TU Clausthal

Module handbook of the Master's degree program Intelligent Manufacturing

based on the implementation regulations of 11.07.2022

last amended on 23.04.2024

Current version as of 15th January 2025

Contents

List of abbreviations

B.Sc	Bachelor of Science
BA	Bachelor thesis (Bachelorarbeit)
E	Excursion
ECTS	Credit points according to the European Credit Transfer and Accumulation System
h	Hours
LN	Certificate of achievement (Leistungsnachweis)
LV	Course (Lehrveranstaltung)
M.Sc	Master of Science
MA	Master's thesis (Masterarbeit)
MP	Module examination (Modulprüfung)
MTP	Partial module examination (Modulteilprüfung)
P	Practical course
PV	Preliminary examination (Prüfungsvorleistung)
S	Seminar
SoSe	Summer semester (Sommersemester)
SWS	Semester hours per week (Semesterwochenstunden)
T	Tutorium
Ü	Exercise (Übung)
V	Lecture (Vorlesung)
WiSe	Winter semester

1 Compulsory Modules of the Master's Program

The Master's Program Intelligent Manufacturing comprises ten modules that have to be completed by students of both fields of study. Each module is described in detail below.

1. Module title (English)

Advanced Cyber-Physical Systems

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing, M.Sc. Computer Science

3. Module Coordinator	4. Relevant faculty	5. Module number
Prof. Dr. Christian Siemers	Faculty for Mathematics/Computer Science and Mechanical Engineering	

6. Language	7. ECTS	8. Duration	9. To be offered
English	6	[X] 1 Semester [ ] 2 Semester	[ ] each semester [X] each study year [ ] irregular

10. Learning/ qualification objectives of the module

In this course, students will acquire basic knowledge of cyber-physical systems as well as advanced knowledge in specific parts. The focus is on explaining the structure, functionality and possible uses of cyber-physical systems in relation to Industry 4.0. The qualification objectives of the module are therefore:

The students acquire knowledge and methodological skills in the use of cyber-physical systems and their capabilities for application in industrial systems and their evaluation.

- The students acquire the essential basic knowledge of technologies from computer science that are important for the application of cyber-physical systems in Industry 4.0.
- After successfully passing, the students can model small systems concerning their behavior inside industrial applications.
- The students acquire basic and advanced knowledge about cyber security inside industrial applications.

The students plan the approach to completing a project task based on the knowledge they have acquired and evaluate it in relation to the state of the art and the required use of resources. The students are able to classify and evaluate the results achieved and present them to a specialist audience and present them in a project report.

Courses						
11. No.	**12. Title of the course**	**13. Lecturer**	**14. Course No.**	**15. Type of course**	**16. SWS**	**17. Work attendance/ internal study**
1	Advanced Cyber-Physical Systems	Prof. Dr. Siemers	W 1260	V	3	42 h / 56 h
2	Project for Advanced Cyber-Physical Systems	Prof. Dr. Siemers	W 1260	P	1	14 h / 68 h
				Sum:	4	56 h / 124 h

About No. 1:	
18a. Recom. Prerequisites	Bachelor's degree in an engineering or natural science discipline, basic knowledge in computer science
19a. Contents	The lecture contains the following topics: ▪ Introduction to modelling techniques ▪ Discrete and hybrid automata ▪ Data types, data representation and their limitations ▪ Microprocessor-based systems ▪ Interfacing between computer systems and machines ▪ Cyber security
20a. Media forms	Lecture in presence, Beamer, Media
21a. Literature	[1] Bolshakov, Alexander A. ; Kravets, Alla G.: Cyber-Physical Systems. Springer Nature Switzerland, ISBN 978-3-0316-7910-0 (2024) [2] Faulconbridge, I, and Ryan, M.J. (2014): Systems Engineering Practice. Argos Press, ISBN: 978-1-9211-3807-2 [3] Suh, S.C. et al.: Applied Cyber-Physical Systems. Springer Publ., ISBN 978-1-4614-7335-0 (2014)
22a. Other	A script is provided for this lecture
About No. 2:	
18b. Recom. Prerequisites	Knowledge in literature studies
19b. Contents	Student project work on a given topic from the focus area, which shows the state of the art in the use of cyber-physical systems, evaluates it and shows a potential solution approach.
20b. Media forms	Literature review, data sheet
21b. Literature	See 21a, further literature will be given specifically.
22b. Other	None

Study/ examination performance					
23. No.	**24. Assigned courses**	**25. P. type**	**26. ECTS**	**27. Evaluation**	**28. Percentage of module grade**
1	Advanced Cyber-Physical Systems	MP	6	graded	100 %
2	Project for Advanced Cyber-Physical Systems	PV	0	passed/ not passed	0 %

About No. 1:	
29a. Form of examination/ prerequisite for the award of credit points	The examination is in written form (90 minutes)
30a. Responsible examiner	Prof. Dr. Christian Siemers
31a. Preliminary examinations	Project work (29b) must be successfully passed
About No. 2:	
29b. Form of examination/ prerequisite for the award of credit points	Submission of the project work and positive evaluation.
30b. Responsible examiner	Prof. Dr. Christian Siemers
31b. Preliminary examinations	None

1. Module title (English)

Advanced System Automation

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing

3. Module Coordinator		4. Relevant faculty	5. Module number
Prof. Dr.-Ing. Stefan Palis		Faculty of Mathematics/Computer Science and Mechanical Engineering	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
English	6	[X] 1 Semester [ ] 2 Semester	[ ] each semester [X] each study year [ ] irregular

10. Learning/ qualification objectives of the module

Students acquire a basic understanding of discrete-event systems and their modeling and control. They are able to:

- model discrete-event systems with finite automata and Petri nets,
- analyse the languages of finite automata,
- design and implement control strategies for finite automata and Petri nets,
- understand and apply advanced models and concepts such as timed Petri nets and max-plus algebra

Courses

11. No.	12. Title of the course	13. Lecturer	14. Course No.	15. Type of course	16. SWS	17. Work attendance/ internal study
1	Advanced System Automation	Prof. Dr.-Ing. Stefan Palis	W 8743	3V/1Ü	4	56 h / 124 h
				Sum:	4	56 h / 124 h

About No. 1:

18a. Recom. Prerequisites	Bachelor's degree in an engineering or natural science discipline.

19a. Contents	The lecture covers the following topics: ▪ Introduction to discrete-event systems ▪ Modeling with finite automata ▪ Languages of finite automata ▪ Analysis and control (supervisory control) of finite automata ▪ Modeling with Petri nets ▪ Control design for Petri nets ▪ Timed Petri nets and max-plus algebra
20a. Media forms	Blackboard, projector/slides
21a. Literature	Recommended literature [1] Introduction to discrete event systems, Springer, C.G. Cassandras, S. Lafortune [2] Control of discrete event systems, Springer, C. Seatzu, M. Silva, J. van Schuppen [3] Supervisory control of discrete event systems, Springer, W.M. Wonham, K. Cai
22a. Other	None

Study/ examination performance					
23. No.	**24. Assigned courses**	**25. P. type**	**26. ECTS**	**27. Evaluation**	**28. Percentage of module grade**
1	Advanced System Automation	MP	6	graded	100 %
About No. 1:					
29a. Form of examination/ prerequisite for the award of credit points	Written exam (60 min) for 15 or more participants, oral exam (30 min) for fewer than 15 participants				
30a. Responsible examiner	Prof. Dr.-Ing. Stefan Palis				
31a. Preliminary examinations	None				

1. Module title (English)

Big Data Management and Analytics

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing, M.Sc. Informatik, M.Sc. Wirtschaftsinformatik

3. Module Coordinator		4. Relevant faculty	5. Module number
Prof. Dr. S. Hartmann		Faculty of Mathematics/Computer Science and Mechanical Engineering	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
English	6	[X] 1 Semester [ ] 2 Semester	[ ] each semester [X] each study year [ ] irregular

10. Learning/ qualification objectives of the module

After successfully completing this module, students understand the challenges of managing and analyzing very large data volumes and data streams in modern data-intensive applications and are proficient in IT-based solutions.

Courses

11. No.	12. Title of the course	13. Lecturer	14. Course No.	15. Type of course	16. SWS	17. Work attendance/ internal study
1	Big Data Management and Analytics	Prof. Dr. S. Hartmann	S 1246	3V/1Ü	4	56 h / 124 h
				Sum:	4	56 h / 124 h

About No. 1:

18a. Recom. Prerequisites	Bachelor's degree in an engineering or scientific discipline and basic knowledge of databases.

19a. Contents	The following topics are covered in this module: ▪ Characteristics, challenges and applications of Big Data ▪ NoSQL and NewSQL databases ▪ Cloud and multi-tenant databases ▪ Data processing with Hadoop, MapReduce and Spark ▪ Management and mining of data streams ▪ Frequent item sets ▪ Pre-processing of data ▪ High-dimensional ▪ Graph databases and analysis of graph data ▪ Social networks, recommender systems
20a. Media forms	Projector presentations, whiteboard, blackboard, exercises in the lab
21a. Literature	[1] Abiteboul et al: Web Data Management, Cambridge University Press [2] Leskovec, Rajaraman, Ullman: Mining von massiven Datenbeständen [3] Frampton: Complete Guide to Open Source Big Data Stack, Apress Emrouznejad, Charles: Big Data for the Greater Good, Springer [4] Kipf u.a.: Skalierbare Analytik auf schnellen Daten, ACM ToDS
22a. Other	None

Study/ examination performance					
23. No.	**24. Assigned courses**	**25. P. type**	**26. ECTS**	**27. Evaluation**	**28. Percentage of module grade**
1	Big Data Management and Analytics	MP	6	graded	100 &
2	Homework Big Data Management and Analytics	PV	0	ungraded	0 %

About No. 1:	
29a. Form of examination/ prerequisite for the award of credit points	Written exam (90 minutes) for more than 15 students, oral exam (30 minutes) for less than 15 students
30a. Responsible examiner	Prof. Dr. S. Hartmann
31a. Preliminary examinations	Homework on Big Data Management and Analytics
About No. 2:	
29b. Form of examination/ prerequisite for the award of credit points	Homework

30b. Responsible examiner	Prof. Dr. S. Hartmann
31b. Preliminary examinations	None

1. Module title (English)

Computer Integrated Manufacturing incl. Lab

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing, M.Sc. Maschinenbau

3. Module Coordinator		4. Relevant faculty	5. Module number
Prof. Dr.-Ing. D. Inkermann		Faculty of Mathematics/Computer Science and Mechanical Engineering	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
English	6	[X] 1 Semester [ ] 2 Semester	[ ] each semester [X] each study year [ ] irregular

10. Learning/ qualification objectives of the module

After completing the module, students will have a basic knowledge of data processing in production and have an overview of modern approaches such as cyber physical system, additive manufacturing and Industry 4.0 as well as the underlying technologies and methods of information processing. Students will be able to recognize key relationships between product design and manufacturability/assemblability, taking into account modern manufacturing processes and use them for product design. The following learning objectives are pursued:

- Students will be able to recognize central systems, methods and technologies for continuous information management in the product development process and explain and differentiate between their functions and modes of action
- Students will be able to distinguish and apply methods for the planning, development and control of production systems and explain the function of production control systems, the function of production control systems and the structure of information systems
- Students can explain the principles of design for assembly, design for manufacturing and design for additive manufacturing and apply them to product design; they are able to assess existing product designs with regard to their compliance with these principles
- Students are familiar with the basic concepts of information processing in Industry 4.0 applications and can explain how cyber physical systems work, they are able to characterize existing Industry 4.0 technologies and locate them in the product development process

The laboratory for the Computer Integrated Manufacturing module enables students to practically apply selected methods for the simulation of production processes (e.g. NC simulation), quality assurance and process planning.

