriculum it is required to take this aspects into account and propose the master study built on these insights. For that reason, this overview is divided on several different sections. Initially, contemporary design master studies are presented in section 2, followed by “Advanced Engineering” programmes in section 3. To embrace different aspects of smart product development and Industry 4.0 perspective in Section 4 and 5, master studies related to “Internet of things” and “Advanced/Digital Manufacturing” will be briefly described.

2. Contemporary Design Master Studies

At the beginning of this overview of existing undergraduate and graduate studies, there is a need to briefly describe contemporary engineering design programmes for eminent design institutions such as TU Delft, University of Strathclyde and Technical University of Denmark. As such, they could serve as a good starting point on which certain "smart" aspects can be integrated or added on existing/traditional design curricula.

2.1. TU Delft - MSc Integrated Product Design

The "MSc Integrated Product Design" study at TU Delft focuses on user-centered innovation perspective on both product and services. As such, programme covers different aspects and interests of users, business and societal challenges throughout a whole design process.
This programme is only offered as a full-time and students are obliged to collect 120 ECTS points (during 24 months).

List of offered courses:

Courses	Units	Semester	Course type
Design Theory and Methodology	3	I semester	Compulsory
Advanced Concept Design	21	I semester	Compulsory
Managing Product Innovation	3	I semester	Compulsory
IDE Academy	4	I-II semester	Compulsory
Manage your Master	2	I-II semester	Compulsory
Strategic and Sustainable Design	3	II semester	Compulsory
Modelling	3	II semester	Compulsory
Advanced Embodiment Design	21	II semester	Compulsory
Generic and Professional Skills	3	III semester	Optional
Joint Master Project	12	III semester	Optional
Internationalisation	3	III semester	Optional
Manage your Master	2	III semester	Optional
Strategic and Sustainable Design	3	III semester	Optional
Design Theory and Methodology	3	III semester	Optional
Graduation Project	33	IV semester	Compulsory

Students can start with the IPD programme either in the autumn or in the spring semester. The starting date determines the order in which courses are taken. In the autumn semester, the programme focuses on the concept design, while in the spring semester on the embodiment design. In third semester students can choose among various elective courses and tailor semester to fulfil their professional ambitions. At the end of second year, students need to complete the individual graduation project.

2.2. University of Strathclyde - MSc Design Engineering and MSc Product Design

This MSc Design Engineering programme has two different streams, MSc Design Engineering with Sustainability and MSc Design Engineering with Advanced Product Development. Duration of full-time study is 12 months, while part-time study takes 24 months.
In addition, at University of Strathclyde they offer MSc Product Design programme that slightly differs in comparison to two previously mentioned programmes.

List of offered courses:

Courses	Course type	
	Design Engineering Msc	Product Design Msc
Global Design	Compulsory	Compulsory
Design Methods	Compulsory	Compulsory
Product Modelling & Visualisation	Compulsory	Compulsory
Design Management	Compulsory	Compulsory
Group Project	Compulsory	Compulsory
Masters Project	Compulsory	Compulsory
People, Organisation & Technology	Optional	Optional
Strategic Supply Chain Management	Optional	Optional
Strategic Technology Management	Optional	Optional
Supply Chain Operations	Optional	Optional
Enterprise Resource Planning	Optional	Optional
Engineering Risk Management	Optional	Optional
Management of Total Quality & Continuous Improvement	Optional	Optional
Fundamentals of Lean Six Sigma	Optional	Optional
Product costing & Financial Management	Optional	Optional
System Thinking and Modelling	Optional	Optional
Design of Experiments for Process Optimization	Optional	Optional
Sustainability	Optional	Optional
Sustainable Product Design & Manufacturing	Optional	Optional
Remanufacturing	Optional	Optional
Advanced Materials & Production Technology	Optional	Optional
Product Design Techniques	Optional	Optional
Design Form & Aesthetics	Optional	Compulsory
Human Centred Design	Optional	Compulsory
Management of Innovation	-	Compulsory

Students studying Design Engineering with Sustainability have additional specialisation in *Sustainability*, *Sustainability Product Design and Manufacturing*, *Remanufacturing*.
Students studying Design Engineering with Advanced Product Development have additional specialisation in *Advanced Materials & Production Technology*, *Product Design Techniques*, and *Engineering Risk Management*.
Unfortunately, on the official programme website details are not provided about timing of individual courses and their corresponding ECTS credits.
In order to be eligible to apply, students need to possess first or second-class honours degree, or equivalent, in a relevant engineering, technology or science discipline.

2.3. Technical University of Denmark (DTU) - MSc Design and Innovation

The next programme that fits with project purpose is the one proposed at DTU. The MSc programme is organized in four semesters. To obtain the MSc degree, students must fulfil the following requirements:

- Have passed General Competence Courses adding up to at least 30 ECTS points
- Have passed Technological Specialization Courses adding up to at least 30 ECTS points
- Have performed a Master Thesis of at least 30 ECTS points within the field of general programme

- Have passed a sufficient number of Elective Courses to bring the total number of ECTS points of the entire study up to 120

The academic year is divided into six teaching periods. Two 13-week periods in the autumn and spring semesters, respectively, each followed by an exam period of about two weeks, and four 3-week periods followed by exams in January, June, July, and August, respectively.
Of course, these requirements and offered flexibility for students to tailor their experience result in quite complex structure of curriculum. Students can choose courses they want to take and, actually, it seems that there are no real compulsory courses.

To fulfil the requirements of the General Competence Courses category, students need to pass mandatory courses:

Courses	Units
Product development in an organizational context	5
Strategy, design and market	5

And choose 10 points among these two courses (GR2):

Courses	Units
Advanced Design Methods	10
Holistic Design of Engineering Systems	10

And choose 10 points among these five courses (G3):

Courses	Units
Industrial Design 2	5
Biomimetics and bio-inspired design (BID)	5
Staging co-creation and creativity	5
Technology and Innovation Management	5
Sociotechnical Design	10

Within Technological Specialization Courses category, students need to collect a minimum of 20 points from this group courses (TS1):

Courses	Units
Design for Interaction	5
Development and operation of product/service-systems	10
Technology platforms and architectures	5
Conceptualisation	10
Robust Design of Products and Mechanisms	5
Engineering Systems Ergonomics	5
Life Cycle Management in industry	5
Mass Customization - application of product configuration	10
Complexity Management	5
Management of Change in Engineering Systems	5

And additional 10 points from these groups (TS2):

Materials in product design

Courses	Units
Polymer Technology	5
Advanced Surface Technology	5

Materials in Advanced Applications and Products	10
Design of plastic products	5

Technical systems

Courses	Units
Building Design Project 1:1	5
Embedded System Innovation	5
Robotics	5
Autonomous Robot Systems	5
MicroElectroMechanical Systems (MEMS)	10
Future Trains: Railway Fleet Acquisition and Management	5

Sustainable systems

Courses	Units
System Safety and Reliability Engineering	5
Sustainability challenges I, Systems thinking	7.5
Sustainability challenges II, Specific systems and capstone project	7.5
Life Cycle Assessment of Products and Systems	10

Digital media user experience

Courses	Units
User Experience Engineering	5
UX Design Prototyping	5
Advanced Project in Digital Media Engineering	10

Technology entrepreneurship

Courses	Units
Innovation and Product Development	10
Knowledge-based Entrepreneurship	5
Commercialization of high tech concepts, entrepreneurship and science in action	5
Business model design for growth entrepreneurship	5
Social Entrepreneurship Theory and Practice	5

To enable even more individualised approach to tailor your study based on student interests, any course classified as MSc course in DTU's course base may be taken for credit as an elective course. This means that students may enrol into courses from previously mentioned course categories in excess of the minimal requirements.
Students that hold Bachelor of Science in Engineering, a Bachelor in Engineering or a Bachelor of Natural Science degree can be admitted to a Master of Science in Engineering programme. Also, degree should not be older than 10 years. List of additional requirements depending on whether students received their degree at DTU, Danish or International universities can be found here: http://www.dtu.dk/english/education/msc/programmes/design_and_innovation#prerequisites.
Applicants need to show their proficiency in English (B-level, IELTS, TOEFL- or Pearson test).

