IE3 Course Action Plan

Draft Report LiU

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1. EXISTING COURSE MODULES

The existing course modules are in this report the course Design and Development of Manufacturing Operations (TPPE74) and Production System Planning and Management (TPPE91) given by the division Production economics at Linköping University.

1.1. Course Module: Design and Development of Manufacturing Operations

Master Program: Mechanical Engineering and Industrial Engineering and Management
Effort: 6 ECTS (160h)
Course code: TPPE74
Students: ~ 50 students
Language: English
It is an elective course in the master program.

1.1.1. Objectives

The course presents different perspectives on how manufacturing operations can be designed and developed and how the value of the company's manufacturing processes can be improved. After completion of the course, the student should possess enhanced knowledge of various analytical tools and approaches of both conceptual and operational nature. The course includes a project (project task) where a company is analysed, using a simulation model, to improve the company's operations. Emphasis is placed on using theoretical models in a practical environment.

1.1.2. Current Syllabus

The current course syllabus is valid since 2021-01-01.

Learning Outcomes

After this course the student should be able to:
- design and develop manufacturing operations using static analysis models
- design and develop manufacturing operations using dynamic analysis models
- understand cause-and-effect relationships within manufacturing operations relating to rate, inventory, and time
- use and evaluate appropriate planning and control methods in operations management
- use and evaluate contemporary development methods in operations management

Examination

UPG1: Seminar Project (U, G) – Project task, 3 hp
TEN1: Written Examination (U, 3, 4, 5) – 3 hp

The project task consists of a larger problem in which a simulation tool is used to design and develop the manufacturing operations of a company. The project task is graded based on the grading criteria for a passing level in the project document. There are 17 possibilities to run the simulations in Task B of the project. Each group is allowed a maximum of 10 simulation runs. If the group fail to run all 10 runs at the final simulation opportunity, the last simulation runs are forfeited. There are 6 possibilities to run the simulations in Task C and D respectively. Each group is allowed a maximum of 3 simulation runs. If the group fail to run all 3 runs at the final simulation opportunity, the last simulation runs are forfeited. Before the simulation runs, Quizzes are used to make sure that pre-knowledge and system design is correct.

Written examination is carried out three times per year. The written examination constitutes the final grade of the whole course. The written examination is done in English, meaning that the questions are in English and the only possible language to write the answers in is English. It is not possible to hand in a completion if the written examination is failed.

Designing Manufacturing Operations: Analyze lead-times, capacity, material flow, customer and manufacturing orders, delivery service, inventories, an information from a systems perspective to meet system requirements by changing system parameters. Developing Manufacturing Operations: Value-based process enhancements through improvements in time, cost, flexibility, and quality, with a special focus on setup-time reduction. Simulation as Support for design and development of operations: Relationships among lead-times, capacity, material flow, inventories, orders, delivery service, costs, information, and planning strategy.

Teaching Methods

The teaching is organized in lectures and seminars and laboratories. The lectures deal with the theoretical approaches and the seminars and laboratory sessions deal with a project.

- Lectures: 14 hours (Filmed lectures in Lisam, Live question sessions)
- Seminars: ca 14 hours (Filmed seminars in Lisam, Live questions session)
- Project (not in Time Edit) in group: 80 hours.
- Own studies: 52 hours
- Sum: 160 hours

1.2. Course Module: Production System Planning and Management

5-year Master of Science in Mechanical Engineering program
Effort: 6 ECTS (160h)
Course code: TPPE91
Students: ~ 120 students
Language: Swedish
Compulsory course year 3

1.1.1. Objectives

The course will give the students insights into economic issues concerning industrial production. After the course, the students must be able to use the most common methods for forecasting, design of production systems and material and production control, and understand the relationships between production, planning and the industrial company's other functions.

1.1.2. Current Syllabus

The current course syllabus is valid since 2021-09-01.