Courses						
11. No.	**12. Title of the course**	**13. Lecturer**	**14. Course No.**	**15. Type of course**	**16. SWS**	**17. Work attendance/ internal study**
1	Computer Integrated Manufacturing	Prof. Dr.-Ing. D. Inkermann	S 8181	2V/1Ü	3	42 h / 78 h
2	Lab Computer Integrated Manufacturing	Prof. Dr.-Ing. D. Inkermann	S 8160	1P	1	28 h / 32 h
				Sum:	4	70 h / 110 h

About No. 1:	
18a. Recom. Prerequisites	Bachelor's degree in an engineering or natural science discipline, basic knowledge of production engineering
19a. Contents	The lecture of the module Computer-Integrated Manufacturing teaches technical and organizational basics as well as current technologies for integrated information management in production. The information flow from product development to machine control is shown, taking into account various manufacturing technologies, and the systems and methods required for data preparation, integration and transfer are introduced. The module is divided into the following topics: 1. Terms and definitions of computer-integrated manufacturing 2. Operational and data interfaces between design & development and production 3. Central information objects, interfaces and information systems in the (virtual) product creation process 4. Technologies of additive manufacturing and Industry 4.0 5. Methods and principles of design for assembly, design for manufacturing and design for additive manufacturing 6. Methods and tools of integrated production planning and control 7. Functionality and types of production control systems 8. Concept of the digital factory and use of cyber physical systems in the product development process 9. Analysis and selection of systems for end-to-end information management in the product development process
20a. Media forms	Slide presentation, script, videos, digital provision of slides for self-study

21a. Literature	[1] Lecture notes [2] Ehrlenspiel, K. and Meerkamm, H. (2017): Integrierte Produktentwicklung. Denkabläufe, Methodeneinsatz, Zusammenarbeit. Carl Hanser Verlag, München, Wien, 6. vollst. überarb. und erweit. Auflage, ISBN 978-3-446-44089-0 [3] Stark, J., 2022. Product Lifecycle Management (Volume 1): 21st Century Paradigm for Product Realisation, Decision Engineering. Springer International Publishing, Cham. https://doi.org/10.1007/978-3-030-98578-3 [4] Hehenberger, P. (2020): Computergestützte Produktion - Eine kompakte Einführung. Springer Vieweg, Berlin, 2. Auflage, DOI 10.1007/978-3662-60876-0 [5] Ustundag, A., Cevikcan, E., 2018. Industry 4.0: Managing The Digital Transformation, Springer Series in Advanced Manufacturing. Springer International Publishing, Cham. https://doi.org/10.1007/978-3-319-57870-5 [6] Molloy, O.; Warman, E.A. and Tilley, S. (1998): Design for Manufacturing and Assembly – Concepts, Architecture and Implementation. Clapham & Hall, London, DOI 10.1007/978-14615-5785-2
22a. Other	None
About No. 2:	
18b. Recom. Prerequisites	Bachelor's degree in an engineering or natural science discipline, basic knowledge of production engineering
19b. Contents	In the laboratory of the computer-integrated manufacturing module, selected methods and tools for the simulation and planning of production manufacturing processes are applied in practice. The laboratory covers the following topics: ▪ Simulation (collision check, machine simulation) ▪ Computer-aided quality assurance (recognition and recording of inspection characteristics, statistical process control) ▪ Computer-aided assembly planning (design for assembly) ▪ Computer-aided process planning and control ▪ Additive manufacturing process chain for Fused Deposition Modeling Project tasks are processed for each of the topics. A CAD/CAM system (Siemens NX) is used for processing.
20b. Media forms	Lecture notes, videos
21b. Literature	See 21a.
22b. Other	None

Study/ examination performance					
23. No.	**24. Assigned courses**	**25. P. type**	**26. ECTS**	**27. Evaluation**	**28. Percentage of module grade**
1	Computer Integrated Manufacturing	MTP	4	graded	80 %
2	Lab Computer Integrated Manufacturing	MTP	2	graded	20 %

About No. 1:	
29a. Form of examination/ prerequisite for the award of credit points	Examination as a written exam (60 min).
30a. Responsible examiner	Prof. Dr.-Ing. D. Inkermann
31a. Preliminary examinations	Successful project work
About No. 2:	
29b. Form of examination/ prerequisite for the award of credit points	Evaluated portfolio (presentation portfolio) of the project work
30b. Responsible examiner	Prof. Dr.-Ing. D. Inkermann
31b. Preliminary examinations	None

1. Module title (English)

Interdisciplinary Engineering Project and Seminar Intelligent Manufacturing

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing

3. Module Coordinator		4. Relevant faculty	5. Module number
Prof. Dr.-Ing D. Inkermann		Faculty of Mathematics/Computer Science and Mechanical Engineering	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
English	6	[X] 1 Semester [ ] 2 Semester	[ ] each semester [X] each study year [ ] irregular

10. Learning/ qualification objectives of the module

By successfully completing the module 'Interdisciplinary Engineering Project and Seminar Intelligent Manufacturing', students acquire the ability to work on interdisciplinary problems in the field of Industry 4.0. Students develop basic problem-solving skills and the necessary contextual knowledge for collaboration with technical experts. The module focuses on the development of methodological and social skills with the following focal points:

- Basic systems and process thinking skills (systems thinking) for analysing problems and developing solutions
- Ability to plan individual approaches to solve problems and adapt them based on findings in the problem-solving process
- Application of basic techniques for researching and evaluating information on various specialised topics
- Problem-orientated selection and application of known engineering methods and tools from product development, production engineering and information technology
- Practical application of techniques and methods for the structured documentation and visualisation of work results

Courses

11. No.	12. Title of the course	13. Lecturer	14. Course No.	15. Type of course	16. SWS	17. Work attendance/ internal study
1	Seminar Intelligent Manufacturing	Prof. Dr.-Ing. D. Inkermann	W 8179	1S	1	14 h / 31 h
2	Interdisciplinary Engineering Project (IEP)	Lecturers of the Master's Program Intelligent Manufacturing	W 8180	3P	3	84 h / 51 h
				Sum:	4	98 h / 82 h

About No. 1:	
18a. Recom. Prerequisites	Bachelor's degree in an engineering or natural science subject.
19a. Contents	In the lecture for the module, students are introduced to the basics of systems and process thinking and trained in selected ways of thinking, e.g. thinking in control loops, thinking in hierarchies and life cycle thinking and scientific thinking. Students also receive an introduction to problem-solving strategies and established procedures for problem-solving in engineering (selected process models).
20a. Media forms	Handouts, presentations, videos
21a. Literature	[1] Bonnema, G.M., Veenvliet, K.T. and Broenink, J.F. (2016): Systems Design and Engineering: Facilitating Multidisciplinary Development Projects. CRC Press, London, DOI: 10.1201/b19135
22a. Other	None
About No. 2:	
18b. Recom. Prerequisites	Bachelor's degree in an engineering or natural science subject.
19b. Contents	In the practical part of the module (Interdisciplinary Engineering Project), students work on an application-oriented problem from a selected topic area of Industry 4.0. For this topic, the state of the art is to be researched and solution approaches are to be developed and demonstrated in a laboratory environment or through simulations. The work is carried out independently, (interim) results and problems that arise are presented and discussed by students and supervisors in the accompanying seminar. The individual results are continuously documented in a portfolio (presentation portfolio) and presented as part of a final presentation.
20b. Media forms	Presentations, experiments, simulations
21b. Literature	See 21a. Topic-specific literature will be announced by the supervisor. General guidance on procedures and research methods will be provided in the form of handouts and a collection of slides.
22b. Other	None

Study/ examination performance

23. No.	**24. Assigned courses**	**25. P. type**	**26. ECTS**	**27. Evaluation**	**28. Percentage of module grade**
1	Seminar Intelligent Manufacturing	MTP	1	graded	20 %
2	Interdisciplinary Engineering Project (IEP)	MTP	5	graded	80 %
About No. 1:					

29a. Form of examination/ prerequisite for the award of credit points	Presentation of the problem (10 minutes) and interim results of the Interdisciplinary Engineering Project with subsequent discussion during the seminar
30a. Responsible examiner	Prof. Dr.-Ing. D. Inkermann
31a. Preliminary examinations	None
About No. 2:	
29b. Form of examination/ prerequisite for the award of credit points	Evaluated portfolio (presentation portfolio) of the project work
30b. Responsible examiner	Lectures of Master's Program Intelligent Manufacturing
31b. Preliminary examinations	Participation in Intelligent Manufacturing seminar

1. Module title (English)

Interdisciplinary Research Project

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing

3. Module Coordinator		4. Relevant faculty	5. Module number
Prof. Dr.-Ing. D. Inkermann		Faculty of Mathematics/Computer Science and Mechanical Engineering	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
English	6	[X] 1 Semester [ ] 2 Semester	[ ] each semester [X] each study year [ ] irregular

10. Learning/ qualification objectives of the module

The successful completion of the Interdisciplinary Research Project enables students to work on interdisciplinary research questions in the field of Industry 4.0. Through the cooperation of students from both fields of study of the Master's programme in Intelligent Manufacturing, individual methodological and social skills are developed and specialist skills are further developed through problem-oriented application.

- The ability to develop a solution within a limited period of time from a given scientific problem in teamwork with experts in the field, to identify the topics required for processing and to specify the necessary contributions of the various experts in the field
- Researching the necessary information on specialised topics and drawing conclusions for dealing with the problem presented
- The ability to select and practically apply suitable methods and tools for the problem and to plan suitable measures for the verification of the results
- Interpret procedures and (interim) results, document them in writing in a suitable form and present them
- Plan and implement procedures and work steps for interdisciplinary teamwork and solve any problems that arise in the collaboration (time and conflict management)

Courses						
11. No.	**12. Title of the course**	**13. Lecturer**	**14. Course No.**	**15. Type of course**	**16. SWS**	**17. Work attendance/ internal study**
1	Interdisciplinary Research Project (IRP)	Lecturers of the Master's Program Intelligent Manufacturing	S 8180	3P	3	42 h / 92 h
2	Interdisciplinary Research Methodology	Prof. Dr.-Ing. D. Inkermann	S 8182	1V	1	14 h / 32 h
				Sum:	4	56 h / 124 h

About No. 1:	
18a. Recom. Prerequisites	Successful completion of the module Interdisciplinary Engineering Project and Seminar Intelligent Manufacturing
19a. Contents	Students work on a research-oriented question from the field of Industry 4.0. The problem statement is defined by lecturers from the Master's degree programme in Intelligent Manufacturing and addresses the fields of action of cyber-physical systems. The project is carried out by one student from the Flexible and Intelligent Products and Processes field of study and one student from the Manufacturing Analytics and Optimisation field of study. The Interdisciplinary Research Project is aimed at the practical application of the specialist and methodological knowledge acquired in the compulsory and compulsory elective areas. The results are continuously documented in a portfolio (presentation portfolio) and presented as part of a final presentation (e.g. as a poster).
20a. Media forms	Presentations, experiments, simulations
21a. Literature	Topic-specific literature will be announced by the supervisor. General guidance on procedures and research methods will be provided in the form of a script. Supplementary literature: [1] Blessing. L.T.M. and Chakrabarti, A. (2009): DRM, a Design Research Methodology. Springer, London, DOI: 10.1007/978-1-84882-587-1 [2] Bonnema, G.M., Veenvliet, K.T. and Broenink, J.F. (2016): Systems Design and Engineering: Facilitating Multidisciplinary Development Projects. CRC Press, London, DOI: 10.1201/b19135 [3] Vogel-Heuser, B.; Ten Hompel, M. and Bauernhansl, T. (2017): Handbuch Industrie 4.0, Band 1 – Produktion. Springer, Heidelberg, Berlin, ISBN 9783662452783
22a. Other	None
About No. 2:	
18b. Recom. Prerequisites	Successful completion of the module Interdisciplinary Engineering Project and Seminar Intelligent Manufacturing

19b. Contents	The module includes an introductory lecture (1 SWS, as a block course at the beginning of the semester). Contents of the lecture are 1. basic procedures and models for structuring research work 2. types of and requirements for research work 3. methods for clarifying the research question 4. visual methods for structuring relevant topics and findings
20b. Media forms	Presentations, handout
21b. Literature	See 21a.
22b. Other	None

Study/ examination performance					
23. No.	**24. Assigned courses**	**25. P. type**	**26. ECTS**	**27. Evaluation**	**28. Percentage of module grade**
1	Interdisciplinary Research Project (IRP)	MTP	5	graded	80 %
2	Interdisciplinary Research Methodology	MTP	1	graded	20 %

About No. 1:	
29a. Form of examination/ prerequisite for the award of credit points	Evaluated portfolio (presentation portfolio) of the project work
30a. Responsible examiner	Lectures of the Master's Program Intelligent Manufacturing
31a. Preliminary examinations	None
About No. 2:	
29b. Form of examination/ prerequisite for the award of credit points	Oral examination (20 minutes)
30b. Responsible examiner	Prof. Dr.-Ing. D. Inkermann
31b. Preliminary examinations	None

1. Module title (English)

Product Design and Process Planning for Casting

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing, M.Sc. Maschinenbau

3. Module Coordinator		4. Relevant faculty	5. Module number
Prof. Dr.-Ing. B. Tonn		Faculty of Natural and Materials Science	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
English	6	[X] 1 Semester [ ] 2 Semester	[ ] each semester [X] each study year [ ] irregular

10. Learning/ qualification objectives of the module

After successfully completing the module, students will be able to determine a suitable production technique, a material and a component design suitable for casting based on the requirements for a given component. The module focuses on the following qualification objectives:

- The students know the basics of casting-compatible component design and can apply these taking into account various casting processes.
- They know modern methods of optimising the properties of components under given casting conditions and are able to apply these in the component development phase.
- They understand the basics of production planning and are able to harmonise the design of cast components, the corresponding casting process and the material, taking into account qualitative and economic aspects.
- They are fundamentally capable of calculating casting systems and using mould filling and solidification simulation for quality-compliant component production.

The lecture concludes with an excursion.

Courses

11. No.	12. Title of the course	13. Lecturer	14. Course No.	15. Type of course	16. SWS	17. Work attendance/ internal study
1	Product Design and Process Planning for Casting	Prof. Dr.-Ing. B. Tonn	W 7995	3V/1Ü	4	56 h / 124 h
				Sum:	4	56 h / 124 h

About No. 1:

18a. Recom. Prerequisites	Bachelor's degree in an engineering or natural science subject.