2.4. Discussion on contemporary design master studies

Although we only analysed and presented brief overview of contemporary design master studies, few main points can be deduced.
First, existing design studies mostly do not include emerging topics relevant for smart product development such as advanced manufacturing technologies, Industry 4.0 requirements, additive

manufacturing, smart materials etc. as a part of their compulsory courses. Maybe they are integrated as a part of course contents, but these topics are not explicitly represented in curriculum. Still, courses related to different design phases and its management are the most common ones. Therefore, it seems reasonable to keep courses on *Design Theory and Methodology* and *Design/Innovation Management* taking special care to tailor it according to the "smart" aspects. For design management courses, existing ones at Uni Strathclyde can serve as a good starting point, while course contents from TU Delft could be modified for creating courses for design methodology.
Second, the topic that seems to be well represented in analysed design master studies is sustainability, either as a part of compulsory (TU Delft, Uni Strathclyde) or optional courses (DTU). For that reason, sustainability needs to be introduced in new curriculum – at least as an optional course.
Third, the Technological Specialization Courses group (especially TS 2) offered at DTU can be used as an initial template for elective courses in CASProD project. They embrace different topics, ranging from *Materials in product design* to *Technology entrepreneurship*.
Fourth, it is important to emphasize that all aforementioned master programmes at least have one joint or group project meaning that project-based learning needs to be utilized as a learning mechanism in newly proposed curriculum, although there may be several obstacles because of different geographical location of students.
Finally, some master programmes are offered in two variations – full-time and part-time. This needs to be considered in the further phase of the project.

Analysis of traditional design master programmes is followed by overview of «Advanced Engineering» bachelor, master and professional degrees. Mostly, these studies are recently established and they all try to tackle (more or less successful) the same issue of combining cutting-edge technical engineering and information technology knowledge and skills and equipping students to work more effectively as a part of digital engineering environment.

3. «Advanced Engineering» Bachelor, Master and Professional degrees

By analysing bachelor and master programme websites, preliminary identification and analysis of the existing advanced engineering studies was done. During this phase, our focus was mostly on design (and engineering) Bachelor and Master studies that already integrate some of the "smart" elements noted above.
Several undergraduate and graduate studies can be found that cover different aspects of Smart Product Design and Development.

3.1. Bachelor Programmes

This part of analysis starts with Bachelor Studies that are relevant topic-wise, although different in timeframe, level of required knowledge and number of offered courses. For that reason, they are not described in detail (the rest can be found on their official websites).

3.1.1. University of Twente – Bachelor Programme Creative Technology

The first example is University of Twente full-time Bachelor Study Programme called Creative Technology. This is one of the very few academic programmes worldwide which combines user interaction with cutting-edge technology and creative design. The main objective of this Bachelor Study is to provide their students technical knowledge and skills as well as expertise in the areas of how technology affects human beings, design (how to convert a question or opportunity into an appealing prototype) and creative processes.
Duration of the Study Programme is 3 years and it is taught in English. During each year, study programme consists of four modules (each module takes 10 weeks). Using the information provided on their website, this is the content during all three years:

- YEAR 1: Students will encounter disciplines such as Design, New Media, Computer Science, Smart Technology and Mathematics & Modelling. Throughout the four modules you will gain an insight into the various professional roles and themes in your future field of interest, and learn how to develop practical solutions to complex problems. One third of first year is spent on project assignments.
    - Modules: We create identity; Smart environments; Living & working tomorrow; Art, impact & technology
- YEAR 2: This year will involve disciplines such as Design, Computer Science, Business, Mathematics and Modelling and is devoted to your specialization in Smart Technology or New Media – students have to choose one!
    - Specialization: Smart Technology (systems, signals and smart environments) and New Media (web, games, visualization); Intelligent interaction design; Innovation & Entrepreneurship; Data: From the sources to the senses
- YEAR 3: You will enhance your knowledge through elective courses aimed at human-technology interaction, ethics and professional conduct.
    - The first half of the third year offers you space to do your minor. In the second half of the third year you will choose electives in the fields of human technology interaction, ethics and professional conduct. The last quarter of the third year is dedicated to your graduation project. Finally, you'll complete your graduation assignment to earn your Bachelor of Science degree.

Since curriculum is organized by modules, it was not possible to analyse courses and elements of these courses specifically (no information about credits or workload related to certain module). During the

first two years of Bachelor study, every student is assigned a personal tutor, whose job is to ensure their progress.

3.1.2. Loughborough University – Undergraduate Programme Product Design and Technology

The second example is full-time Product Design and Technology undergraduate programme at Loughborough University that combines lectures, practical classes, workshops, CAD sessions, computer laboratory sessions, working with tools & machinery in tutorials in groups and one on one with academic staff, practical demonstrations, studio sessions and independent study (http://www.lboro.ac.uk/study/undergraduate/courses/product-design-technology/). All teaching and learning is completed via a number of modules across two semesters.
During 1st year students develop your designing and making skills, modelling skills including 2-D sketching and drawing, 3-D physical modelling (e.g. in foam and resistant materials), computer modelling and electronics, mechanics and materials technologies. Compulsory modules include Design Context, Prototyping for Design, Electronics for Design, Mechanics for Design, User Centered Design, Materials and Processes for Design, Design Practice (40 ECTS points) and Design Research Methods (10 ECTS). In the second year students enhance their knowledge and skills in research, planning, modelling, building and evaluating. They have following compulsory modules: Design Practice (25 ECTS), Electronics, Programming and Interacting with Design (15 ECTS), Further Mechanics for Design (15 ECTS), Design Communication (15 ECTS), Design and Manufacturing Technologies (30 ECTS). In the final year students have to complete number of projects: Applications of Mechanical and Electronics for Design (20 ECTS), Design Research (20 ECTS), Live Projects (20 ECTS), Final Year Design Practice (60 ECTS).

Distribution of courses throughout the years of the programme:

Modules	Credits	Year	Course type
Design Practice	40	I Year	Compulsory
Design Context	TBD	I Year	Compulsory
Prototyping for Design	TBD	I Year	Compulsory
Electronics for Design	TBD	I Year	Compulsory
Mechanics for Design	TBD	I Year	Compulsory
User Centred Design	10	I Year	Compulsory
Materials and Processes for Designers	TBD	I Year	Compulsory
Design Research Methods 1	10	I Year	Compulsory
Design Practice	25	II Year	Compulsory
Electronics, Programming and Interfacing For Design	15	II Year	Compulsory
Further Mechanics for Design	15	II Year	Compulsory
Design Communication	15	II Year	Compulsory
BSc Design and Manufacturing Technologies	30	II Year	Compulsory
Sustainable Design	20	II Year	Optional
Computer-aided Ergonomics	20	II Year	Optional
User Experience Design	20	II Year	Optional
Universal Design	20	II Year	Optional
Polymer Processing and Applications	20	II Year	Optional
Optional salaried professional placement or study abroad			

Applications of Mechanical and Electronics for Design	20	Final Year	Compulsory
Design Research	20	Final Year	Compulsory
Live Projects	10	Final Year	Compulsory
Final Year Design Practice	60	Final Year	Compulsory
Universal Design	10	Final Year	Optional
Computer-aided Ergonomics	10	Final Year	Optional
User Experience Design	10	Final Year	Optional
Computer Aided Modelling and Manufacture	10	Final Year	Optional
The Global Studio	10	Final Year	Optional
Entrepreneurship and Innovation	10	Final Year	Optional
Recycling and Environmental Issues	10	Final Year	Optional

Assessments for modules will include: reports, CAD files, essays, assessed laboratory sessions, class tests, group presentations and reports, submission of prototypes, folios, logbooks, e-posters, presentation boards, computer simulations & examinations.
On the second year, students choose 20 credits from the optional modules, and on the third year, 10 credits from the optional modules specified for that year. Entry requirements are specified on the link: http://www.lboro.ac.uk/study/undergraduate/apply/entry-requirements/.

3.1.3. Discussion on Bachelor programmes

As it was stated before, these programmes significantly differ from the master studies. However, topic-wise Creative Technology programme seems to be very relevant for CASProD project. During first and second year, students become familiar with Smart Environments, Smart Technologies and Big Data approaches. Because of time constraints of master study, it is not possible to replicate these courses, however content of these courses needs to be thoroughly studied. The special emphasis should be put on second year modules. *Smart Technology* Module includes components such as Circuits & Electronics, Sensors, Control Systems etc., while *Data: From the sources to the senses* Module covers topics such as Internet technologies, Data Driven Applications and so forth. In Loughborough University programme, there are also some courses that could bring new content to CASProD courses. However, topics are about the same as in design master studies covered in Section 2 (of course, more on introductory level). In addition, again project-based learning component of programmes was emphasized.