Learning Outcomes

After taking this course, the student should:

- have knowledge in the relation between a production system and a industry company other functions
- have knowledge about the most important business processes in a manufacturing company, and understand the internal and external supply chains
- have knowledge about the basics in production economics, economical issues for industrial production and the connection to business strategies
- be able to describe different production systems and their layout and be able to identify critical factors when designing a production system
- have knowledge about different ways of organising material handling and distribution
- be able to describe and use demand models and forecast methods to evaluate future demand
- be able to describe material- and production management, in both a long and a short horizon, and their methods, from forecast, via sale and production planning, main planning and material and resource planning down to detail planning
- have basic knowledge about lean production

- be able to describe and use the most common methods for inventory control
- be able do describe inportant factors regarding purchase/manufacturing decisions and decisions about outsourcing
- have knowledge about different way of measure flow- and resource efficiency and have understanding how they are related
- have a basic knowledge in the methology how to analyse and improve flows and processes

Examination

PRA2: Project work (Fail/Pass), 2 hp
TEN2: Written Examination (Fail, 3, 4, 5), 4 hp

The project task consists of a larger problem divided into three parts, Inventory control, Purchase or inhouse manufacturing, and Value stream mapping. The first and the last parts are examined through a quiz and an oral examination in groups of 4 students. The students need to answer all questions in the quiz correctly before coming to the oral examination. The questions are some multichoice questions and some questions that need a numerical value, where the students are using evaluations in excel to come up with the answers. The second part is examined by a written report and seminar.

Written examination is carried out three times per year. The written examination constitutes the final grade of the whole course. It is not possible to hand in a completion if the written examination is failed.

Course Content

The basics in Production economics, important concepts and categorising of companies. Developing and construction of production systems for effective production based on essential business management. Different production systems, Sale- and production planning, main planning and resource material planning, detail planning, inventory control, business processes, economical key factors. Principles for distribution and lean production. Purchase and distribution in a manufacturing industry. Purchase/manaufacturing decisions and the basic knowledge about outsourcing.

Teaching Methods

Lectures are mainly concerned with introduces theoretical issues and conscepts, but also ties together various parts of the course. The lessons are concentrating on exercises connected to the most important course sections. A practical case runs through the course, where different approaches are presented and discussed at the seminars. A number of assignments in various parts of the case study are the basis for examination.

1.3 Need for Revision

TPPE74 Design and development of manufacturing operations has been developed in several steps for the last 30 years. Now, we see a high potential to include digitalization and especially AI technologies in the course.

TPPE91 Production System Planning and Management is a rather new courses (started 2015) giving the students basic knowledge of production and logistics. We also here see a high potential to include basic knowledge and understanding about Industry 4.0, big data and how to use digitalization in a production industry.

2. REVISION RELATED TO THE BODY OF KNOWLEDGE

From the outcomes of the Body of Knowledge (BoK), these course modules are strongly connected to Problem Solving and Decision Making, Team Working, and Operations Management from A1(Knowledge, Skills and Competencies). In A2 (Operations tools) these modules are strongly connected to Management Software Tools, Big Data Analysis, and Machine Learning/AI Competences addressing mainly the Analytical components.

In the Body of Knowledge, there is a large gap between Problem Solving and Decision Making in A1, Big Data Analysis and Machine Learning/AI Competences in A2 which are easily filled in these two courses. By adding a module in the basic course TPPE91, our aim is to take a first step to fill that gap, and in the second course TPPE74, we chose to work with a stand-alone lecture for AI and update the project for Problem Solving and Decision Making.

2.1. Course Module: Design and Development of Manufacturing Operations

In the course TPPE74 Design and development of manufacturing operations, two modules have been part of the IE3 project.

2.1.1. Module: Project

A project is part of the course (3 credits) which have been updated as part of the IE3 initiative. The project has been added two new tasks aiming at introducing Expert system-like knowledge-based rules and regulations.

The project PicSim is a simulation model driven design and development project where students develop a manufacturing system towards specific cost targets, see Figure 2.1. Task A (New) contains understanding of interrelationships between design parameters and economic measures. Task D (New) contains a re-optimization of the system under new stochastic behavior, see Figure 2.2.