19a. Contents	Lecture and exercise of the module cover the following topics: 1. Basics of casting (a) Requirements for component design (b) Prerequisites for mould design 2. Fundamentals of material design 3. Process management (a) Design - material - production technology (b) Production planning (c) Mould filling and solidification simulation 4. Basics of casting and gating technology 5. Excursion
20a. Media forms	Blackboard, beamer/slides, PDF scripts, exercises (solutions will be calculated)
21a. Literature	[1] Lecture notes [2] Lumley, R. (2011): Fundamentals of aluminium metallurgy. Woodhead Publishing Limited (Standardwerk) [3] Berns, H. and Theisen, W. (2008): Eisenwerkstoffe. Springer-Verlag, Berlin Heidelberg (Standardwerk) [4] Nogowizin, B. (2011): Theorie und Praxis des Druckgusses. Schiele & Schön (Standardwerk) [5] Hasse, S. (2017): Guss- und Gefügefehler. Schiele & Schön, 2003 (Standardwerk)
22a. Other	None

Study/ examination performance					
23. No.	**24. Assigned courses**	**25. P. type**	**26. ECTS**	**27. Evaluation**	**28. Percentage of module grade**
1	Product Design and Process Planning for Casting	MP	6	graded	100 %

About No. 1:	
29a. Form of examination/ prerequisite for the award of credit points	Oral examination (30 min.)
30a. Responsible examiner	Prof. Dr.-Ing. B. Tonn
31a. Preliminary examinations	None

1. Module title (English)

Subtractive Manufacturing

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing

3. Module Coordinator		4. Relevant faculty	5. Module number
Prof. Dr.-Ing. V. Wesling		Faculty of Mathematics/Computer Science and Mechanical Engineering	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
English	6	[X] 1 Semester [ ] 2 Semester	[ ] each semester [X] each study year [ ] irregular

10. Learning/ qualification objectives of the module

This module introduces the basics of subtractive manufacturing. After successfully completing the module, students will be able to

- understand the basic material-mechanical processes and mechanisms involved in machining processes
- identify the service life and wear mechanisms acting on tools
- describe and classify the properties of cutting and auxiliary materials
- explain the design and construction of suitable tool systems

The students also know the basics of economic and technological assessment of the manufacturing processes introduced.

Courses

11. No.	12. Title of the course	13. Lecturer	14. Course No.	15. Type of course	16. SWS	17. Work attendance/ internal study
1	Subtractive Manufacturing	Prof. Dr. V. Wesling, Dr. J. Hamje	W 8136	3V/1Ü	4	56 h / 124 h
				Sum:	4	56 h / 124 h

About No. 1:

18a. Recom. Prerequisites	Bachelor's degree in an engineering or natural science subject.

19a. Contents	Lectures and exercises of the module cover the following topics of ablative manufacturing processes: 1. Ablation by gas 2. Spark erosion ablation 3. Ablation by laser beam 4. Ablation by electron beam 5. Etching ablation 6. Thermal-chemical deburring 7. Chemical-thermal ablation 8. Electrochemical ablation 9. Metal etching 10. Cutting with high-pressure water jet 11. Ultrasonic vibratory lapping 12. Cutting with geometrically indeterminate cutting edge (a) Grinding (b) Honing (c) Lapping
20a. Media forms	Powerpoint presentation
21a. Literature	[1] Lecture notes [2] Spur, G. and Stöferle, T. (1987): Handbuch der Fertigungstechnik, Band 4.1, Abtragen & Beschichten, Carl Hanser Verlag, München Wien (Standardwerk) [3] König, W. (2007): Fertigungsverfahren, Band 3, Abtragen, Generieren [4] Lasermaterialbearbeitung. Springer, Berlin, Heidelberg, 4. Auflage, DOI 10.1007/978-3-540-48954-2 [5] Perovic, B. (2000): Spanende und abtragende Fertigungsverfahren – Grundlagen und Berechnungen. Expert-Verlag, Renningen, Malmsheim, ISBN 381691911-1
22a. Other	None

Study/ examination performance

23. No.	24. Assigned courses	25. P. type	26. ECTS	27. Evaluation	28. Percentage of module grade
1	Subtractive Manufacturing	MP	6	graded	100 %

About No. 1:

29a. Form of examination/ prerequisite for the award of credit points	Oral examination (30 minutes)

30a. Responsible examiner	Prof. Dr.-Ing. V. Wesling
31a. Preliminary examinations	None

1. Module title (English)

Welding Manufacturing

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing

3. Module Coordinator		4. Relevant faculty	5. Module number
Prof. Dr.-Ing. V. Wesling		Faculty of Mathematics/Computer Science and Mechanical Engineering	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
English	6	[X] 1 Semester [ ] 2 Semester	[ ] each semester [X] each study year [ ] irregular

10. Learning/ qualification objectives of the module

This module introduces the basics of welding production. After successfully completing the module, students will be able to:

- describe the functionalities of the different joining processes
- describe the physical processes in the welding arc and the material transition
- explain the control of the arc processes and describe how the different types of control work and categorise them in terms of their suitability

Furthermore, students can assess the welding parameters and analyse their effect on the properties of the welded joints.

Courses

11. No.	12. Title of the course	13. Lecturer	14. Course No.	15. Type of course	16. SWS	17. Work attendance/ internal study
1	Welding Manufacturing	Prof. Dr. V. Wesling, Dr. J. Hamje	S 8137	3V/1Ü	4	56 h / 124 h
				Sum:	4	56 h / 124 h

About No. 1:

18a. Recom. Prerequisites	Bachelor's degree in an engineering or natural science subject.

19a. Contents	Lectures and tutorials of the module cover the following topics of ablative manufacturing processes: 1. Introduction: Structure of the subject matter and economic significance 2. Autogenous welding and cutting processes: Processes in the flame, process sequence, process conditions and their effects 3. Arc welding processes ▪ Classification and differentiation of the processes: Manual metal arc welding, submerged arc welding, MIG/MAG welding, TIG welding, plasma welding, process combinations, welding, plasma processes, process combinations ▪ Processes in the arc: Physical principles, calculations, parameters, characteristic curves, VDE, influence of shielding gases shielding gases ▪ Material transitions in the arc: Processes in the arc arc, droplet transfer, control ▪ Welding machines: principles and characteristics, auxiliary units, direct/alternating current ▪ Control of arc welding processes: Principle possibilities, mechanisation, automation, sensors, path guidance, use of robots 4. Beam welding processes: Electron beam welding, laser beam welding, beam generation, welding process, application 5. Pressure welding processes: Friction stir welding, resistance pressure welding, high-frequency welding 6. Additive manufacturing / moulding welding
20a. Media forms	Powerpoint presentation

21a. Literature	[1] Lecture notes [2] Stahl Eisen Liste (1994): Register Europäischer Stähle, Teil 2: Elektrotechnische Grundlagen, Verlag Stahleisen mbH, Düsseldorf, 9. Auflage (Standardwerk) [3] Ruge, J. (1993): Handbuch der Schweißtechnik, Band 1: Werkstoffe, Band 2: Verfahren und Fertigung, Springer Verlag, Berlin [4] Killing, R. (1999): Handbuch der Schweißverfahren, Teil 1: Lichtbogenschweißverfahren, Fachbuchreihe Schweißtechnik (Standardwerk) [5] Fahrenwald, H.J. (2013): Schweißtechnik, Verfahren und Werkstoffe, Vieweg-Verlagsgesellschaft [6] Dilthey, U.; Eichhorn, F. (1994): Schweißtechnische Fertigungsverfahren, Band 1: Schweiss- und Schneidtechnologien, VDI-Verlag [7] Schellhase, M. (1985): Der Schweißlichtbogen - ein technologisches Werkzeug, DVS-Verlag Düsseldorf (Standardwerk) [8] Becken, O. (1969): Handbuch des Schutzgasschweißens, Teil 1: Grundlagen und Anwendung, DVS-Verlag Düsseldorf, Fachbuchreihe Schweißtechnik (Standardwerk) [9] Boese, U. (1995): Das Verhalten der Stähle beim Schweißen, Teil 1: Grundlagen, DVS-Verlag Düsseldorf, Fachbuchreihe Schweißtechnik (Standardwerk)
22a. Other	None

Study/ examination performance

23. No.	24. Assigned courses	25. P. type	26. ECTS	27. Evaluation	28. Percentage of module grade
1	Welding Manufacturing	MP	6	graded	100 %

About No. 1:

29a. Form of examination/ prerequisite for the award of credit points	Oral examination (30 minutes)
30a. Responsible examiner	Prof. Dr.-Ing. V. Wesling
31a. Preliminary examinations	None

1. Module title (English)

Wireless Sensor Networks

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing, M.Sc. Informatik, M.Sc. Wirtschaftsinformatik

3. Module Coordinator		4. Relevant faculty	5. Module number
Prof. Dr. A. Reinhardt		Faculty of Mathematics/Computer Science and Mechanical Engineering	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
English	6	[X] 1 Semester [ ] 2 Semester	[ ] each semester [X] each study year [ ] irregular

10. Learning/ qualification objectives of the module

The main qualification objectives of this module are:

- Familiarisation with application areas of networked embedded systems and the associated technical requirements for hardware and software
- Developing an in-depth understanding of wireless communication and the ability to identify, implement and evaluate solution approaches (e.g. in the area of media access methods)
- Knowledge of modern tools and procedures for application development on embedded systems, in particular using the Contiki OS operating system
- Overview of the design space and technologies for implementing applications based on networked embedded systems (e.g. cyber-physical systems, Internet of Things, machine-to-machine communication)
- Development of the ability to practically test implemented solutions and derive boundary conditions for their use

Courses

11. No.	12. Title of the course	13. Lecturer	14. Course No.	15. Type of course	16. SWS	17. Work attendance/ internal study
1	Wireless Sensor Networks	Prof. Dr. A. Reinhardt	W 1256	2V/2Ü	4	56 h / 124 h
				Sum:	4	56 h / 124 h

About No. 1:

18a. Recom. Prerequisites	Basic knowledge of maths is necessary for understanding. Successful participation in the course "Embedded Systems I" is recommended.

19a. Contents	The following topics are covered in this module: ▪ Typical application scenarios for wireless sensor networks ▪ Hardware components and platforms ▪ Operating systems for wireless sensors ▪ Methods for local data acquisition and processing ▪ Energy- and bandwidth-efficient media access ▪ Routing protocols for data transmission across multiple intermediate nodes ▪ Integration of wireless sensor networks with the Internet ▪ Simulation tools and practical experiments in testbeds
20a. Media forms	Slides, whiteboard, computer demonstration
21a. Literature	[1] Lecture notes [2] Dargie, W. und Poellabauer, C. (2010): "Fundamentals of Wireless Sensor Networks": Theory and Practice&ldquo John Wiley & Sons. ISBN 978-0470997659 [3] Akyildiz, I.F. und Vuran, M.C. (2010): "Wireless Sensor Networks". John Wiley & Sons. ISBN 978-0470036013 [4] Karl, H. und Willig, A. (2005): "Protocols and Architectures for Wireless Sensor Networks". John Wiley & Sons. ISBN 978-0470095102 Shelby, [5] Z. und Bormann, C. (2009): "6LoWPAN - The wireless embedded Internet", John Wiley & Sons. ISBN 978-0-470-74799-5
22a. Other	None

Study/ examination performance

23. No.	24. Assigned courses	25. P. type	26. ECTS	27. Evaluation	28. Percentage of module grade
1	Wireless Sensor Networks	MP	6	graded	100 %
2	Homework Wireless Sensor Networks	PV	0	ungraded	0 %

About No. 1:	
29a. Form of examination/ prerequisite for the award of credit points	Written exam (90 minutes) or oral exam (25 minutes)
30a. Responsible examiner	Prof. Dr. A. Reinhardt
31a. Preliminary examinations	Homework on wireless sensor networks
About No. 2:	

29b. Form of examination/ prerequisite for the award of credit points	Homework
30b. Responsible examiner	Prof. Dr. A. Reinhardt
31b. Preliminary examinations	None

1. Module title (English)

Master Thesis

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing

3. Module Coordinator		4. Relevant faculty	5. Module number
Prof. Dr.-Ing D. Inkermann		Faculty of Mathematics/Computer Science and Mechanical Engineering	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
English	30	[X] 1 Semester [ ] 2 Semester	[X] each semester [ ] each study year [ ] irregular

10. Learning/ qualification objectives of the module

The Master's thesis enables students to carry out independent scientific work under supervision in a subject area of Industry 4.0. The successful completion of the Master's thesis ensures that students have the necessary technical and methodological skills to solve and evaluate engineering problems and can independently plan and implement their approach as well as the selection and application of methods and tools. In addition, students develop important skills for presenting and discussing results with experts. In this way, students acquire the in-depth competences necessary for the transition to a career. The following qualification objectives are pursued with the Master's thesis:

- Within a given period of time, students analyse a challenging task on a topic of their choice
- They plan their approach based on the procedures they have learnt and carry out project and time planning
- They identify suitable models and methods, develop them further if necessary in line with the progress of their work and knowledge and use them to solve the task
- Students reflect on their approach and results based on advice from their supervisor

For the written documentation, students apply their knowledge of academic writing. In the presentation as part of an academic seminar, they demonstrate their ability to prepare a specialised topic in a suitable form, present it in an understandable way and defend it in a discussion.