3.2. Master Programmes

3.2.1. Nanyang Technological University – Master Programme Smart Product Design

The first example of master programmes is Smart Product Design held at Nanyang Technological University in Singapore. The main focus of this programme is on product design and development, advanced mechatronics, human-centred ergonomics, rapid prototyping and management of innovation. The programme is offered in two different versions:

Option	Description	No. of Courses	Compulsory	Optional
1	Coursework and Dissertation	8 Courses + Dissertation	4	4
2	Coursework Only	10 Courses	4	6

The courses at this programme are listed below:

Courses	Credits	Semester	Course type
Product Design & Development	3	I semester	Compulsory
Physical Ergonomics in Design	3	I semester	Compulsory
Advanced Materials Engineering	3	I semester	Optional
Fundamentals of Precision Engineering	3	I semester	Optional
Advanced Design for Manufacturing	3	I semester	Optional
Engineering Measurements	3	I semester	Optional
Systems & Project Management	3	I semester	Optional
Advanced Microprocessor Applications	3	II semester	Compulsory
Advanced Mechanism Design	3	II semester	Compulsory
Quality Engineering	3	II semester	Optional
Prototype & Rapid Prototyping	3	II semester	Optional
Human Factors Experimental Design	3	II semester	Optional
Accident Causation and Safety Management	3	II semester	Optional

To get impression about scoring system e.g. 15 AU credits can be perceived 30 ECTS (1 AU credit = 2 ECTS) meaning that programme overall comprises equivalent of 60 ECTS points.
Out of four courses that are compulsory within this programme, the courses in the first semester are very generic and from the course synopsis it is not clear how “smart” aspect is included. Since studying in both streams offers students to choose 50% and 60% of optional courses, it is not clear if the final aim of this master project could be obtained. Especially, due to quite big difference topic-wise among optional courses.
For their programme, admission requirements are mostly related to student qualification and information about English language ability. Candidates must possess a good Bachelor's degree in Mechanical, Manufacturing, Production, Electrical or Electronic Engineering or other equivalent qualifications. In addition, A TOEFL/IELTS or equivalent is required for graduates from universities with non-English medium of instruction.
More details about this programme can be found at the following link. http://www.mae.ntu.edu.sg/Programmes/ProspectiveStudents/Graduate%28Coursework%29/MScProgrammes/MSc%28SPD%29/Pages/default.aspx

3.2.2. Carnegie Mellon University – Master Programme “Integrated Innovation for Products & Services” (MIIPS)

The next example is Master of Integrated Innovation for Products & Services (MIIPS) held at Carnegie Mellon University. Courses within this 9-month programme were mostly developed exclusively for MIIPS implying that this programme was not just combination of various already offered courses at CMU. Although most of the courses were taught in Pittsburgh, some of them were streamed via video-conferencing from CMU campus at Silicon Valley.
Courses are organized during Fall 2017 and Spring 2018 semester. The courses listed below were taught in Fall 2017:

Course	Credits	Semester	Course type
Engineering Design Fundamentals	6	Mini 1	Compulsory*
Industrial Design Fundamentals	6	Mini 2	Compulsory*

Business Fundamentals	6	Mini 1	Compulsory*
Career Planning for Integrated Innovators	6	Semester	Compulsory
Integrated Innovation Seminar & Workshop Series	0	Semester	Compulsory
User Research Methods	6	Mini 1/2	Compulsory
Product & Brand Management	6	Mini 2	Compulsory
Design for Manufacture	6	Mini 1	Compulsory
Design for the Environment	6	Mini 2	Compulsory
IPD Methods	6	Mini 1	Compulsory
Entrepreneurship Course (one of the following)			
Commercializing IP	12	Semester	-
Innovation & Entrepreneurship I&II	12	Semester	-
Business Models & Strategy	6	Mini 2	-
Electives (if space is available, after ENT course selection)	6	Varies	Optional

The courses listed below will be taught in Spring 2018:

Course	Credits	Semester	Course type
Integrated Innovation Seminar & Workshop Series	0	Semester	Compulsory
Visual Processes	6	Mini 3	Compulsory
Designing for the Internet of Things	6	Mini 3	Compulsory
IPD Capstone	12	Semester	Compulsory
The Leadership Challenge	6	Mini 4	Compulsory
Electives	Up to 18		Optional

In tables, code “Compulsory” stands for a required course and “Optional” for elective course, while “Compulsory*” should be interpreted as “based on academic background, complete two of three courses”.
In comparison to NTU programme, this one has business/managerial/entrepreneurship/leadership courses and less “advanced engineering” courses. Of course, they have different focus. However, there is a common ground in Engineering and Industrial Design courses that cover same topics as the compulsory ones at NTU (in the first semester). One of the crucial differences is smaller number of optional courses pointing out less flexibility and more structured programme.
In terms of CASProD project, a particular attention needs to be devoted to the course “Designing for the Internet of Things”.
Students are required to collect a minimum of 102 units of coursework during these two semesters (maximum of 60 during fall semester and 48 during spring semester). At least 18 needs to be collected through elective courses. An additional requirement is that students need to have minimum QPA of 3.0 to graduate.

Complete course descriptions can be found at:
https://www.cmu.edu/iii/degrees/CMUiii_CourseDescriptions.pdf

3.2.3. University of Aberdeen – Master Programme “Advanced Mechanical Engineering”

At University of Aberdeen students can enrol to full-time master study “Advanced Mechanical Engineering” that is focused on the application of computational techniques for solving complex engineering problems. The duration of the programme is 12 months

Offered courses:

Course	Credits	Semester	Course type
Computational Fluid Dynamics	15	I semester	Compulsory
Numerical Simulation of Waves	15	I semester	Compulsory
Fire and Explosion Engineering	15	I semester	Optional
Structural Vibrations	15	I semester	Optional
Project Management	15	I semester	Optional
Finite Element Methods	15	II semester	Compulsory
Mathematical Optimisation	15	II semester	Compulsory
Engineering Risk and Reliability Analysis	15	II semester	Compulsory
Risers Systems and Hydrodynamics	15	II semester	Optional
Hydro, Marine, and Wind Energy	15	II semester	Optional
Individual Project in Advanced Mechanical Engineering	60	III semester	Compulsory

During first two semesters, students are obliged to choose one among offered optional courses. As most other master studies, they specified their entry requirements in terms of language proficiency and academic success. For different language proficiency measurement scale, they defined thresholds (IELTS, TOEFL, PTE etc.). Also, to qualify for master study student should possess Honours degree to be of equivalent worth in Mechanical/Civil/Materials/Chemical/Aerospace Engineering with additional requirement that key subjects that must be covered are mathematics and mechanical subjects.
This programme is a typical representative of "advanced engineering" master studies that are held all across UK. They try to introduce students to application of various computational techniques and tools in different mechanical engineering domains. As such, their focus is mostly on highly technical content. However, they do not really offer more recent "smart" topics, and are mostly focused on traditional mechanical engineering education. In addition, they mostly have only one "Project management" or "Management for Technology" (e.g. @Cranfield) course and do not explicitly provide any specialized Transferable Skills or managerial/entrepreneurship courses. In addition, design is not in their prime focus as well.

3.2.4. Kingston University London – Master Programme "Advanced Product Design Engineering"

The master study "Advanced Product Design Engineering" is offered by Kingston University London (KUL) and it significantly differs from the previously described "advanced mechanical engineering" programmes. This master study can be taken in two different ways – one-year full time and two or three years part time:

Option	Mode	Duration	Attendance
1	Full time	1 year	Delivered in one-week blocks
2	Full time	2 years including professional placement	Delivered in one-week blocks plus professional placement
3	Part time	2 years	Delivered in one-week blocks

All courses are taught in a two one-week blocks (sometimes there are not taught two weeks in a row. Master study consists of introduction programme, four taught modules and final project.
Here you can find list of modules offered within this programme (detailed description at the link http://www.kingston.ac.uk/postgraduate-course/product-design-engineering-msc/):

Course	Units	Semester	Course type

Engineering Research Techniques, **Entrepreneurship and Quality Management**	30	-	Compulsory
Computer Integrated Product Development	30	-	Compulsory
Advanced CAD/CAM Systems	30	-	Compulsory
Engineering Individual Project	60	-	Compulsory
Industrial Operation Management and Resources Simulation	30	-	Optional
Green Engineering and Energy Efficiency	30	-	Optional
Mechatronics Design and Automation	30	-	Optional

Many postgraduate courses at Kingston University allow students to do a 12-month work placement as part of their course. However, the responsibility for finding work placement is with the student and Kingston University cannot guarantee the work placement (just the opportunity to undertake it). The work placement is subject to assessment, and therefore it is covered by a student's tier 4 visa.
In order to be eligible to apply, students need to possess good honours degree or equivalent in a relevant engineering discipline, and/or suitable industrial experience. In addition, non-MESC applicant should have good command of English proved by certificated proof of English language competence (minimum requirement is Academic IELTS of 6.5 overall with 6.0 in Writing and 5.5 in Reading, Listening and Speaking). For applicants that cannot fulfil language requirement, they may join pre-sessional English language course.
As an online learning management system, they use Canvas that can provide access to course materials, online chat rooms and bulletin boards and multimedia features.
On their official website, they emphasize that their "MSc will meet, in part, the academic benchmark requirements for registration as a Chartered Engineer" (as it is quite common with some other UK master studies).