In the last lecture, we address the knowledge-based solution (Task B) and compare to the use of DoE and regression analysis. We see this as the first step towards Machine Learning. As part of this, all seminars in the project and the last lecture have been newly developed.

PicSim Project

- The objectives of this project are:
    - to give a deeper understanding for decision making problems of this kind,
    - to illustrate how alternative planning and control systems can be analysed through simulation,
    - to give a deeper understanding for the interrelationships among parameters,
    - to analyse manufacturing operations through studying relationships between different variables,
    - to analyse the impact of different factors such as demand variations and load,
    - to study development of manufacturing operations through for example set-up time reduction.
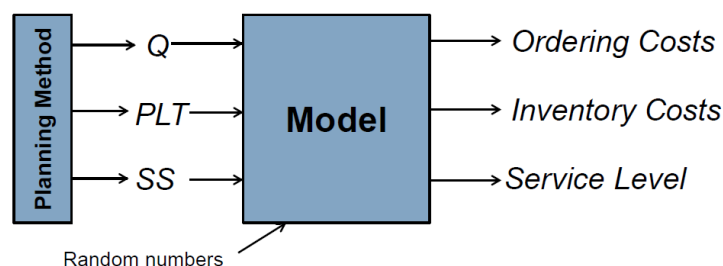

Figure 2.1: Project PicSim

Four Tasks in the Project

- Task A
    - Create graphs over nine different relationships.
    - Lisam Quiz to test conceptual shape.
- Task B
    - Run 10 simulations (we run the model) with the target to reach:
    Inventory cost: 340 000 kr
    Service level: 95 %
    Total Cost: 680 000 kr
    - Test all different planning methods
    - Lisam Quiz before simulations (at least one in each group needs to pass)
- Task C
    - Carry out a setup time reduction and study the effects.
    - Run 3 simulations (we run the model) to study the effects.
- Task D
    - Formulate system specific guidelines and rules that apply to the design parameters.
    - Run 3 simulations (we run the model) to "optimize" the system.
    - Competition!

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Figure 2.2: Project Tasks

2.1.2. Module: Lecture in AI

The company Implema AB have been responsible for a lecture in AI and a corresponding seminar, see Figures 2.3 and 2.4. Both carried out by Eskil Rehme at Implema AB. This highlights the new focus on machine learning in the course even further and gives the students a deeper understanding about how to use AI in operations management.

Both project and AI lecture and seminar adds on a new dimension of the course where novel technologies such as AI and other digital solutions to the course. The developed material will not be available on the open market. The combination of AI, machine learning, DoE and regression analysis gives a high-level knowledge in the field of Industry 4.0 relevant techniques in operations management.
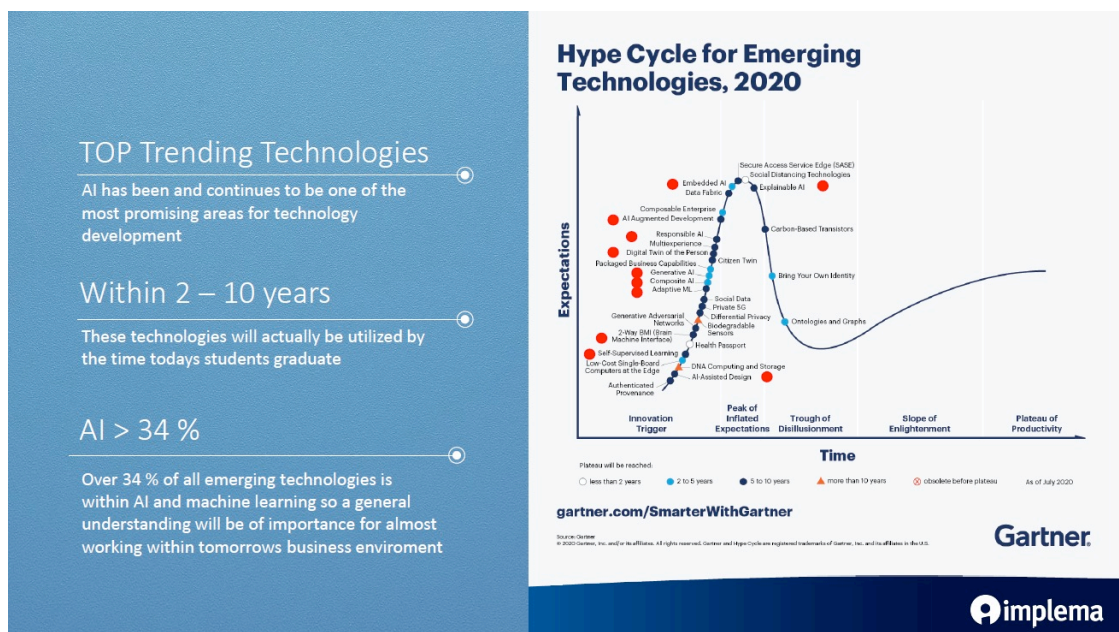