Courses						
11. No.	**12. Title of the course**	**13. Lecturer**	**14. Course No.**	**15. Type of course**	**16. SWS**	**17. Work attendance/ internal study**
1	Master Thesis incl. Colloquium	Lectures of the Master's Program Intelligent Manufacturing		Ab	20 (6 Months)	168 h / 732 h
				Sum:	20 (6 Months)	168 h / 732 h

About No. 1:	
18a. Recom. Prerequisites	Proof of at least 75 LP
19a. Contents	As part of the Master's thesis, students work on a scientific question within a research project at Clausthal University of Technology. The work is largely carried out independently and with knowledge of the subject and methods from the previous degree program. Results and findings are documented in the form of a written paper and presented in a colloquium.
20a. Media forms	Text system with formula set, presentations
21a. Literature	Topic-specific literature will be announced by the supervisor. The supervising institutes will provide assistance and guidelines for the procedure and written elaboration.
22a. Other	None

Study/ examination performance					
23. No.	**24. Assigned courses**	**25. P. type**	**26. ECTS**	**27. Evaluation**	**28. Percentage of module grade**
1	Master Thesis incl. Colloquium	MP	30	graded	100%

About No. 1:	
29a. Form of examination/ prerequisite for the award of credit points	Written elaboration, final presentation of approx. 30 minutes (including discussion) as part of a seminar.
30a. Responsible examiner	Lectures of the Master's Program Intelligent Manufacturing
31a. Preliminary examinations	None

2 Field of Study „Flexible and Intelligent Products and Processes“ – Elective Modules

Study programme "Flexible and Intelligent Products and Processes"

- Exactly one specialisation must be selected.
- The module selection is binding with the first examination attempt in a compulsory elective module. A change of compulsory elective module is only possible if no examination attempts have been made or are deemed to have been made in a compulsory elective module.
- **Modules amounting to exactly 24 credit points** must be selected from the catalogue of compulsory elective modules 'Flexible and Intelligent Products and Processes' and successfully completed. Further examinations can only be taken as additional examinations.

1. Module title (English)

Module Additive Manufacturing using Polymers

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing

3. Module Coordinator		4. Relevant faculty	5. Module number
Dr. L. Steuernagel		Faculty of Mathematics/Computer Science and Mechanical Engineering	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
English	6	[X] 1 Semester [ ] 2 Semester	[ ] each semester [X] each study year [ ] irregular

10. Learning/ qualification objectives of the module

Students can describe the processes of 3D printing depending on the material and compare and evaluate them for defined structures. They have the ability to design structures along the entire process chain in an application-orientated manner and to produce them appropriately using 3D printing.

Courses

11. No.	12. Title of the course	13. Lecturer	14. Course No.	15. Type of course	16. SWS	17. Work attendance/ internal study
1	Additive Manufacturing using Polymers	Dr. L. Steuernagel	S 7985	4S/P	4	80 h / 100 h
				Sum:	4	80 h / 100 h

About No. 1:

18a. Recom. Prerequisites	Bachelor's degree in an engineering or natural science subject.
19a. Contents	The following topics are covered in this module: ▪ Industrial significance of additive manufacturing ▪ 3D printing basics ▪ Workflow of additive manufacturing processes ▪ Overview of manufacturing processes ▪ Performance comparison of home vs. high-performance 3D printers ▪ Trouble shooting in 3D printing ▪ 3D community ▪ 3D printing in professional applications

20a. Media forms	PowerPoint presentation, videos, demonstrators, practical exercises, slide collection
21a. Literature	[1] Berger, U.; Hartmann, A. und Schmid, D. (2013): Additive Fertigungsverfahren. Europa Lehrmittel, ISBN 978-3808550335 [2] Fastermann, P. (2014): 3D-Drucken - Wie die generative Fertigungstechnik funktioniert. Springer Verlag, ISBN 9783642409639
22a. Other	None

Study/ examination performance

23. No.	**24. Assigned courses**	**25. P. type**	**26. ECTS**	**27. Evaluation**	**28. Percentage of module grade**
1	Additive Manufacturing using Polymers	MP	6	graded	100 %

About No. 1:

29a. Form of examination/ prerequisite for the award of credit points	Written project work
30a. Responsible examiner	Dr. L. Steuernagel
31a. Preliminary examinations	None

1. Module title (English)

Module Applied Computational Engines

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing

3. Module Coordinator		4. Relevant faculty	5. Module number
Prof. Dr. R. Ehlers		Faculty of Mathematics/Computer Science and Mechanical Engineering	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
English	6	[X] 1 Semester [ ] 2 Semester	[ ] each semester [X] each study year [ ] irregular

10. Learning/ qualification objectives of the module

Successful completion of the module enables students to:

- identify difficult computational problems that may arise in the professional life of a computer scientist or engineer that can be solved using standard computing machines.
- know the strengths and limitations of a variety of computing machines such as SAT solvers, QBF solvers and linear programming tools.
- apply some commonly used computational engines to a variety of decision and optimisation problems.

Courses

11. No.	12. Title of the course	13. Lecturer	14. Course No.	15. Type of course	16. SWS	17. Work attendance/ internal study
1	Applied Computational Engines	Prof. Dr. R. Ehlers	W 1364	3V/1Ü	4	56 h / 124 h
				Sum:	4	56 h / 124 h

About No. 1:

18a. Recom. Prerequisites	Bachelor's degree in an engineering or natural science subject as well as basics of computer science

19a. Contents	The following topics are covered in this module ▪ SAT Solving (Basic algorithms for SAT solving: unit propagation, backtracking, variable selection, and learning; Tseitin encoding and alternatives; SAT encodings in practice; Theory of tractability: "Backdoors") ▪ Quantified Boolean Formula (QBF) solving ▪ Integer Linear Programming (ILP) and Linear Programming (LP) as an "easy" subset (Definitions & encodings, extension: Quadratic programming) ▪ SMT solving (Basic idea and algorithms, SMT encodings of complex problems) ▪ Supporting the encoding of difficult problems (Delta debugging & fuzz testing) ▪ BDDs ▪ Maximum flow algorithms & their applications ▪ Automata for PSPACE-complete problems ▪ Robust problem solving: games of infinite duration ▪ Applied branch-and-bound
20a. Media forms	Blackboard, beamer/slides, PDF scripts, exercises (solutions will be calculated)
21a. Literature	[1] Lecture notes [2] Biere, A.; Heule, M.; van Maaren, H. and Walsh, T. (2009): Handbook of Satisfiability. IOS Press [3] Knuth, D.E. (2014): The Art of Computer Programming (Volumes 1-4A). Addison Wesley [4] Clarke Jr., E.M.; Grumberg, O.; Kroening, D.; Peled, D. and Veith, H. (2018): Model Checking. second edition, MIT Press
22a. Other	None

Study/ examination performance

23. No.	24. Assigned courses	25. P. type	26. ECTS	27. Evaluation	28. Percentage of module grade
1	Applied Computational Engines	MP	6	graded	100 %
2	Homework Applied Computational Engines	PV	0	ungraded	0 %

About No. 1:

29a. Form of examination/ prerequisite for the award of credit points	Oral examination (30 minutes)
30a. Responsible examiner	Prof. Dr. R. Ehlers

31a. Preliminary examinations	Homework for Applied Computational Engines
About No. 2:	
29b. Form of examination/ prerequisite for the award of credit points	Homework
30b. Responsible examiner	Prof. Dr. R. Ehlers
31b. Preliminary examinations	None

1. Module title (English)

Module Design for Industry 4.0

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing

3. Module Coordinator		4. Relevant faculty	5. Module number
Prof. Dr.-Ing. D. Inkermann		Faculty of Mathematics/Computer Science and Mechanical Engineering	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
English	6	[X] 1 Semester [ ] 2 Semester	[ ] each semester [X] each study year [ ] irregular

10. Learning/ qualification objectives of the module

In this module, students learn important fundamentals and methods for utilising the potential of Industry 4.0 technologies for product design. The fundamental interactions between product design (geometry, material, tolerances, etc.) and production processes (process sequence, parameters, etc.) are demonstrated. After successfully completing the module, students will be able to:

- explain the relationships between product design and manufacturing using the concept of product architecture and name specific limitations and potentials of selected manufacturing processes,
- explain solution approaches of Industry 4.0 (intelligent product, intelligent machine, assisted operator) and explain available technologies for their implementation,
- name possibilities of flexibilisation (e.g. number of pieces, material, geometry, etc.) in product design and analyse given product designs with regard to their potential and
- apply selected methods for Design for Industry 4.0 to given tasks

The acquired basics are deepened in a semester-accompanying application project (Lab Design for Industry 4.0).

Courses

11. No.	12. Title of the course	13. Lecturer	14. Course No.	15. Type of course	16. SWS	17. Work attendance/ internal study
1	Design for Industry 4.0	Prof. Dr.-Ing. D. Inkermann	S 8183	2V	2	28 h / 62 h
2	Lab Design for Industry 4.0	Prof. Dr.-Ing. D. Inkermann	S 8161	2P	2	56 h / 44 h
				Sum:	4	84 h / 106 h

About No. 1:

18a. Recom. Prerequisites	Bachelor's degree in an engineering or natural science subject as well as basics of product development and design methodology.
19a. Contents	The lecture for the Design for Industry 4.0 module covers the following topics: ▪ Fundamentals of Design for X (focus on the manufacturing life cycle phase) ▪ Concept of product architecture and selected methods for analysing and developing product architectures ▪ Construction and manufacturing methods for products ▪ Concepts of flexibility and changeability of products and production processes ▪ Basic concept and types of integration (vertical, horizontal) in Industry 4.0 Technology paradigms in Industry 4.0 (product, machine, operator)
20a. Media forms	Slide presentation, script, videos, digital provision of slides for self-study
21a. Literature	[1] Lecture notes [2] LBender, B.; Gericke, K. (2021): Pahl/Beitz Konstruktionslehre: Methoden und Anwendung erfolgreicher Produktentwicklung. 9. Auflage, Springer-Vieweg, Berlin, Heidelberg, DOI: https://doi.org/10.1007/978-3-662-57303-7 [3] Gilchrist, A., 2016. Industry 4.0. Apress, Berkeley, CA. https://doi.org/10.1007/978-1-4842-2047-4 [4] LBauernhansel, T.; ten Hompel, M.; Vogel-Heuser, B. (2014): Industrie 4.0 in Produktion, Automatisierung und Logistik – Anwendung, Technologien, Migration. Springer-Vieweg, Wiesbaden, DOI: 10.1007/978-3-658-04682-8 [5] LKrause, D.; Gebhardt, N. (2018): Methodische Entwicklung modularer Produktfamilien - Hohe Produktvielfalt beherrschbar entwickeln. Springer-Vieweg, Wiesbaden, DOI: https://doi.org/10.1007/978-3662-53040-5 [6] Ustundag, A., Cevikcan, E., 2018. Industry 4.0: Managing The Digital Transformation, Springer Series in Advanced Manufacturing. Springer International Publishing, Cham. https://doi.org/10.1007/978-3-319-57870-5 [7] Lindemann, U., Maurer, M., Braun, T., 2009. Structural Complexity Management. Springer Berlin Heidelberg, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-87889-6
22a. Other	None
About No. 2:	
18b. Recom. Prerequisites	Bachelor's degree in an engineering or natural science subject as well as basics of product development and design methodology.

19b. Contents	In the practical part of the module (Lab Design for Industry 4.0), students work on an application project during the semester. At the beginning of the semester, students are given a task for which they must independently select and apply methods and technologies for Design for Industry 4.0. The individual results are continuously documented in a portfolio (presentation portfolio) and presented in a final presentation.
20b. Media forms	Presentations, concept models, CAD models, simulations
21b. Literature	See 21a
22b. Other	None

Study/ examination performance					
23. No.	**24. Assigned courses**	**25. P. type**	**26. ECTS**	**27. Evaluation**	**28. Percentage of module grade**
1	Design for Industry 4.0	MTP	3	graded	40 %
2	Lab Design for Industry 4.0	MTP	3	graded	60 %

About No. 1:	
29a. Form of examination/ prerequisite for the award of credit points	Oral exam (30 minutes)
30a. Responsible examiner	Prof. Dr.-Ing. D. Inkermann
31a. Preliminary examinations	Passed application project (MTP Lab Design for Industry 4.0)
About No. 2:	
29b. Form of examination/ prerequisite for the award of credit points	Assessed presentation portfolio
30b. Responsible examiner	Prof. Dr.-Ing. D. Inkermann
31b. Preliminary examinations	None

1. Module title (English)

Module Intelligent Forming systems

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing, M.Sc. Materialwissenschaft und Werkstofftechnik

3. Module Coordinator		4. Relevant faculty	5. Module number
Prof. Dr.-Ing. Johannes Buhl		Faculty of Mathematics/Computer Science and Mechanical Engineering	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
English	6	[X] 1 Semester [ ] 2 Semester	[ ] each semester [X] each study year [ ] irregular

10. Learning/ qualification objectives of the module

One aim of the course is to build up selected knowledge on the basis of the lecture and to familiarise non-specialist students with the methods and theories of forming technology and metallurgy. The educational objective is achieved when the students understand the importance of the various disciplines (computer science, mathematics, mechanical engineering and metallurgy) in practice and are able to automate conventional forming machines with future-oriented algorithms through the networked interdisciplinary tasks.

The ability to work in a team is promoted in the large group (all participants) and in many small groups. Working on the topic of the small group encourages creativity and independence in the application of knowledge from the students' respective disciplines. Various interdisciplinary contexts train the interface competence and a final presentation with a test and demonstration of the self-regulating forming system trains presentation skills and rhetoric.