3.2.5. Discussion on Master programmes

At first sight, these master programmes can be perceived as the logical sequence of the previously introduced bachelor programmes (some course titles are almost the same). However, in these "advanced engineering" master programmes more "smart" relevant topics are appearing such as Advanced materials, Advanced Microprocessor Applications etc.
The drawback of these programmes is that some of them completely neglect managerial aspects and they are only implicitly included through project-based courses.
Building on these premises, it would be beneficial to cover both aspects and assign at least certain amount of ECTS points to entrepreneurship/management courses. This definitely seems to be trend in many recently established master studies. In that way it would be possible to bridge these topics that are at the moment on the opposite sides of spectrum.
"Advanced mechanical engineering" programmes seem to be irrelevant at these stage of CASProD project, however, potentially these programmes could make us think about some new engineering application areas. On the contrary, "Advanced Product Design Engineering" programmes could be interesting due to its emphasis on computer-based tools and techniques (e.g. 2 out of 3 compulsory courses at KUL). In particular these master programmes could be helpful when defining content for *Virtual product development* module within CASProD curriculum.
Although, in general, master programmes last two years, duration of analysed programmes is only one year causing differences in a range of topics that these programmes can embrace.
Additional aspect that needs to be pointed out is the inclusion of industrial placement in master programme e.g. Kingston University London. However, they explicitly stated that they cannot guarantee the work placement. This strategy could be worth discussion and definitely an option, in case the future CASProD programme will lack industrial partners. In addition, it is necessary to check

requirements to qualify graduate engineers to be registered with the Engineering Council in all three countries, as it seems that these can increase their odds of getting job in industry afterwards.
Finally, these master studies enable to define "specification" of the future master study and allow to focus on crucial aspects for bringing improved master programme that involves smart aspects that are still mostly neglected.

3.3. Professional programmes

In addition to presented undergraduate and graduate university programmes that put focus on scientific aspects, we included in this overview professional programmes that emphasize applicability and practicality of newly emerging smart technologies.

3.3.1. Siberian Federal University – Programme "Modern Technologies of Product Development"

Programme "Modern Technologies of Product Development" held at Siberian Federal University seems to also be relevant for CASProD project. The main objective of this programme is to introduce students into contemporary methods, techniques and tools throughout different product development phases. This one-semester programme lasts 18 weeks and is worth 30 ECTS points.

Courses within this programme are listed below:

Courses	Units	Semester	Course type
Product lifecycle management	3	-	Compulsory
Improvement of product design (CAD-technologies)	4	-	Compulsory
Support of product working capacity on the designing stage (CAE-technologies)	5	-	Compulsory
Technological design of automated manufacturing (CAM-technologies) Optimized design of products and technologies	4	-	Compulsory
Optimized design of products and technologies	4	-	Compulsory
Programming of CAD/CAE/CAM-problems	3	-	Compulsory
Research project	4	-	Compulsory
3D-printing technologies of parts and assembly units of prototypes and products; Reverse engineering	3	-	Optional
Research methods of highly nonlinear rapid processes	3	-	Optional
Methods of connected problems from different areas of Physics	3	-	Optional
Advanced course in computational fluid dynamics	3	-	Optional

In order to be eligible to apply, student applicants need to possess BSc or MSc degree in Engineering (transcript of records) and good command of English.
More detailed description about this programme can be found at the link: http://www.sfu-kras.ru/en/education/masters/product-development.

3.3.2. Swinburne University of Technology – Professional Programme "Associate Degree of Applied Technologies"

Swinburne University of Technology offers two-year "Associate Degree of Applied Technologies" with both full-time and part-time modes. Programme should equip students with "cutting-edge technical engineering and information technology skills" and prepare them to work in digital revolution

environment. The curriculum covers wide range of topics such as cloud computing, advanced algorithms, advanced manufacturing practices, automation and robotics, smart sensor and cyber-physical systems, and the machine-to-machine communication of the Internet of Things.
In order to receive degree, students need to complete 200 credit points on these courses. Each course consist of 12 weeks of workplace learning in addition to coursework requirements.

All offered courses are compulsory and last one semester:

Course	Units	Year	Course type
Working in industry 4.0	12.5	I year	Compulsory
Engineering skills for industry 4.0	12.5	I year	Compulsory
CAD / CAM and engineering materials	12.5	I year	Compulsory
Industrial networking and cloud computing	12.5	I year	Compulsory
Electrical systems	12.5	I year	Compulsory
Object oriented programming: Industrial control systems	12.5	I year	Compulsory
Digital control systems	12.5	I year	Compulsory
Cyber physical system integration (Major Project)	12.5	I year	Compulsory
Software tools for industry 4.0	12.5	II year	Compulsory
Advanced digital control systems	12.5	II year	Compulsory
Advanced electrical machines	12.5	II year	Compulsory
Predictive engineering analytics	12.5	II year	Compulsory
Robotics and digital twin	12.5	II year	Compulsory
Cyber security and cloud services	12.5	II year	Compulsory
Distributed control in a smart factor	12.5	II year	Compulsory
Smart product design using industry 4.0	12.5	II year	Compulsory

However, it is important to emphasize the planned career opportunities for graduates. The students graduating from this program will be certified para-professionals within the engineering industry and can work as technicians and technologists (e.g. Service technician, Engineering technician, Site installation technician and Mechatronic / Manufacturing technologist).

For more details, please consult: https://www.swinburne.edu.au/study/course/Associate-Degree-of-Applied-Technologies-AB-APPTEC/local.

3.3.3. Universitat Autònoma de Barcelona – Professional Programme "Smart Products Design"

One of the closest master study programmes content-wise is "Smart Products Design" held at Universitat Autònoma de Barcelona. However, the official language of the programme is Spanish. This professional programme accounts for 30 ECTS points and the maximum number of students for this study is 30.
On their official website, they specified only one admission requirement - To hold a university degree or diploma, preferably within the ambits of Engineering, Industrial Design or Product Design. Also, they mentioned that employment experience will be considered while selecting suitable candidates.
Unfortunately, course titles with their descriptions were not provided on the official website of the programme (http://www.uab.cat/web/postgraduate/graduate-diploma-in-smart-products-design/general-information-1217916968009.html/param1-3391_en/param2-2006/).

3.3.4. Discussion on Professional programmes

These professional programmes can point us to some topics that were previously uncovered in mentioned undergraduate and graduate study programmes. Unfortunately, SFU and UAB programmes

do not have sufficient course description publicly available and, as such, can only be used as reference point or benchmark to check whether necessary topics are addressed in new curriculum.
Professional programme offered at Swinburne University of Technology lasts longer and covers more topics in detail. For that reason, it can be used as an inspiration to build a content in newly proposed courses or to integrate it into existing ones.

4. “Advanced/Digital manufacturing” Master programmes

4.1 MIT - Master of Engineering in Advanced Manufacturing and Design

The mission of the programme is to gain the leadership skills needed for continual growth in competence and competitiveness in manufacturing, and to be at the leading edge of a new form of engineering education. By adding a single year to a 4 year degree, students are exposed to the full range of topics necessary for manufacturing excellence. Students get to experience many of them with class-based projects and seminars, and finally, get to join leading manufacturing companies for a group – based project on a topic that the company feels is vital to their continued success. The curriculum includes subjects in manufacturing processes and process control, factory systems and supply chains, business fundamentals and the product development process. Several subjects include hands-on labs and most of which have significant project components.