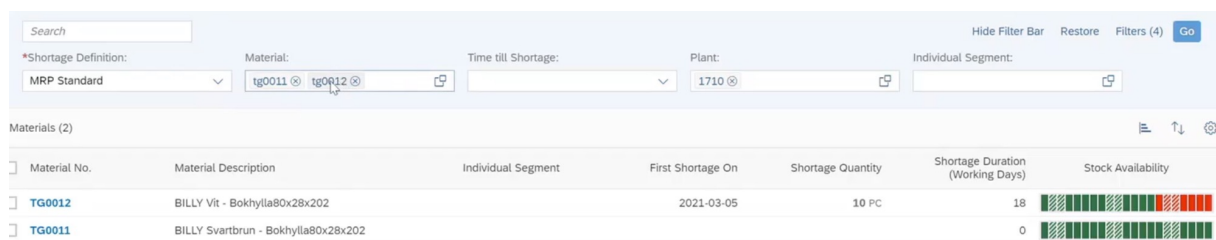*Figure 2.3: Overview of the AI area*

Figure 2.4: Lecture Agenda

2.2. Course Module: Production System Planning and Management

The course content is about the basics in production economics, important concepts and categorising of companies. The main parts are different production systems, sale- and production planning, main planning and resource material planning, detail planning, inventory control, lean production and distribution in a manufacturing industry. The course includes a "real world" case with a number of assignments with "real" data. However, what has been missing in this course is the connection to how the above methods are used in the industry and how established ERP-system on the market looks like. The purpose of the module included in the course in to give the students a first glimpse of an ERP-system and see that standard methods in the course are used frequently in commercial ERP-systems. Therefore, the course TPPE91 Production System Planning and Management, includes two modules that have been a part of the IE3 project, one laboration with assignments using an ERP-system and one lecture about digitalization in the manufacturing industry.

2.2.1 Module: Laboration in an ERP-system

The laboration was included, for the first time, in the course 2020 just before the covid pandemic, given by our industry partner Implema. However, during the covid pandemic, we have focused on online material, but with clear thoughts about how to expand this module 2022. The new learning material 2021 are a film made by our industry partner, Implema, where they describe how Material Resource Planning (MRPII) is working and used in an ERP-system (SAP) and a lecture, also from Implema, where they, based on the film, are extending the material about MRP in an ERP-system. The film and the powerpoint-presentations are available for the students on the course internal homepage. This course module will be extended in coming years and Implema will support this during the IE3 project. There are ideas with hand on assignments or a game for the students. The figures below show screenshots from the SAP system, mainly describing MRPII and Inventory control.