Courses

11. No.	12. Title of the course	13. Lecturer	14. Course No.	15. Type of course	16. SWS	17. Work attendance/ internal study
1	Intelligent forming systems	Prof. Dr.-Ing. J. Buhl	W 7948	V/P	4	56 h / 124 h
				Sum:	4	56 h / 124 h

About No. 1:

18a. Recom. Prerequisites	Bachelor's degree in an engineering or natural science subject as well as basics of product development and design methodology.

19a. Contents	1. Fundamentals of forming processes (Lecture) 2. Fundamentals of forming machines (Lecture) 3. Further basics depending on the individual subtasks 4. Work experience with various sub-tasks (specified by lecturers) for the joint development of an intelligent forming process. Key aspects: Design of the forming tools, if necessary with FEM and construction of the production plant. Selection of sensor technology and development of pattern/feature recognition and AI for setting the process parameters. Development of data management with connection to the forming machine, WEB and simulation server. Networking and control of the system components 5. Consolidation of the group work and presentation
20a. Media forms	Board, slides, videos, publications, articles, construction kit with machine parts and sample material
21a. Literature	[1] Web, trade journals, company brochures [2] Doege, E., Behrens, B. (2007). Handbuch Umformtechnik: Grundlagen, Technologien, Maschinen. Deutschland: Springer Berlin Heidelberg. ISBN: 9783540489245 [3] Dietrich, J. (2017). Praxis der Umformtechnik: Umform- und Zerteilverfahren, Werkzeuge, Maschinen. Deutschland: Springer Fachmedien Wiesbaden. ISBN: 9783658195304
22a. Other	If possible, interdisciplinary collaboration between students of materials science, mechanical engineering, mathematics and computer science. Each group (4-6 persons) develops its part of the intelligent forming machine. Maximum number of participants 20.

Study/ examination performance

23. No.	24. Assigned courses	25. P. type	26. ECTS	27. Evaluation	28. Percentage of module grade
1	Intelligent forming systems	PA	6	graded	100 %

About No. 1:

29a. Form of examination/ prerequisite for the award of credit points	Presentation of the practical and theoretical work in conjunction with a graded project report
30a. Responsible examiner	Prof. Dr.-Ing. J. Buhl
31a. Preliminary examinations	None

1. Module title (English)

Module Fundamentals of Systems Engineering

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing, M.Sc. Maschinenbau

3. Module Coordinator		4. Relevant faculty	5. Module number
Prof. Dr.-Ing. D. Inkermann		Faculty of Mathematics/Computer Science and Mechanical Engineering	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
English	6	[X] 1 Semester [ ] 2 Semester	[ ] each semester [X] each study year [ ] irregular

10. Learning/ qualification objectives of the module

The module Fundamentals of Systems Engineering comprises a lecture (2 SWS), an exercise (1 SWS) and a semester project (1 SWS). The module introduces the fundamentals of system-oriented and model-based development of technical systems. For this, basic terms and concepts of systems engineering are taught and selected process models and methods for structuring and supporting development work are introduced. Students should acquire the competence to plan and control strategies for the structured problem-solving process of complex mechatronic systems and to evaluate them with regard to boundary conditions and success. As part of exercises and a project during the semester, students learn to apply selected methods and tools of model-based development in practice using examples.

- Students know the basic terms and concepts of systems technology and systems engineering and can identify these in various development situations
- Students can explain elements and principles of systems engineering and name and assess them in discussions with developers
- Students can analyse (complex) systems, describe their function and structure and place them in a system context
- Students know the basic activities of system-orientated development and can name and select suitable methods and tools for their processing
- Students can plan and control development tasks using process models and define focal points depending on the task at hand
- Students know the principles and techniques of modelling and can apply these to various systems and issues
- Students can differentiate between languages, methods and tools of model-based development and can practically apply basic diagram types of SysML (Systems Modelling Language)
- Students are able to differentiate between the perspectives of different development disciplines and explain their own approach and relevant system characteristics in the development process and represent them in discussions with non-specialist developers

The lecture for the module Fundamentals of Systems Engineering initially teaches the necessary fundamentals of systems technology and systems engineering in the form of presentations. Selected methods for analysis and modelling are developed independently by the students according to the concept of the flipping classroom and presented and applied in plenary sessions. In the exercise, students are introduced to model-based development using ULM/SysML by means of example tasks. The procedures, methods and tools learnt are applied by the students during the semester to work on a specific problem.

Courses

11. No.	12. Title of the course	13. Lecturer	14. Course No.	15. Type of course	16. SWS	17. Work attendance/ internal study
1	Fundamentals of Systems Engineering	Prof. Dr.-Ing. D. Inkermann	W 8181	2V/2Ü	4	56 h / 124 h
				Sum:	4	56 h / 124 h

About No. 1:

18a. Recom. Prerequisites	Bachelor's degree in an engineering or natural science subject as well as basics of product development and design methodology.

19a. Contents	▪ Terms and fundamentals of systems engineering and systems theory ▪ Fundamentals and types of systems engineering ▪ Components of systems engineering (systems engineering development environment) ▪ Process models and principles of systems engineering ▪ Systems thinking methods ▪ Fundamentals, concepts and principles of modelling in systems engineering ▪ Basis and selected diagrams of SysML (Systems Modelling Language)
20a. Media forms	PowerPoint, group work, web conferences, weekly team meetings
21a. Literature	[1] Ehrlenspiel, Klaus/Meerkamm, Harald (Hg.): Integrierte Produktentwicklung. Denkabläufe, Methodeneinsatz, Zusammenarbeit, Hanser: München/Wien (6. vollst. überarb. und erweit. Auflage) 2017. [2] Haberfellner, Reinhard u. a. (Hg.): Systems Engineering. Fundamentals and Applications, Birkhäuser: Basel 2019. [3] Haberfellner, Reinhard u. a. (Hg.): Systems Engineering. Grundlagen und Anwendung, Orell Füssli Verlag: Zürich (14. überarb. Auflage) 2018. [4] Hubka, Vladimir: Theorie Technischer Systeme. Grundlagen einer wissenschaftlichen Konstruktionslehre, Springer Verlag: Berlin/Heidelberg/New York (3. Auflage) 1984. [5] Martin, James N.: Systems Engineering Guidebook. A Process for Developing Systems and Products, CRC Press, Inc.: Boca Raton/FL u. a. 1997. [6] Ropohl, Günter: Allgemeine Technologie. Eine Systemtheorie der Technik, Universitätsverlag Karlsruhe: Karlsruhe (3. überarb. Auflage) 2009. [7] Weilkiens, Tim: Systems Engineering mit SysML/UML. Modellierung, Analyse, Design, dPunkt Verlag: Heidelberg (2. aktual. und erweit. Auflage) 2008.
22a. Other	None

Study/ examination performance

23. No.	24. Assigned courses	25. P. type	26. ECTS	27. Evaluation	28. Percentage of module grade
1	Fundamentals of Systems Engineering	MP	6	graded	100 %

About No. 1:

29a. Form of examination/ prerequisite for the award of credit points	Oral examination, research discussion (30 minutes) Project work (completion of a task)

30a. Responsible examiner	Prof. Dr.-Ing. D. Inkermann
31a. Preliminary examinations	None

1. Module title (English)

Module Sustainable Industrial Ecosystems

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing

3. Module Coordinator		4. Relevant faculty	5. Module number
Prof. Dr.Ani Melkonyan-Gottschalk		Faculty of Energy and Economics	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
English	6	[X] 1 Semester [ ] 2 Semester	[ ] each semester [X] each study year [ ] irregular

10. Learning/ qualification objectives of the module

- Understanding of the industrial ecosystem definition, analysis of its sustainability and circularity
- Understanding and analysis of the specificities of the supply chain design within industrial ecosystems, its transformation potential for circularity
- Deep knowledge of the business model concepts, such as the Osterwalder and Pigneur concept or the St. Gallen Business Model Navigator. Understanding how innovations in business models for sustainability can take place and how business models can be built in circular economy
- Analyze traditional and new business models and work out the underlying patterns
- Describe business model strategies and understand their industry contexts
- Classify the emergence of new business models into overall social and economic developments.
- Be enabled to develop own ideas and put them into the context of circular industrial systems.

Courses

11. No.	12. Title of the course	13. Lecturer	14. Course No.	15. Type of course	16. SWS	17. Work attendance/ internal study
1	Sustainable and Circular Supply Chain perspective	Prof. Dr.Ani Melkonyan-Gottschalk	S 6204	V	2	28 h / 62 h
2	Business Model Innovations for Circularity and Sustainability	Prof. Dr.Ani Melkonyan-Gottschalk	S 6205	V + Case Studies	2	28 h / 62 h
				Sum:	4	56 h / 124 h

About No. 1:

18a. Recom. Prerequisites	No prerequisites
19a. Contents	Industrial Ecosystems, Circular Economy, Stakeholder Analysis, Supply Chain Networks, Closed and Open Loop Supply Chains
20a. Media forms	Internet
21a. Literature	[1] Ansari, Z. N., Qureshi, M. N., 2015. Sustainability in Supply Chain Management: An Overview. IUP Journal of Supply Chain Management 12(2), 24-46. [2] Beske-Janssen, P., Johnson, M. P., Schaltegger, S., 2015. 20 years of performance measurement in sustainable supply chain management–what has been achieved? Supply chain management: An international Journal 20(6), 664-680. [3] Carter, C., Easton, P., 2011. Sustainable Supply Chain Management: Evolution and Future Directions. In: International Journal of Physical Distribution & Logistics Management 41(1), 46-62. [4] Seuring, S., Müller, M., 2008. From a Literature Review to a Conceptual Framework for Sustainable Supply Chain Management. Journal of Cleaner Production 16(15), 1699-1710.
22a. Other	None
About No. 2:	
18b. Recom. Prerequisites	No Prerequisites
19b. Contents	Business Models, Business Model Canvas, Innovation for Circularity, Navigation within Business Models, Sustainability assessment in businesses, consumer perspectives
20b. Media forms	Internet
21b. Literature	[1] Osterwalder, Alexander, Pigneur, Yves. (2011): Business Model Generation, Frankfurt am Main 2011. [2] Gassmann, Oliver, Frankenberger, Carolin, Csik, Michaela (2017): Geschäftsmodelle entwickeln: 55 innovative Konzepte mit dem St. Galler Business Model Navigator, 2. überarbeitete und erweiterte Aufl., München 2017. [3] Zhu Q., Cordeiro J., J. Sarkis J. (2013). Institutional pressures, dynamic capabilities and environmental management systems: Investigating the ISO 9000 – environmental management system implementation linkage. Journal of Environmental Management 114,1-11. [4] Neumeyer X., Santos S. C. (2018). Sustainable business models, venture typologies, and entrepreneurial ecosystems: A social network perspective. Journal of Cleaner Production 172, 4565-4579.
22b. Other	None

Study/ examination performance					
23. No.	**24. Assigned courses**	**25. P. type**	**26. ECTS**	**27. Evaluation**	**28. Percentage of module grade**
1	Sustainable and Circular Supply Chain perspective	MTP	3	graded	50 %
2	Theoretical Work (Case Studies and presentations) (20 minutes for presentations, 15 pages report	MTP	3	graded	50 %

About No. 1:	
29a. Form of examination/ prerequisite for the award of credit points	Theoretical Work (Case Studies and presentations), 20 minutes for presentations, 15 pages report
30a. Responsible examiner	Prof. Dr.Ani Melkonyan-Gottschalk
31a. Preliminary examinations	None
About No. 2:	
29b. Form of examination/ prerequisite for the award of credit points	Business Model Innovations for Circularity and Sustainability
30b. Responsible examiner	Prof. Dr.Ani Melkonyan-Gottschalk
31b. Preliminary examinations	None

1. Module title (English)

Module System Identification (+)

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing

3. Module Coordinator		4. Relevant faculty	5. Module number
Prof. Dr.-Ing. C. Bohn		Faculty of Mathematics/Computer Science and Mechanical Engineering	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
English	6	[X] 1 Semester [ ] 2 Semester	[ ] each semester [X] each study year [ ] irregular

10. Learning/ qualification objectives of the module

Students learn methods for determining unknown properties (e.g. model parameters) of linear and non-linear systems.

Courses

11. No.	12. Title of the course	13. Lecturer	14. Course No.	15. Type of course	16. SWS	17. Work attendance/ internal study
1	System Identification +	Prof. Dr. C. Bohn, Dr. A. Tarasow	S 8932	3V/1Ü	4	56 h / 124 h
				Sum:	4	56 h / 124 h

About No. 1:

18a. Recom. Prerequisites	Bachelor's degree in an engineering or natural science subject.