List of common core and curriculum core courses:

Courses	Units	Semester	Course type
Introduction to Manufacturing Systems	NA	Fall	Compulsory
Manufacturing Processes and Systems	NA	Fall	Compulsory
Management for Engineers	NA	Fall	Compulsory
Global Engineering	NA	Fall	Optional
Micro/Nano Engineering Laboratory	NA	Fall	Optional
Selection and Process of Structural Materials	NA	Fall	Optional
Introduction to Robotics	NA	Fall	Optional
Analysis and Design of Digital Control Systems	NA	Fall	Optional
Bio-inspired Robotics	NA	Fall	Optional
New Process Development - "Bench to Money“	NA	Midterm	Compulsory
Control of Manufacturing Processes	NA	Spring	Compulsory
Manufacturing System and Supply Chain Design	NA	Spring	Compulsory
Product Design and Development	NA	Spring	Compulsory
Professional Seminar in Global Manufacturing and Entrepreneurship	NA	Spring	Compulsory
Graduate Thesis	24+9	Summer	Compulsory

These courses comprise four course-based components, or pillars — **manufacturing physics, manufacturing systems, product design, and business fundamentals** — that require both individual and group work on class projects. Student efforts in these courses ultimately culminate during a three-month group project in a manufacturing industry, about which students will compose a thesis.

Recent projects:

- Supply Chain Planning in Semiconductor Manufacturing
- Template Modelling for Control Assembly
- Continuous Micro Contact Printing
- Wash Cycle Improvement in High Performance Circuit Board Production
- Reduce the Cycle Time in Ion Implanter Manufacturing

Detailed info on programme and course is available at:
https://manufacturing.mit.edu

4.2 University of Strathclyde - Master of Engineering in Digital Manufacturing

This programme is ideal for graduates wishing to transfer smoothly and effectively to a career in the digital, creative and business services oriented sector of the manufacturing industry.
Digital Manufacturing is technology-enabled manufacturing that uses the latest developments in Information and Communication Technologies (ICT) to transform, augment and boost traditional manufacturing through new digital technologies and thinking.
The power of digital manufacturing also allows creating agile and autonomous production processes that can deliver at scale through smart global digital communication technologies. Industry business models are also shifting significantly; extensive mass customisation is augmented by direct prosumer engagement and services become instantaneous and ubiquitous.
Digital Manufacturing utilises Industry 4.0 technologies such as Cyber Physical Systems, Industrial Internet of Things, Additive Manufacturing and Autonomous Mechatronic Systems. Digital Manufacturing also feeds into new business models such as Through-Life Engineering and Cloud Manufacturing – all extremely hot topics with vast industrial as well as academic potential.

Students will develop specialist skills in:

- digital manufacturing concepts
- manufacturing automation
- mechatronic system design
- design for Industry 4.0 and smart products
- knowledge & information management for engineers

List of common core and curriculum core courses:

Courses	Units	Semester	Course type
Digital Manufactruing Concepts			Compulsory
Manufacturing Automation			Compulsory
Design for Industry 4.0 & Smart Products			Compulsory
Mechatronics Systems Design Techniques			Compulsory
Knowledge Engineering and Management for Engineers			Compulsory
Sustainable Product Design and Manufacturing			Optional
Systems Thinking and Modelling			Optional
Micro and Nano Manufacturing			Optional
Advanced Materials and Production Technology			Optional
Management of Innovation			Compulsory

During the programme, students will have to undertake an individual project and a group project.
For group projects, students have the opportunity to work with fellow students and an industrial client to address a practical problem. They gain direct industry experience, develop skills and manage a project through to completion. Previous students have worked with major organisations such as Rolls Royce or BAE Systems, as well as local Scottish SMEs.
For individual projects, students will have the opportunity to combine the skills learned in other course modules and apply them to an industry-involved or funded project within a specific area of manufacturing.
The Advanced Forming Research Centre (AFRC) near Glasgow Airport is hosted by Department of Design, Manufacture & Engineering Management (DMEM), the only department in the UK combining end-to-end expertise from creative design, through engineering design, manufacture and management of the entire system. The AFRC is a powerful platform with very strong links into industry

and host to the latest manufacturing technologies. This gives students direct access to the latest high-tech equipment. The AFRC has invested £35M in equipment for the development of forming and forging technologies.
The programme is part of the MSc. group consisting of:

- Advanced Manufacturing: Technology & Systems
- Autonomous Robotic Intelligent Systems
- Design Engineering
- Digital Manufacturing
- Engineering Management for Process Excellence

Detailed info on programme and course is available at:
https://www.strath.ac.uk/courses/postgraduatetaught/digitalmanufacturing/

4.3. Discussion on "Advanced Manufacturing" Master programmes

Obviously, this group could bring insights into most important aspects of application for the smart products for the Industry 4.0 internet and contributing to the manufacturing technology/materials module within CASProD programme.
These programmes offer a lot of content related to the smart product development and design primarily addressing the needs of the manufacturing systems. In addition to the manufacturing, they emphasise the supply chain design topic as integrated part of the digital manufacturing. Similar to the previously analysed advanced design curricula, they include topics of sustainability, innovation and knowledge management for the engineers.
Among the specific new topics, Micro/Nano manufacturing course/laboratory is present within the both programmes.
The programme from the University of Strathclyde is good example and potential very good lead in designing this module within the CASPRoD project.

5. “Internet of Things” Master programmes

Analysis in previous sections implies that “Internet of Things” aspect of Smart product development still doesn’t have significant role in design education. To address to “Big Data” and “Internet of things” segment of design education in the context of Industry 4.0, few additional graduate programmes were analysed that were specifically developed for that purpose.

5.1. Universities of Trieste and Udine – Master Study “Data Science and Scientific Computing”

The first one was international study “Data Science and Scientific Computing” (DSCC) offered by the Universities of Trieste and Udine, with the collaboration of SISSA (International School for Advanced Studies), ICTP (International Centre for Theoretical Physics), and of many other research institutions and companies of the area. This international study is taught in English language.
The DSSC have two potential streams: one is focused on data management and data analysis, (particularly in terms of Big Data) and other one on computational modelling, optimization, scientific programming, and simulation. Both curricula put strong emphasis on 3 main areas:

- Data analytics and machine learning
- Mathematical and computational modelling
- Informatics (High-performance and distributed computing)

Students have to complete 60 CFU (equals to ECTS) points during the first year, while in second year they can earn 30 CFU points by acquiring knowledge in specific application field. During the second year, students can also apply for internship in a research institution or a company.
The more relevant stream for CASProD project is “Data Science” (http://dssc.units.it/curriculum-data-science) that is organized in common core courses (I semester), curriculum specific courses (II semester) and application specific courses (II year).
List of common core and curriculum core courses:

Courses	Units	Semester	Course type
Advanced Programming and Algorithmic Design	12 CFU	I-II semester	Compulsory
Machine Learning and Data Analytics	12 CFU	I semester	Compulsory
Foundations of High Performance Computing	9 CFU	I semester	Compulsory
Numerical Analysis	6 CFU	I semester	Compulsory
Statistical Methods for Data Science	6 CFU	II semester	Optional
Statistical Machine Learning	6 CFU	II semester	Optional
Data Management for Big Data	9 CFU	II semester	Optional

In the second year, students need to select one among different study plans (application areas):

- Data Science for Healthcare
- Data Science for Life Sciences
- Data Science for Social Sciences
- Foundations of Data Science
- Data Engineering

Each of these study plans consists of at least 3 compulsory courses and several optional courses. As such, it provides students a lot of flexibility in the final year.
Applicant selection process consists of evaluation of applicants’ CVs and interview session with an applicant. Maximum number of accepted students for this programme is 30. Details of the admission

procedure can be found at the following link: http://dssc.units.it/sites/default/files/media/pdf/bando2017_ENG.pdf.