Figure 2.5 Screenshot from MRP Standards, Materials from the SAP film and lecture
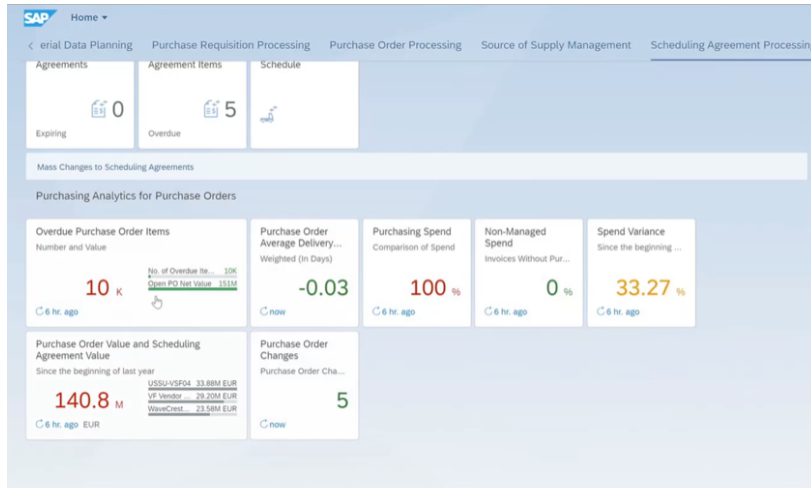
Figure 2.6 Screenshot of Purchasing Analytics for Purchase Orders from the SAP film and lecture
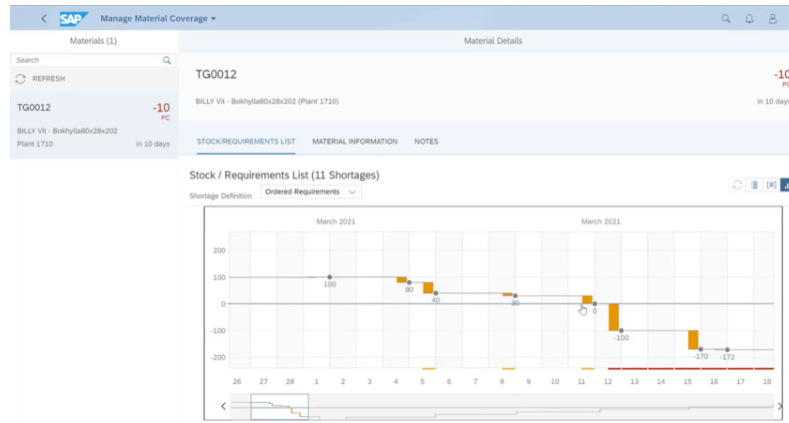

Figure 2.7 Screenshot of Stock / Requirement List from the SAP film and lecture

2.2.2 Module: Lecture About Industry 4.0, Smart Factories and Digitalization

The new learning material also includes a new developed lecture about Industry 4.0, smart factories and big data. The aim with the lecture is to give the students some basic knowledge about Industry 4.0 and what is happening in the manufacturing industry. Two of the slides in the presentation are shown below in figure 2.8 and 2.9.
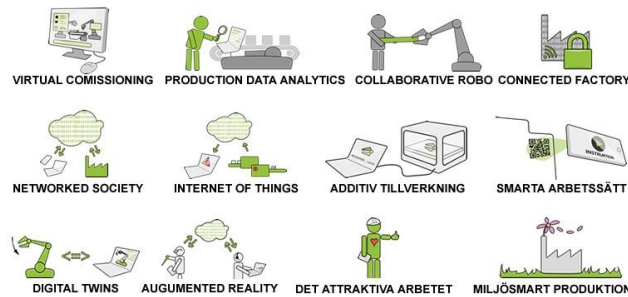

Figure 2.8 Smart Factories from the lecture about Industry 4.0 and Digitalization
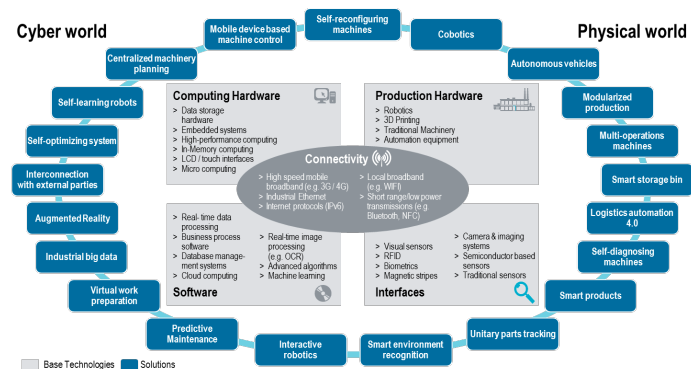
Figure 2.9 Cyber world and Physical world from the lecture about Industry 4.0 and Digitalization