19a. Contents	Lecture and tutorial of the module cover the following topics of System Identification: 1. Types of system models used in information technology 2. Areas of application of the theory for parameter estimation and event detection 3. Basics of probability theory (distribution functions, conditional probabilities, expected fidelity, consistency, Cramer-Rao bound) 4. Estimation methods according to the principle of least squares for linear and non-linear systems, recursive and non-recursive 5. Optimisation with constraints (active set/interior point method) 6. Probability-based estimation methods (Bayes / maximum likelihood) 7. Hypothesis testing and information criteria for structure/significance testing and model selection
20a. Media forms	Blackboard, beamer presentation
21a. Literature	[1] Bohn, C. und Unbehauen, H. (2016): Identifikation dynamischer Systeme. Wiesbaden, Springer Vieweg. [2] Ljung, L. und Söderström, T. (1983): System identification. USR: Prentice [3] Zypkin, J. (1995): Informationnaja teorija identifikatii. Moskau, Nauka, Fismatlit (Transkript in Russisch: Informationelle Theorie der Identifikation) [4] Papageorgiou, M.; Leibold, M. und Buss, M. (2012): Optimierung. Berlin: Springer
22a. Other	None

Study/ examination performance					
23. No.	**24. Assigned courses**	**25. P. type**	**26. ECTS**	**27. Evaluation**	**28. Percentage of module grade**
1	System Identification +	MP	6	graded	100 %
About No. 1:					
29a. Form of examination/ prerequisite for the award of credit points	Determination of examination form (written or oral examination) and duration in accordance with the applicable examination regulations, usually an oral examination lasting 30 minutes				
30a. Responsible examiner	Prof. Dr. C. Bohn, Dr. A. Tarasow				
31a. Preliminary examinations	None				

3 Field of Study „Manufacturing Analytics and Optimization“ – Elective Modules

Field of study "Manufacturing Analytics and Optimization"

- Exactly one specialisation must be selected.
- The module selection is binding with the first examination attempt in a compulsory elective module. A change of compulsory elective module is only possible if no examination attempts have been made or are deemed to have been made in a compulsory elective module.
- **Modules amounting to exactly 24 credit points** must be selected and successfully completed from the 'Manufacturing Analytics and Optimization' compulsory elective module catalogue. Further examinations can only be taken as additional examinations

1. Module title (English)

Module Statistical Data Science

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing, M.Sc. Wirtschafts- / Technomathematik, M.Sc. Informatik, M.Sc. Wirtschaftsinformatik, B.Sc. Wirtschafts- /Technomathematik

3. Module Coordinator		4. Relevant faculty	5. Module number
Prof. Dr. Benjamin Säfken		Faculty of Mathematics/Computer Science and Mechanical Engineering	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
German or English	6	[X] 1 Semester [ ] 2 Semester	[ ] each semester [X] each study year [ ] irregular

10. Learning/ qualification objectives of the module

Professional competence: Students are familiar with practically relevant standard methods of data analysis, in particular for the graphical processing of data, techniques for dimension reduction and grouping of data, as well as methods of inductive statistics and statistical modelling. They are able to understand the procedures, use them appropriately for specific data analysis with the help of statistical software and interpret the results meaningfully.

Social skills: Students have experienced how complex new issues can be developed in a dialogue and application-oriented course and how practical problems can be worked on. They have learnt to work independently and in teams and to apply their knowledge to new issues. Furthermore, they have learnt to work independently on a complex problem over a longer period of time and how to present their results in the form of a scientific report or to a group in an appropriate form. They can solve any problems that arise largely independently with the help of literature or online research. In the event of major difficulties, students can seek specific help.

Courses

11. No.	12. Title of the course	13. Lecturer	14. Course No.	15. Type of course	16. SWS	17. Work attendance/ internal study
1	Statistical Data Science	Prof. Dr. Benjamin Säfken	S 0425	3V/1Ü	4	56 h / 124 h
				Sum:	4	56 h / 124 h

About No. 1:

18a. Recom. Prerequisites	Basic knowledge of descriptive and inductive statistics and probability theory, e.g. from Introduction to Probability Theory and Statistics or (Engineering) Statistics I + II

19a. Contents	▪ Visualisation of data ▪ Principal component analysis ▪ Cluster analysis ▪ Statistical tests ▪ Linear and generalised linear (additive/mixed) models ▪ Analysis of variance ▪ Introduction to statistical programming and data analysis with R or Python
20a. Media forms	Projector, slides, presentation, blackboard, software and application examples, computer exercises, project work
21a. Literature	[1] Dalgaard, Peter: Introductory Statistics with R, Springer: New York (2. Auflage), 2008. [2] Everitt, Brian & Hothorn, Torsten: An Introduction to Applied Multivariate Analysis with R, Springer: New York, 2011. [3] Fahrmeir, Ludwig et.al. (Hg.): Multivariate statistische Verfahren, de Gruyter: Berlin u. a. (2. überarb. Auflage), 1996. [4] Fahrmeir, Ludwig, Kneib, Thomas & Lang, Stefan: Regression. Modelle, Methoden und Anwendungen, Springer: Berlin (2. Auflage), 2009. [5] Groß, Jürgen: Grundlegende Statistik mit R. Eine anwendungsorientierte Einführung in die Verwendung der Statistik-Software R, Vieweg + Teubner: Wiesbaden, 2010. [6] Hothorn, Torsten & Everitt, Brian S.: A Handbook of Statistical Analyses Using R, CRC Press: Boca Raton (3. Auflage), 2014. [7] Venables, William N. et. al.: An Introduction to R. Notes on R – A Programming Environment for Data Analysis and Graphics, Network Theory: Bristol (3. überarb. und aktual. Auflage), 2005. [8] Venables, William N. & Ripley, Brian D.: Modern Applied Statistics with S, Springer: New York (4. Auflage) 2010. [9] Wollschläger, Daniel: Grundlagen der Datenanalyse mit R. Eine anwendungsorientierte Einführung, Springer Spektrum: Berlin (4. überarb. und erweit. Auflage), 2017.
22a. Other	None

Study/ examination performance

23. No.	24. Assigned courses	25. P. type	26. ECTS	27. Evaluation	28. Percentage of module grade
1	Statistical Data Science	MP	6	graded	100 %
2	Homework on Statistical Data Science	PV	0	ungraded	0 %

About No. 1:

29a. Form of examination/ prerequisite for the award of credit points	Written exam (90 minutes) or oral exam (30 minutes)
30a. Responsible examiner	Prof. Dr. Benjamin Säfken
31a. Preliminary examinations	Homework on Statistical Data Science
About No. 2:	
29b. Form of examination/ prerequisite for the award of credit points	Homework on Statistical Data Science
30b. Responsible examiner	Prof. Dr. Benjamin Säfken
31b. Preliminary examinations	None

1. Module title (English)

Module Optimization in Engineering

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing, M.Sc. Verfahrenstechnik/Chemieingenieurwesen

3. Module Coordinator		4. Relevant faculty	5. Module number
Prof. Dr.-Ing. Jens Bremer		Faculty of Mathematics/Computer Science and Mechanical Engineering	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
English	6	[X] 1 Semester [ ] 2 Semester	[ ] each semester [X] each study year [ ] irregular

10. Learning/ qualification objectives of the module

Students learn the basics of numerical, model-based optimisation; exemplified by simple process engineering systems.

Students acquire the following skills/qualifications:

- Formulate and classify optimisation problems from technical or economic problems
- Overview of available computer-aided solution methods for stationary optimisation problems
- Selection of appropriate algorithms for different optimisation problems
- Detailed knowledge of the advantages and disadvantages of the methods learned
- Implement optimisation problems in simulation environments and adequately evaluate their results - both in the event of failure of the method and for the evaluation of an found approximate solution

Courses

11. No.	12. Title of the course	13. Lecturer	14. Course No.	15. Type of course	16. SWS	17. Work attendance/ internal study
1	Optimization in Engineering	Prof. Dr.-Ing. Jens Bremer	S 8418	V/Ü	4	56 h / 124 h
				Sum:	4	56 h / 124 h

About No. 1:

18a. Recom. Prerequisites	Engineering mathematics, programming skills

19a. Contents	1. Structure and formulation of optimisation problems (objective function, constraints, degrees of freedom) 2. Optimisation problems without constraints (a) Optimality conditions (necessary and sufficient conditions) (b) One-dimensional optimisation methods (equidistant search, interpolation method, golden section) (c) Multidimensional optimisation methods; line search directions (sequential variation of variables, steepest descent, conjugate gradients), Nelder-Mead method, Newton methods (Newton-Raphson, quasi-Newton methods, Gauss-Newton for quadratic problems) (d) Line search methods (Wolfe conditions, 'trust region' method, 'dogleg' method, Marquardt method) 3. Optimisation problems with constraints (a) Optimality conditions (Karush-Kuhn-Tucker conditions), uniqueness of the solution (b) Non-linear programming (reduced gradient, sequential quadratic programming, 'active set' strategy) (c) Penalty functions, barrier functions (d) Linear programming (Dantzig's simplex method) 4. Global optimisation (a) Genetic algorithms (b) Evolutionary algorithms 5. Optimal control (a) Optimality conditions (Euler-Lagrange equations) for unconstrained and constrained problems (b) Hamilton function
20a. Media forms	Blackboard, slides, computer work
21a. Literature	[1] M. Papageorgiou, Optimierung, Oldenbourg Verlag, München, 1996 [2] J. Nocedal, S. Wright, Numerical Optimization, Springer-Verlag, New York, 2008 [3] T.F. Edgar, D.M. Himmelblau, Optimization of Chemical Processes, McGraw-Hill, 1988
22a. Other	None

Study/ examination performance

23. No.	24. Assigned courses	25. P. type	26. ECTS	27. Evaluation	28. Percentage of module grade
1	Optimization in Engineering	MP	6	graded	100 %
About No. 1:					

29a. Form of examination/ prerequisite for the award of credit points	Written exam (120 minutes), possibly also oral exam if the number of participants is low.
30a. Responsible examiner	Prof. Dr.-Ing. Jens Bremer
31a. Preliminary examinations	None

1. Module title (English)

Module Product Data Management in Industry 4.0

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing

3. Module Coordinator		**4. Relevant faculty**	**5. Module number**
Prof. Dr.-Ing. D. Inkermann		Faculty of Mathematics/Computer Science and Mechanical Engineering	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
English	6	[X] 1 Semester [ ] 2 Semester	[ ] each semester [X] each study year [ ] irregular

10. Learning/ qualification objectives of the module

The module introduces the basics of product data management in the context of product creation in Industry 4.0. After successfully completing the module, students will be able to:

- to differentiate between data for the planning and control of product creation processes and to link this data with tasks from product development and production planning,
- explain technologies for data collection in the context of Industry 4.0,
- describe the functionality and utilisation of selected PDM systems and formulate requirements for the selection of PDM systems

This is based on the following knowledge, which is acquired upon completion of the module:

- Basics of product data technology
- Components and use cases of digital twins in product creation

After completing the module, students will be able to practically apply a selected PDM system for specified use cases in product development and develop solutions for the collection and provision of product data.

Courses

11. No.	**12. Title of the course**	**13. Lecturer**	**14. Course No.**	**15. Type of course**	**16. SWS**	**17. Work attendance/ internal study**
1	Product Data Management in Industry 4.0	Prof. Dr.-Ing. D. Inkermann	S 8184	1V	1	14 h / 16 h
2	Lab Product Data Management in Industry 4.0	Prof. Dr.-Ing. D. Inkermann	S 8188	3P	3	84 h / 66 h
				Sum:	4	98 h / 82 h

About No. 1:	
18a. Recom. Prerequisites	Bachelor's degree in an engineering or natural science subject. Basic knowledge of product development.
19a. Contents	Using an exemplary PDM system, application-orientated basics in the following subject areas are taught: 1. Product structure management (part master records and variant management) 2. Document management, incl. interfaces to external systems (CAD, Office, ...) 3. Classification and characteristics 4. Workflow and process management (incl. release and change management) 5. Process modelling and documentation 6. Structure and types of digital twins 7. Selected technologies for Industry 4.0 solutions
20a. Media forms	PDF script, blackboard and beamer/slides, exercises on the PC
21a. Literature	[1] Vajna , S. et al. (2018): CAx für Ingenieure – Eine praxisbezogene Einführung. Springer Vieweg, 3. Auflage. [2] Hehenberger, P. (2020): Computerunterstützte Produktion. Springer Vieweg, 2. Auflage. [3] Eigner, M.; Stelzer, R. (2009): Product Lifecycle Management - Ein Leitfaden für Product Development und Life Cycle Management. SpringerVerlag, 2. Auflage. [4] Ustundag, A., Cevikcan, E., 2018. Industry 4.0: Managing The Digital Transformation, Springer Series in Advanced Manufacturing. Springer International Publishing, Cham. https://doi.org/10.1007/978-3-319-57870-5 [5] Lindemann, U., Maurer, M., Braun, T., 2009. Structural Complexity Management. Springer Berlin Heidelberg, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-87889-6
22a. Other	None
About No. 2:	
18b. Recom. Prerequisites	Bachelor's degree in an engineering or natural science subject. Basic knowledge of product development.
19b. Contents	In the practical part of the module (Lab Product Data Management in Industry 4.0), students work on an application project with a strong practical focus. A task and rough project plan are announced at the start of the semester. Within the application project, students work on the individual steps for setting up a solution for product data management in a team. For this purpose, students analyse and develop workflows, data models and evaluation and visualisation functions in the PDM system Siemens TeamCenter. The results are continuously documented in a portfolio (presentation portfolio) and presented and discussed as part of a final presentation.