5.2. Bournemouth University – Master Study "Internet of Things with Data Analytics"

The second programme "Internet of Things with Data Analytics" held at Bournemouth University (BU) can be taken full-time or part-time. With a similar focus as previously mentioned programme, this Msc shares its core modules with the MSc "Internet of Things" offered at the same university. The main objective of this programme is to provide understanding and practical experience of data analytics methods, processes and applications in the area of IoT. Duration of the programme depends whether programme is taken full-time or part-time:

Option	Mode	Duration	Additional comment
1	Full time	1 year	September intake
2	Full time	2 years including professional placement	September intake
3	Full time	1,5 years (18 months)	January intake
4	Full time	2,5 years including professional placement	January intake
5	Part time	2 years	-

The duration of the placement is minimum 30 weeks and takes place after the end of the second semester.
List of Core Units (more detailed description at the following link https://www1.bournemouth.ac.uk/study/courses/msc-internet-things-data-analytics):

Courses	Units	Semester	Course type
Mobile & Pervasive Technology	20 C	-	Compulsory
Wireless, Sensor and Actuator Networks	20 C	-	Compulsory
Security and Privacy in IoT	20 C	-	Compulsory
Research Methods & Professional Issues	20 C	-	Compulsory
Individual Masters Project (IoT)	60 C	-	Compulsory
Analytics for Data Streams	20 C	-	Optional
Big Data & Cloud Computing.	20 C	-	Optional
Business Intelligence	20 C	-	Optional
Optional Industrial Placement			Optional

Students are required to complete 4 core units and choose 2 optional units together with a compulsory project unit. However, there are no progression requirements.
The minimum credit value of a unit is normally 20 credits, above which credit values normally increase at 20-point intervals. 20 credits is the equivalent of 200 study hours required of the student, including lectures, seminars, assessment and independent study. 20 University credits are equivalent to 10 European Credit Transfer System (ECTS) credits.
As a rule, time devoted to assessment should normally represent approximately 25% of the student learning time for a unit (i.e. 50 hours for a 20-credit unit), leaving the rest for specific programme-related activities, including lectures, seminars, preparatory work, practical activities, reading, critical reflection and independent learning. Of the time devoted to assessment, every 10 hours of student effort is equivalent to approximately 1,000 words of coursework or 1 hour of examination. Therefore, as a guideline, a 20-credit unit would normally require the equivalent of approximately 5,000 words in total (e.g. a 2,000-word written coursework and a 3-hour unseen examination).
As with the most of master studies, there are two main entry requirements. The first one is to possess Bachelors Honours degree with 2:2 in any subject (or equivalent) and the second one is for students whose first language is not English to have IELTS 6.5 (Academic) or above. However, they have an additional requirement for students to have experience in the computing area (can be checked in the form of test).

5.3. Queen Mary University of London – Master Study "Internet of Things"

MSc "Internet of Things" (three streams – Data, Engineering, Intelligent Sensing)) offered at Queen Mary University of London (QMUL) is currently available for one year full-time study and two years part-time study. This master study combines academic study with one-year industrial placement (several examples can be found).

For full-time students, 8 modules (6 compulsory and 2 optional ones) have to be completed in first two semesters, and MSc project in third semester. The modules are listed on the following table:

Stream - Data	**Stream - Engineering**	**Stream – Intelligent Sensing**
Compulsory Modules		
Introduction to IOT	Enabling Communication Technologies for IOT	Enabling Communication Technologies for IOT
Enabling Communication Technologies for IOT	Introduction to IOT	Fundamentals of DSP
Applied Statistics	Mobile Services	Graphical User Interfaces
Mobile Services	Security and Authentication	Introduction to IOT
Security and Authentication	MSc Project (Semester 3)	Mobile Services
Data Analytics		Security and Authentication
MSc Project (Semester 3)		MSc Project (Semester 3)
Optional modules		
Big Data Processing	21st Century Networks	Cloud Computing
Data Mining	Cloud Computing	Design for Human Interaction
Machine Learning	Embedded Systems	Introduction to Computer Vision
The Semantic Web	Interactive System Design	Machine Learning
Digital Media and Social Networks	Mobile and WLAN Technologies	Machine Learning for Visual Data Analytics
Cloud Computing	Network Modeling and Performance	Real-Time DSP
	Real-Time and Critical Systems	

Teaching of these modules consists of lectures, seminars and usage of a virtual learning material. Each module provides 36 hours of contact time, supported by labs and directed further study.
Assessment of student work will be done mostly through coursework and exams, while some modules will only require coursework (usually result in research project or dissertation).
Again, this master study has entry requirements of the equivalent of a British first or good second class honours degree in Computer Science, Electronic Engineering, Maths, Physics or related discipline and Non-native English speakers are required to have minimum of IELTS 6.5. It is highly recommended to have a good knowledge of computer programming.
Alternative to these master programmes is **"**Internet of Things with Entrepreneurship**"** taught at The City, University of London.

5.4. Discussion on "Internet of Things" Master programmes

Obviously, this group could bring insights into most important aspects of internet of things that needs to be transferred as part of computing/data analytics module within CASProD programme.
These programmes offer a lot of content with a limited applicability to Smart Product Development as it was envisaged at the time of project proposal preparation. Therefore, more advanced courses from the second year probably should not be included into the future curriculum. However, courses during the first semester can offer necessary level of knowledge for students that plan to enrol to CASProD programme (e.g. Introduction to IOT, Machine Learning and Data Analytics etc.).
The DSCC programme has interesting structure and allows a lot of flexibility for students in the final year. In the second year students can also choose between different application areas. At QMUL students can choose between different streams from the beginning of the programme (though there is a big overlap – minimum four compulsory courses *Enabling Communication Technologies for IOT*, *Mobile Services, Introduction to IOT, Security and Authentication*). This seems hard to accomplish in distributed environment, but it is still something worth further consideration.
The BU and QMUL programmes offer a lot of options in terms of duration of the programme. In addition, they introduced an option to experience industrial placement (UK or international) as a part of Erasmus mobility programmes or volunteering projects. Industrial placement as a additional module could definitely provide added value to enrolled students.

6. Joint and dual degree programmes

The abovementioned undergraduate and graduate studies were all held at one location (except for CMU). However, ERASMUS Mundus facilitates and fosters proposal of joint master studies jointly delivered by an international consortium of higher education institutions. In order to fund these studies, ERASMUS defined two main requirements:

- Study must take place in at least two of the Programme countries.
- Part of the studies can also take place in a Partner countries if there is a partner-country institution involved.

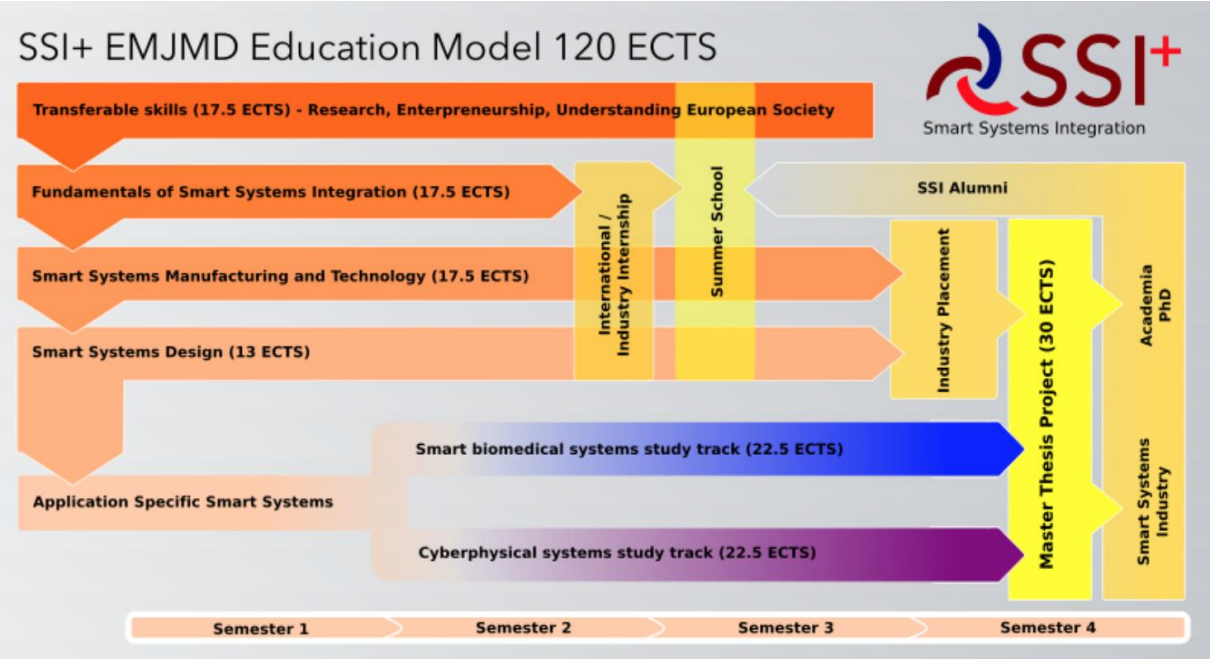
To remove any ambiguities about terminology, please use the following definitions of joint and dual degree study programmes.

- Joint degree program: A degree program that is designed and delivered by two or more partner institutions in different countries. A student receives a single qualification endorsed by each institution.
- Dual degree program: A degree program that is designed and delivered by two or more partner institutions in different countries. A student receives a qualification from each of the partner institutions. Such programs are also referred to as "double" degrees.