20b. Media forms	Process models, CAD models, exercises on the PC
21b. Literature	See 21a.
22b. Other	None

Study/ examination performance					
23. No.	**24. Assigned courses**	**25. P. type**	**26. ECTS**	**27. Evaluation**	**28. Percentage of module grade**
1	Product Data Management in Industry 4.0	MTP	1	graded	20 %
2	Lab Product Data Management in Industry 4.0	MTP	5	graded	80 %

About No. 1:	
29a. Form of examination/ prerequisite for the award of credit points	Oral examination (30 min)
30a. Responsible examiner	Prof. Dr.-Ing. D. Inkermann
31a. Preliminary examinations	None
About No. 2:	
29b. Form of examination/ prerequisite for the award of credit points	Evaluated presentation portfolio of the application project
30b. Responsible examiner	Prof. Dr.-Ing. D. Inkermann
31b. Preliminary examinations	None

1. Module title (English)

Module Simulation Engineering

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing, M.Sc. Informatik, M.Sc. Wirtschaftsinformatik

3. Module Coordinator		4. Relevant faculty	5. Module number
PD Dr. Umut Durak		Faculty of Mathematics/Computer Science and Mechanical Engineering	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
English	6	[X] 1 Semester [ ] 2 Semester	[ ] each semester [X] each study year [ ] irregular

10. Learning/ qualification objectives of the module

After successful completion of the course the students will:

- Understand key methods and tools for developing simulation systems,
- Understand elementary types of simulation applications: real time simulations, Monte Carlo simulations and distributed simulations,
- Understand basics of simulation development process including conceptual modeling, requirements engineering, design, implementation, validation & verification and project management

In the course students will acquire hands-on experience on conceptual modeling, requirements engineering, design, development and testing over simple case studies in practice hours and as homework.

Courses

11. No.	12. Title of the course	13. Lecturer	14. Course No.	15. Type of course	16. SWS	17. Work attendance/ internal study
1	Simulation Engineering	PD Dr. Umut Durak	W 1269	2V+2Ü	4	56 h / 124 h
				Sum:	4	56 h / 124 h

About No. 1:

18a. Recom. Prerequisites	Basic programming knowledge (mandatory), Basic knowledge in C++ programming (recommended)

19a. Contents	Topics include: ▪ Introduction to Simulation Engineering ▪ Simulating Continuous Systems ▪ Simulating Discrete Systems ▪ Basic Elements of Simulations ▪ Monte Carlo Simulation ▪ Real Time Simulation ▪ Distributed Simulation ▪ Visualization ▪ Simulation Engineering Process ▪ Conceptual Modeling and Requirements Engineering ▪ Simulation Tools and Languages ▪ Simulation Design and Implementation ▪ Verification and Validation ▪ Simulation Project Management The students will conduct a literature survey on selected simulation engineering topics of interest and present the results in class.
20a. Media forms	Beamer presentation, group projects, lab tutorials
21a. Literature	Slides of the lecture as well as the following books: [1] Ledin: Simulation Engineering - Building Better Embedded Systems Faster, CMP [2] Sokolowski, Banks: Modeling and Simulation Fundamentals, Wiley [3] IEEE Recommended Practice for Distributed Simulation Engineering and Execution Process (DSEEP) [4] Pace: Ideas About Simulation Conceptual Model Development, John Hopkins APL Technical Digest, 21(3)
22a. Other	None

Study/ examination performance

23. No.	24. Assigned courses	25. P. type	26. ECTS	27. Evaluation	28. Percentage of module grade
1	Simulation Engineering	MP	6	graded	100 %
2	Homework on Simulation Engineering	PV	0	ungraded	0 %

About No. 1:

29a. Form of examination/ prerequisite for the award of credit points	Written exam (120 minutes) or oral exam (30 minutes)

30a. Responsible examiner	PD Dr. Umut Durak
31a. Preliminary examinations	Homework on Simulation Engineering
About No. 2:	
29b. Form of examination/ prerequisite for the award of credit points	Homework
30b. Responsible examiner	PD Dr. Umut Durak
31b. Preliminary examinations	None

1. Module title (English)

Module Fundamentals of Systems Engineering

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing, M.Sc. Maschinenbau

3. Module Coordinator		**4. Relevant faculty**	**5. Module number**
Prof. Dr.-Ing. D. Inkermann		Faculty of Mathematics/Computer Science and Mechanical Engineering	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
English	6	[X] 1 Semester [ ] 2 Semester	[ ] each semester [X] each study year [ ] irregular

10. Learning/ qualification objectives of the module

The module Fundamentals of Systems Engineering comprises a lecture (2 SWS), an exercise (1 SWS) and a semester project (1 SWS). The module introduces the fundamentals of system-oriented and model-based development of technical systems. For this, basic terms and concepts of systems engineering are taught and selected process models and methods for structuring and supporting development work are introduced. Students should acquire the competence to plan and control strategies for the structured problem-solving process of complex mechatronic systems and to evaluate them with regard to boundary conditions and success. As part of exercises and a project during the semester, students learn to apply selected methods and tools of model-based development in practice using examples.

- Students know the basic terms and concepts of systems technology and systems engineering and can identify these in various development situations
- Students can explain elements and principles of systems engineering and name and assess them in discussions with developers
- Students can analyse (complex) systems, describe their function and structure and place them in a system context
- Students know the basic activities of system-orientated development and can name and select suitable methods and tools for their processing
- Students can plan and control development tasks using process models and define focal points depending on the task at hand
- Students know the principles and techniques of modelling and can apply these to various systems and issues
- Students can differentiate between languages, methods and tools of model-based development and can practically apply basic diagram types of SysML (Systems Modelling Language)
- Students are able to differentiate between the perspectives of different development disciplines and explain their own approach and relevant system characteristics in the development process and represent them in discussions with non-specialist developers

The lecture for the module Fundamentals of Systems Engineering initially teaches the necessary fundamentals of systems technology and systems engineering in the form of presentations. Selected methods for analysis and modelling are developed independently by the students according to the concept of the flipping classroom and presented and applied in plenary sessions. In the exercise, students are introduced to model-based development using ULM/SysML by means of example tasks. The procedures, methods and tools learnt are applied by the students during the semester to work on a specific problem.

Courses

11. No.	12. Title of the course	13. Lecturer	14. Course No.	15. Type of course	16. SWS	17. Work attendance/ internal study
1	Fundamentals of Systems Engineering	Prof. Dr.-Ing. D. Inkermann	W 8181	2V/2Ü	4	56 h / 124 h
				Sum:	4	56 h / 124 h

About No. 1:

18a. Recom. Prerequisites	Bachelor's degree in an engineering or natural science subject as well as basics of product development and design methodology.

19a. Contents	▪ Terms and fundamentals of systems engineering and systems theory ▪ Fundamentals and types of systems engineering ▪ Components of systems engineering (systems engineering development environment) ▪ Process models and principles of systems engineering ▪ Systems thinking methods ▪ Fundamentals, concepts and principles of modelling in systems engineering ▪ Basis and selected diagrams of SysML (Systems Modelling Language)
20a. Media forms	PowerPoint, group work, web conferences, weekly team meetings
21a. Literature	[1] Ehrlenspiel, Klaus/Meerkamm, Harald (Hg.): Integrierte Produktentwicklung. Denkabläufe, Methodeneinsatz, Zusammenarbeit, Hanser: München/Wien (6. vollst. überarb. und erweit. Auflage) 2017. [2] Haberfellner, Reinhard u. a. (Hg.): Systems Engineering. Fundamentals and Applications, Birkhäuser: Basel 2019. [3] Haberfellner, Reinhard u. a. (Hg.): Systems Engineering. Grundlagen und Anwendung, Orell Füssli Verlag: Zürich (14. überarb. Auflage) 2018. [4] Hubka, Vladimir: Theorie Technischer Systeme. Grundlagen einer wissenschaftlichen Konstruktionslehre, Springer Verlag: Berlin/Heidelberg/New York (3. Auflage) 1984. [5] Martin, James N.: Systems Engineering Guidebook. A Process for Developing Systems and Products, CRC Press, Inc.: Boca Raton/FL u. a. 1997. [6] Ropohl, Günter: Allgemeine Technologie. Eine Systemtheorie der Technik, Universitätsverlag Karlsruhe: Karlsruhe (3. überarb. Auflage) 2009. [7] Weilkiens, Tim: Systems Engineering mit SysML/UML. Modellierung, Analyse, Design, dPunkt Verlag: Heidelberg (2. aktual. und erweit. Auflage) 2008.
22a. Other	None

Study/ examination performance

23. No.	24. Assigned courses	25. P. type	26. ECTS	27. Evaluation	28. Percentage of module grade
1	Fundamentals of Systems Engineering	MP	6	graded	100 %

About No. 1:

29a. Form of examination/ prerequisite for the award of credit points	Oral examination, research discussion (30 minutes) Project work (completion of a task)

30a. Responsible examiner	Prof. Dr.-Ing. D. Inkermann
31a. Preliminary examinations	None

1. Module title (English)

Module Digital Entrepreneurship

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing, M.Sc. Technische BWL, M.Sc. Wirtschaftsingenieurwesen

3. Module Coordinator		4. Relevant faculty	5. Module number
Prof. Dr. Thomas Niemand		Faculty of Energy and Economics	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
English	6	[X] 1 Semester [ ] 2 Semester	[ ] each semester [X] each study year [ ] irregular

10. Learning/ qualification objectives of the module

In this module, students learn the basics of entrepreneurship and deepen their knowledge in essential fields of its application (e.g., startups, corporate entrepreneurship, social enterprises, digital business models). Furthermore, the relationship to innovation management (esp. to the necessity of opportunity recognition as a task of entrepreneurship) and the strategic orientation of the entrepreneur compared to the classical manager will be delineated. A major focus of the course is the entrepreneurship orientation as a central object of research in recent years. With the help of this orientation, students will be shown how companies, teams and company representatives must be aligned to take advantage of the dynamics of digitalization. Finally, crucial components from initiating over developing entrepreneurial ventures to final growth will be considered. In this way, students not only gain competencies in recognizing and differentiating entrepreneurship, but also in evaluating its strengths and weaknesses regarding digital and non-digital issues.

Courses

11. No.	12. Title of the course	13. Lecturer	14. Course No.	15. Type of course	16. SWS	17. Work attendance/ internal study
1	Digital Entrepreneurship	Prof. Dr. Thomas Niemand	S 6797	V/Ü	4	56 h / 124 h
				Sum:	4	56 h / 124 h

About No. 1:

18a. Recom. Prerequisites	None

19a. Contents	▪ Entrepreneurial Mind-Set – Development – Mind-Sets in Individuals – Mind-Sets in Organizations – Social Entrepreneurship ▪ Initiating Entrepreneurial Ventures – Entrepreneurial Ventures and Innovation – Assessment of Entrepreneurial Opportunities – Pathways to Entrepreneurial Ventures – Sources of Capital for Entrepreneurs ▪ Developing Entrepreneurial Ventures – Legal Challenges – Marketing Challenges – Financial Preparation – Business Plan ▪ Growth Strategies for Entrepreneurial Ventures – Strategic Entrepreneurial Growth – Valuation of Entrepreneurial Ventures – Harvesting the Entrepreneurial Venture
20a. Media forms	Projector, slides, instructional videos, Moodle, blackboard writing
21a. Literature	[1] Kuratko, D. F. (2020). Entrepreneurship: Theory, Process, Practice, 11th ed., Boston: Cengage. [2] Morris, M. H., Kuratko, D. F. & Covin, J. G. (2010). Corporate Entrepreneurship and Innovation, 3rd ed., Mason: South-Western.
22a. Other	None

Study/ examination performance					
23. No.	**24. Assigned courses**	**25. P. type**	**26. ECTS**	**27. Evaluation**	**28. Percentage of module grade**
1	Digital Entrepreneurship	MP	6	graded	100 %
About No. 1:					
29a. Form of examination/ prerequisite for the award of credit points	Written exam (120 minutes) or oral exam (20 - 60 minutes)				
30a. Responsible examiner	Prof. Dr. Thomas Niemand				
31a. Preliminary examinations	None				

4 Compulsory elective catalogue „Interdisciplinary and Cross-Culture Collaboration“

Compulsory elective catalogue „Interdisciplinary and Cross-Culture Collaboration“

The list of modules may be updated annually for the following academic year by resolution of the Faculty Council. The updated lists are announced publicly by the Study Centre:

https://www.tu-clausthal.de/studieninteressierte/studiengaenge/masterstudiengaenge/intelligent-manufacturing

- In the module Interdisciplinary and Cross-Culture Collaboration, **two courses, optionally three courses/examinations, with a total of exactly 6 CP** must be selected from the compulsory elective catalogue 'Interdisciplinary and Cross-Culture Collaboration' and successfully completed.
- Further courses/examinations from this compulsory elective catalogue can only be taken as additional examinations.
- The selection is binding with the first examination attempt in a course/examination

1. Module title (English)

Business English I

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing, M.Sc. Maschinenbau, M.Sc. Verfahrenstechnik/Chemieingenieurwesen

3. Module Coordinator	4. Relevant faculty	5. Module number
K. Böhlefeld	Language Center of the International Center Clausthal	

6. Language	7. ECTS	8. Duration	9. To be offered
English	2	[X] 1 Semester [ ] 2 Semester	[X] each semester [ ] each study year [ ] irregular

10. Learning/ qualification objectives of the module

Upon completion of this course students:

- can express specialized vocabulary comprehensively in various forms of communication relating to company structures, management and marketing;
- can use improved oral communications skills to interact effectively in small talk, meetings and presentations;
- can understand the basic principles of business grammar;
- can comprehend complex details in listening tasks in specialized areas;
- have developed knowledge concerning working in international, professional, and business-oriented contexts

Courses

11. No.	12. Title of the course	13. Lecturer	14. Course No.	15. Type of course	16. SWS	17. Work attendance/ internal study
1	Business English I	K. Böhlefeld Dr. H. Gür	W/S 9096	2Ü	2	28 h / 62 h
				Sum:	2	28 h / 62 h