According to Dania Brandford-Calvo, director of the Global Education Office at the University of Rhode Island, while joint degrees are "exciting once they get off the ground," they often entail years of preparation, an extensive amount of work, and numerous stumbling blocks.
Based on the initial CASProD proposal, the focus was put on building a joint master degree programme related to "Smart product development". By reviewing the existing programmes, we identified only one that seems to show a lot of similarities with the CASProD programme idea.

6.1. Smart Systems Integration Plus - Master Study programme (http://ssi-master.eu/)

This master study programme is called Smart Systems Integration Plus (SSI+) and it is delivered by three institutions: Heriot-Watt University (HWU), University College of Southeast Norway (HSN) and Budapest University of Technology and Economics (BME). SSI+ is a two-year (120 ECTS) Joint Master Programme, with full student mobility between the three partner institutions with leading expertise in the academic fields of Smart Systems and Microsystems Technology. This programme has rotational style with movement between different institutions every semester.
The first semester is hosted at HWU in Edinburgh (Scotland) and is dedicated to the fundamental knowledge and training in Smart Systems Integration. The second semester takes place at HSN in Vestfold (Norway) and is dedicated to study manufacturing methods and characterisation techniques for smart systems. The third semester is hosted by BME in Budapest (Hungary) and focuses on MEMS modelling, analogue and digital hardware design for Smart Systems. The third semester ends with an Industrial Placement where the already achieved knowledge, skills and competences can be utilized in industrial environment. The fourth semester includes the master thesis project (25% of the total ECTS value) where students carry out individual projects with the consortium partners, or with industrial or other academic partners, thus offering a broad range of possibilities for specialization for the individual student.



Students can choose between two study tracks in the second semester based on two fundamental Smart Systems Application area: Cyberphysical Systems (e.g. autonomous vehicles, smart sensors) or Smart Biomedical Systems (Lab-on-a-Chip devices, health monitors).
Individual semesters include courses that try to develop Transferable skills (17.5 ECTS points), Manufacturing and Technology skills (34 ECTS) and Design/Application skills (14 ECTS). Courses related to these categories are distributed evenly throughout the curriculum. The remaining ECTS points are related to Master thesis project (30 ECTS) and Smart Systems Application Area (25,5 ECTS in both streams).

List of offered courses:

Courses	Units	Semester	Course type
Advanced Writing Skills, Research preparation and Entrepreneurship	5	I semester	Transferrable skills
Introduction to Scottish Society	2,5	I semester	Transferrable skills
Fundamentals of Smart Systems Integration	7,5	I semester	Manufacturing and technology
Advanced Packaging and Integration	7,5	I semester	Manufacturing and technology
Sensors, Actuators and IoT	7,5	I semester	Smart systems applications
Norwegian Society, Language and Culture	5	II semester	Transferrable skills
Measurements and Characterization	10	II semester	Manufacturing and technology
Manufacturing Processes for Smart Systems	5	II semester	Manufacturing and technology
Microsystem Design[1]	10	II semester	Smart systems applications
Micro and Nano Biological Systems[2]	10	II semester	Smart systems applications
Introduction to Hungarian Language and Culture	5	III semester	Transferrable skills
Testing, Validation and Virtual Instrumentation	4	III semester	Manufacturing and technology
Intelligent Sensor Devices Project[1]	8	III semester	Smart systems applications

Smart Biomedical Devices Project[2]	8	III semester	Smart systems applications
MEMS and IC co-design	4	III semester	Smart systems design
System Level Design	4	III semester	Smart systems design
Individual Project Laboratory	5	III semester	Smart systems design

All admission criteria are quite the same as in all other programmes (bachelor degree in electrical engineering, electronics, computer engineering, physics, materials science, mechanical engineering, biomedical engineering or a closely related discipline; Language ability; Motivation letter).
It is interesting to mention a bit of basic statistics so far:

- 60 students in 4 cohorts, 28 nationalities
- 2 cohorts graduated (30 students)
- 94% of graduates employed

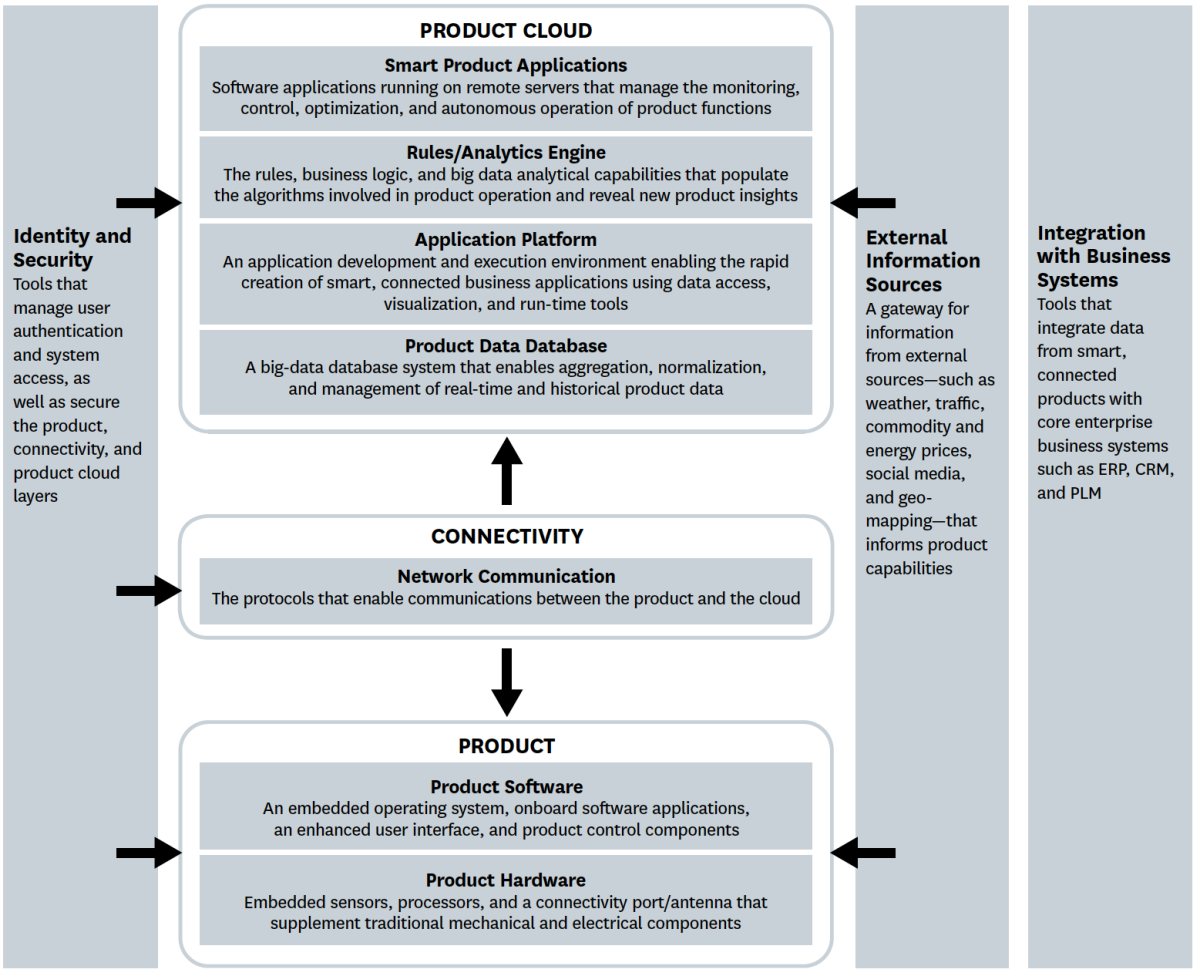
Recently, on the official SSI+ website course administrators published list of university/research institution collaborators and industrial partners implying potential industrial placement options. This aspect of programme organization seems to be very relevant for CASProD project.

6.2. Discussion on SSI+ programme

Since SSI+ programme has the same overall idea as a CASProD project, more thorough analysis was conducted.
Structure-wise, rotational style of the programme and clear distribution of the responsibilities between participating universities seems to be plausible approach. However, on their webpage they haven't specified how will students cope with failed courses and whether they can attend "similar" courses at other institutions.
By going through their streams, it is noticeable that their master programme is more focused on specific application areas and for that reason it cannot give range of topics that are planned for CASProD programme. SSI+ covers different aspects of smart system, but without real focus on its design (except in the final semester).
Courses related to Transferrable skills are too related to the culture and language of the hosting countries. Probably, one of the possibilities is to split "Advanced Writing Skills, Research preparation and Entrepreneurship" into more specific courses from which students could reap more benefits.
Again, industrial placement seems to have quite important role in the programme. Additionally, SSI+ organizers also introduced summer school as a five-day professional programme where students can listen lectures about "state of the art" by academic and industrial experts and participate in workshops with industry.
This project was co-funded by Erasmus+ Programme and therefore it is recommended to apply for Erasmus+ scholarships to participate in the SSI+ programme. In that way, the scholarship covers all tuition fees and subsistence costs. Also, this may be the reason why SSI+ programme had 28 nationalities in their first 4 cohorts.