About No. 1:

18a. Recom. Prerequisites	None
19a. Contents	This course aims at the development of commercial and business communication skills. The language practiced in this course goes beyond the B2 level of the CEFR and familiarizes learners with the finer points of business correspondence, conversation, and business-related procedures
20a. Media forms	Blackboard, slides, slide collection/handout, e-learning module

21a. Literature	The course uses authentic and up-to-date texts from the respective subject areas, which are constantly updated and named in the first session.
22a. Other	None

Study/ examination performance					
23. No.	**24. Assigned courses**	**25. P. type**	**26. ECTS**	**27. Evaluation**	**28. Percentage of module grade**
1	Business English I	LN	2	graded	0 % (§ 1 Abs. 6 APO i. V. m. § 13 Abs. 2 APO and §18 Abs. 7 APO

About No. 1:	
29a. Form of examination/ prerequisite for the award of credit points	Written exam (90 minutes)
30a. Responsible examiner	K. Böhlefeld, Dr. H. Gür
31a. Preliminary examinations	None

1. Module title (English)

Chinese for Beginners

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing, M.Sc. Maschinenbau, M.Sc. Verfahrenstechnik/Chemieingenieurwesen

3. Module Coordinator		4. Relevant faculty	5. Module number
G. Cholewa		Language Center of the International Center Clausthal	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
English / Chinese	4	[X] 1 Semester [ ] 2 Semester	[ ] each semester [X] each study year [ ] irregular

10. Learning/ qualification objectives of the module

- The module is aimed at beginners with little or no previous knowledge of the Chinese language.
- After successfully completing the module, participants should be able to hold simple conversations from the areas learnt (see content) if the conversation partners speak slowly and clearly.
- They have an active vocabulary of approx. 350 words and can read and understand approx. 140 characters well.
- Participants can identify and translate all Chinese characters using the Pleco app.
- With the help of the Hanyu Pinyin transcription, participants can digitally create a text from the areas they have learnt, mostly without errors.
- After passing the exam, participants should be able to pass the state language exam HSK 1 (equivalent to A1).

Courses

11. No.	12. Title of the course	13. Lecturer	14. Course No.	15. Type of course	16. SWS	17. Work attendance/ internal study
1	Chinese for Beginners	G. Cholewa	W 9200	4V	4	56 h / 64 h
				Sum:	4	56 h / 64 h

About No. 1:

18a. Recom. Prerequisites	None

19a. Contents	▪ Teaching the Hanyu Pinyin transcription and its pronunciation ▪ Different pronunciation of the four tones in Chinese ▪ Getting to know and introducing yourself ▪ Using the Pleco app to recognise and read characters and use them as a lexicon ▪ Be able to state the nationality, place of residence, mobile phone number, email address and profession of yourself and your closest family members ▪ Understand and name numbers from 1 to 100 million ▪ Date and time ▪ Appointments for dinner or going to the cinema.
20a. Media forms	Blackboard, slides, slide collection/handout, use of the Pleco APP, Audio CDs
21a. Literature	[1] Anqi, Ding/Xin, Chen (2015): China entdecken. Lehrbuch 1, Verlag China Books: Zürich
22a. Other	Not for Chinese

Study/ examination performance					
23. No.	**24. Assigned courses**	**25. P. type**	**26. ECTS**	**27. Evaluation**	**28. Percentage of module grade**
1	Chinese for Beginners	LN	4	graded	0 % (§ 1 Abs. 6 APO i. V. m. § 13 Abs. 2 APO and §18 Abs. 7 APO
About No. 1:					
29a. Form of examination/ prerequisite for the award of credit points	Written exam (90 minutes) = 90 % 5 vocabulary tests + 1 long-term homework assignment = 10 %				
30a. Responsible examiner	G. Cholewa				
31a. Preliminary examinations	None				

1. Module title (English)

Intercultural Competence

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing, M.Sc. Maschinenbau, M.Sc. Verfahrenstechnik/Chemieingenieurwesen

3. Module Coordinator		4. Relevant faculty	5. Module number
K. Böhlefeld		Language Center of the International Center Clausthal	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
English	3	[X] 1 Semester [ ] 2 Semester	[X] each semester [ ] each study year [ ] irregular

10. Learning/ qualification objectives of the module

After successfully completing the Intercultural Competence module, students have the following qualifications:

- Students are familiar with different cultural models, especially dynamic ones,
- they are able to recognise different cultural dimensions and their effects in the cooperation of international project teams,
- they are able to recognise cultural diversity as an opportunity and
- develop culturally sensitive communication strategies

Courses

11. No.	12. Title of the course	13. Lecturer	14. Course No.	15. Type of course	16. SWS	17. Work attendance/ internal study
1	Intercultural Competence	K. Böhlefeld	W/S 9221	2Ü	2	24 h / 66 h
				Sum:	2	24 h / 66 h

About No. 1:

18a. Recom. Prerequisites	English language skills at level B2 and German are recommended
19a. Contents	The module covers the following topics: ▪ What is culture? A comparison of static and dynamic cultural models ▪ Own culture - foreign culture, different value systems and their impact on collaboration in international teams ▪ Respectful treatment of differences and effective communication in a foreign language
20a. Media forms	Video, audio materials, e-learning materials (Moodle), Powerpoint presentations

21a. Literature	[1] Maude, B. (2016). Managing Cross-Cultural Communication, Houndmills, Basingstoke Hampshire: Palgrave Macmillan [2] Gesteland, R. R. (2002). Cross-cultural business behavior: Marketing, negotiating, sourcing and managing across cultures. Copenhagen Business School Pr. 77 [3] Ting-Toomey, S. (1999). Communicating Across Cultures. New York: The Guilford Press [4] Comfort, J. & Franklin, P. (2014): The Mindful International Manager. How To Work Effectively Across Cultures (2nd and expanded edition). London: Kogan Page Further literature will be announced in the seminar.
22a. Other	None

Study/ examination performance					
23. No.	**24. Assigned courses**	**25. P. type**	**26. ECTS**	**27. Evaluation**	**28. Percentage of module grade**
1	Intercultural Competence	LN	3	graded	0 % (§ 1 Abs. 6 APO i. V. m. § 13 Abs. 2 APO and §18 Abs. 7 APO

About No. 1:	
29a. Form of examination/ prerequisite for the award of credit points	Group presentation and home assignment
30a. Responsible examiner	K. Böhlefeld
31a. Preliminary examinations	None

1. Module title (English)

Technical Writing

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing, M.Sc. Maschinenbau, M.Sc. Verfahrenstechnik/Chemieingenieurwesen

3. Module Coordinator	4. Relevant faculty	5. Module number
J. Schulze-Bentrop	Language Center of the International Center Clausthal	

6. Language	7. ECTS	8. Duration	9. To be offered
English	2	[X] 1 Semester [ ] 2 Semester	[X] each semester [ ] each study year [ ] irregular

10. Learning/ qualification objectives of the module

Upon completion of this course students:

- can communicate fluently, both orally and in written form, in academic and professional technical oriented situations;
- can comprehend complex details in technical reading and listening texts;
- can express themselves more clearly with a wide range of Technical English vocabulary;
- can understand and properly use specific technical-oriented grammar structures;
- can produce a variety of technical, professional and academic documents.

Courses

11. No.	12. Title of the course	13. Lecturer	14. Course No.	15. Type of course	16. SWS	17. Work attendance/ internal study
1	Technical Writing	J. Schulze-Bentrop	W/S 9009	2Ü	2	28 h / 62 h
				Sum:	2	28 h / 62 h

About No. 1:

18a. Recom. Prerequisites	B2 English level
19a. Contents	This course aims at the development of the writing skills and specialized language required for scientific, technical and engineering settings. The language practiced in this course goes beyond the B2 level of the CEFR to enable the participants to express themselves appropriately and effectively in a scientific and technical context.
20a. Media forms	Students work with various forms of print and digital media.

21a. Literature	The course uses authentic and up-to-date texts from the respective subject areas, which are constantly updated and named in the first session.
22a. Other	None

Study/ examination performance					
23. No.	**24. Assigned courses**	**25. P. type**	**26. ECTS**	**27. Evaluation**	**28. Percentage of module grade**
1	Technical Writing	LN	2	graded	0 % (§ 1 Abs. 6 APO i. V. m. § 13 Abs. 2 APO and §18 Abs. 7 APO

About No. 1:	
29a. Form of examination/ prerequisite for the award of credit points	Report (about 3 pages), or Written Exam (120 min)
30a. Responsible examiner	J. Schulze-Bentrop
31a. Preliminary examinations	None

1. Module title (English)

Technical Presentations in English

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing, M.Sc. Maschinenbau, M.Sc. Verfahrenstechnik/Chemieingenieurwesen

3. Module Coordinator	4. Relevant faculty	5. Module number
K. Böhlefeld	Language Center of the International Center Clausthal	

6. Language	7. ECTS	8. Duration	9. To be offered
English	2	[X] 1 Semester [ ] 2 Semester	[X] each semester [ ] each study year [ ] irregular

10. Learning/ qualification objectives of the module

Upon completion of this course students:

- can comprehend complex ideas and details in technical-oriented reading and listening tasks;
- can communicate ideas and opinions in a professional and technical way;
- can use appropriate grammar and sentence structures for technical-oriented texts;
- can explain a technical idea, process, or procedure clearly in front of an audience;
- have developed knowledge concerning working in international, professional, and scientific contexts.

Courses

11. No.	12. Title of the course	13. Lecturer	14. Course No.	15. Type of course	16. SWS	17. Work attendance/ internal study
1	Technical Presentations in English	A. Rose	W/S 9092	2Ü	2	28 h / 62 h
				Sum:	2	28 h / 62 h

About No. 1:

18a. Recom. Prerequisites	None
19a. Contents	The aim of this course is to develop the verbal and presentational skills necessary to deliver technical and/or scientific presentations in English. The course consists of a formal instruction phase in which students are taught the skills needed to deliver presentations (usually in PTT), followed by a workshop phase in which students draft their own presentations. The course culminates in the delivery and assessment of student presentations. The language practiced in this course goes beyond the B2 level of the CEFR to enable participants to express themselves fluently in a scientific and technical context.

20a. Media forms	Blackboard, slides, slide collection/handout
21a. Literature	▪ Reading materials will be discussed in the first class meeting. ▪ The course uses authentic and up-to-date texts from the respective subject areas, which are constantly updated and named in the first session.
22a. Other	None

Study/ examination performance					
23. No.	**24. Assigned courses**	**25. P. type**	**26. ECTS**	**27. Evaluation**	**28. Percentage of module grade**
1	Technical Presentations in English	LN	2	graded	0 % (§ 1 Abs. 6 APO i. V. m. § 13 Abs. 2 APO and §18 Abs. 7 APO

About No. 1:	
29a. Form of examination/ prerequisite for the award of credit points	Presentation
30a. Responsible examiner	A. Rose
31a. Preliminary examinations	None

1. Module title (English)

Technical English

2. Usability of the module in degree programmes

M.Sc. Intelligent Manufacturing, M.Sc. Maschinenbau, M.Sc. Verfahrenstechnik/Chemieingenieurwesen

3. Module Coordinator		4. Relevant faculty	5. Module number
J. Schulze-Bentrop		Language Center of the International Center Clausthal	
6. Language	**7. ECTS**	**8. Duration**	**9. To be offered**
English	4	[X] 1 Semester [ ] 2 Semester	[X] each semester [ ] each study year [ ] irregular

10. Learning/ qualification objectives of the module

Upon completion of this course students:

- can communicate fluently, both orally and in written form, in academic and professional technical oriented situations;
- can comprehend complex details in technical reading and listening texts;
- can express themselves more clearly with a wide range of Technical English vocabulary;
- can understand and properly use specific technical-oriented grammar structures.

Courses

11. No.	12. Title of the course	13. Lecturer	14. Course No.	15. Type of course	16. SWS	17. Work attendance/ internal study
1	Technical English	J. Schulze-Bentrop Dr. H. Gür	W/S 9000	4V	4	56 h / 64 h
				Sum:	4	56 h / 64 h

About No. 1:

18a. Recom. Prerequisites	B2 English level
19a. Contents	This course aims at the development of the communication skills and specialized language required for scientific, technical and engineering settings. The language practiced in this course goes beyond the B2 level of the CEFR to enable the participants to express themselves appropriately in a scientific and technical context.
20a. Media forms	Students work with various forms of print and digital media.

21a. Literature	[1] Ibbotson, M. (2013): Cambridge English for Engineering. Cambridge University Press: Cambridge u. a. (8. Auflage). Furthermore, authentic and up-to-date texts from the respective subject areas are used, which are constantly updated and named in the first session.
22a. Other	70 % compulsory attendance

Study/ examination performance					
23. No.	**24. Assigned courses**	**25. P. type**	**26. ECTS**	**27. Evaluation**	**28. Percentage of module grade**
1	Technical English	LN	4	graded	0 % (§ 1 Abs. 6 APO i. V. m. § 13 Abs. 2 APO and §18 Abs. 7 APO
About No. 1:					
29a. Form of examination/ prerequisite for the award of credit points	Written Exam (90 Min) or Report (about 3 pages)				
30a. Responsible examiner	J. Schulze-Bentrop, Dr. H. Gür				
31a. Preliminary examinations	None				