7. Conclusions

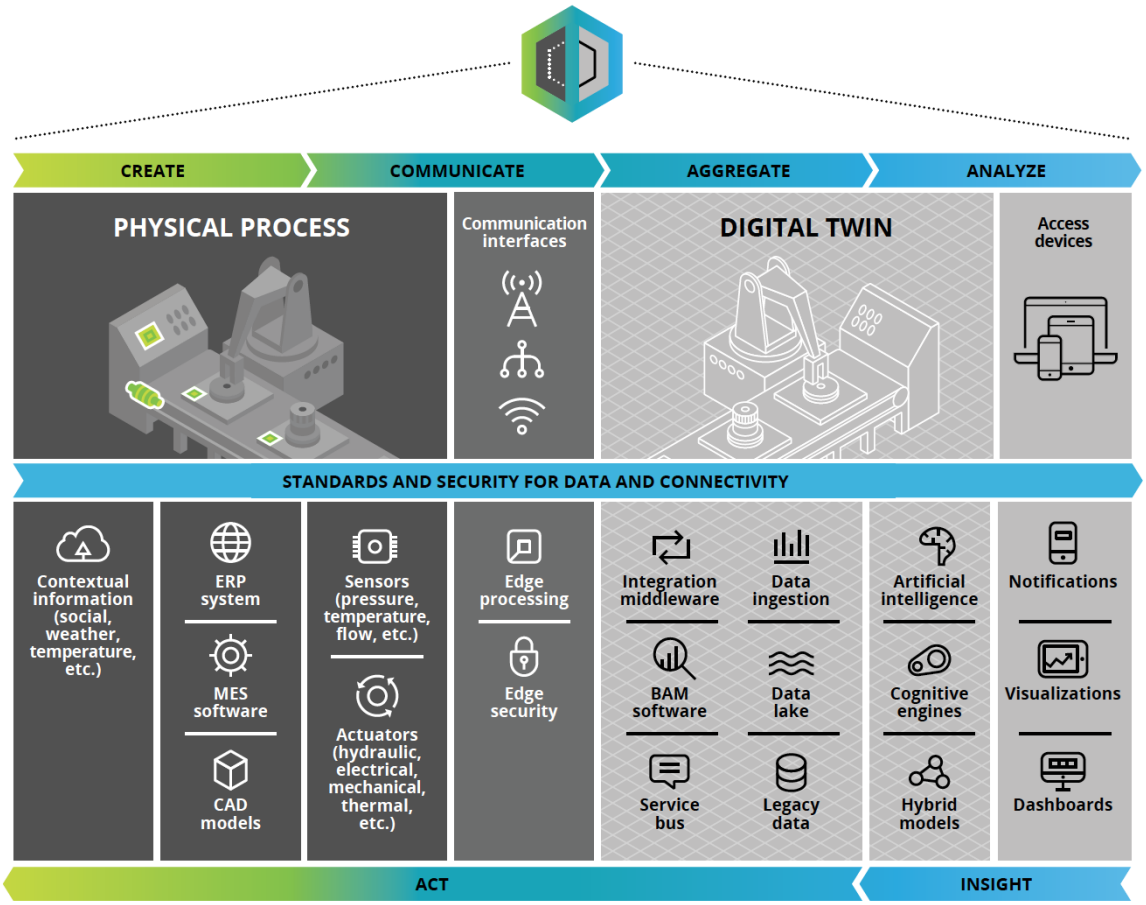
Going through the different programmes particular focusing on engineering design and innovation, there is obvious need for new direction and specialisation that will take into account the changes we are witnessing in the smart product-systems development.
It is also related to the new proposed architecture for the smart systems that was highlighted in the HBR article from the November 2014 and that is depicted on the following figure.



They also highlighted the implications on strategic but also development process that are caroused by the new paradigm, that require a fundamental rethinking of design. Particularly the following priciples have been highlighted as the key aspects, and should be included in the education of the future engineers

- Implications for the design: low-cost variability, evergreen design, New user interfaces and augmented reality, ongoing quality management, connected services, support for new business models, system interoperability
- Implications for manufacturing: smart factories, simplified components, reconfigured assemplying process, continous product operations
- Implications for the service: one stop service, remote service, preventive service, augmented reality supported service.

Extension of the paradigm applied for consumer products is also highlighted by the Deloitte report on Industry 4.0, focusing on how manufacturing processes become digital, and similar paradigm could be applied to all phases in the product-service life cycle.



Therefore, the new expertise is needed, and that is where is the gap in the current education. The skills needed to design, manufacture, and service smart, connected products are in high demand but short supply. Indeed, manufacturers are experiencing a growing sense of urgency about finding the right talent as their skill requirements shift from mechanical engineering to blend with a software engineering, from selling products to selling services, and from repairing products to managing product uptime.

Manufacturers have a need to hire experts in applications engineering, user interface development, and systems integration, and, most notably, data scientists capable of building and running the automated analytics that help translate data into action.

The business or data analyst of the past is evolving into a new type of professional, who must possess both technical and business acumen as well as the ability to communicate insights from analytics to business and IT leaders.

Development of the smart, connected products and services requires far more coordination across functions and disciplines than traditional engineering education does.

Among the all reviewed programme, the Smart Systems Integration Programme being the joint initiative across three different universities is one of the good examples how education of the future specialist could look like. However, in their programme they more focus to the integration than development.

The authors from the Ruhr University Bochum proposed in 2017, the following new competences model for the development of the smart products:

Product development	Engineering industry 4.0	New Job roles	Design Methodologies
Defining function, concept and architecture			Definition of value creating lifecycle activities
			Structure the co-creation
			Task and context analysis
			Definition of use cases,
			Consider flexibility of system goals,
			Extract factors that influence system goals
			Identify the potential for self-optimization,
			Identify cognitive functions,
			Analyse possible architecture changes,
			Strategies to modify structure and behaviour,
			Specification of partner networks
			Specification of risk allocation,
			Spatial allocation of processes and resources,
			Specification of socio-technical interfaces.
Development project management		Requirement exchange	Ascertaining business model requirements
		Technical project management for downstream development	
Design process	Synchronization between discipline specific engineering processes	Customization of engineering processes, methods and tools,	
	Process optimization with feedback information	Requirements engineering on systems level	
Design for x		Consider service-orientation in design reviews	
System thinking			
Core Engineering fundamental knowledge			
Utilization of knowledge in design	Use of knowledge management tools,		
Entrepreneurship	Simultaneous development of products and business models	Contracting with customer	Risk Management of Business Models
		contracting suppliers	
Understanding needs and setting goals		Customer involvement for need analysis	Establish relevant stakeholders and contextual issues, analyse their impact on systems goals and define possible strategies to manage it,
			Analysis of customer value creation and business environment
Disciplinary design (e.g. appropriate techniques, tools and processes)	Methodical competences for the engineering 4.0	Strategies to approach service oriented design	
Communications	Anticipatory thinking and combinatorial action in combination with advanced communicative and coordinative skills	Moderate PSS idea generation	
Attitudes, thoughts and learning		Train colleagues	
Analytical reasoning and problem solving			
Enterprise and business context			Analysis of matches between provider and customer strategy,
			Analyse customers and provider's capabilities,
Teamwork			

Taking all previously mentioned into account and to preserve the education tradition existing at the CASProD involved institutions, and based on the mapping of the current courses offered at all three of them, we believe that the proposed CASProD join master programme should be focusing around the following core pillars:

- Smart engineering product-services systems design
- Advanced materials and digital manufacturing
- Industrial IoT and applied big data science for the engineers
- Innovation, sustainability, management and entrepreneurship (as transferable skills)
- Application specific smart systems:
    - Transportation and urban mobility
    - Health care and wellbeing
    - Industry 4.0 and factories of the future

There is a vast of the current courses offered at three partner universities for each of the above-mentioned pillars. Depending on the new-joint master programme structure and execution plan, the courses should be selected to contribute with the explicit learning output at least to the one of pillars.