3. TEACHING METHODOLOGY

Linköping University works with several different digital platforms for teaching. The main course resource is called Lisam and is developed by the university based on MS Share Point. In Lisam, all digital resources such a lecture slides and documents in PDF, recorded material, and information is stored and published. Lisam also contain functionality to give quizzes, have signup lists, do submissions, and grade students. Lisam is also connected to MS Teams where all courses in Lisam have a corresponding Team setup automatically.

In the courses TPPE74 Design and Development of Manufacturing Operations all lectures are pre-recorded and a session for questions is given for each lecture according to the time schedule. In the course TPPE91 Production System Planning and Management most of the lectures and the seminars were given live in Teams and recorded during the live presentation. Some of the lectures were pre-recorded. All supervision in both courses has been caried out in Teams and communications have utilized both Lisam and emails.

The basic pedagogical method has been to first introduce a topic area, then to do simple applications on the area, to later in the projects do a full-scale implementation. One example of this is the implementation of Cyclic planning (periodic planning) in TPPE74. First, the concept of cyclic planning is covered at a lecture. The next step is to solve simple problems in the range of three products in one resource at a seminar. The final step is to implement cyclic planning in a larger environment including five resources and nine products.

4. IMPLEMENTATION OF THE REVISED COURSE MODULES

All course modules were implemented and tested during the spring 2021. See the subheadings below for the details of each course module.

4.1. Course Module: Design and Development of Manufacturing Operations

The course module stared 2021-03-29 with the first lecture and ended 2021-05-24 with the last lecture, see the game plan for the course in figure 4.1.
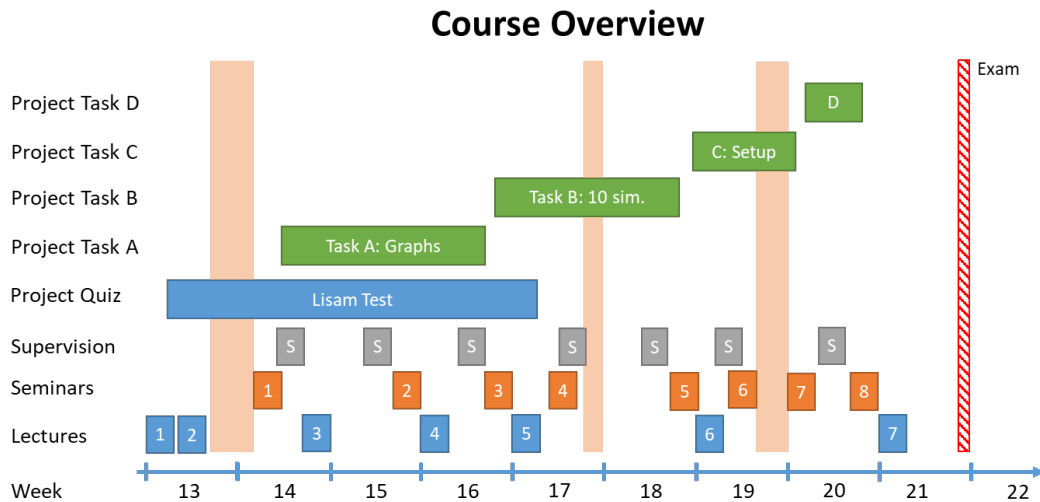
Figure 4.1. TPPE74 Course Plan

In the Project part of the course, newly developed tasks were Task A and Task D. The Lecture in AI is Lecture 6 together with seminar 6.

4.2. Course Module: Production System Planning and Management

The course module stared 2021-01-18 (week 3) with the first lecture and ended 2021-03-12 (week 10) with the last lecture, see the game plan for the course in figure 4.2

Figure 4.2. TPPE91 Course Plan

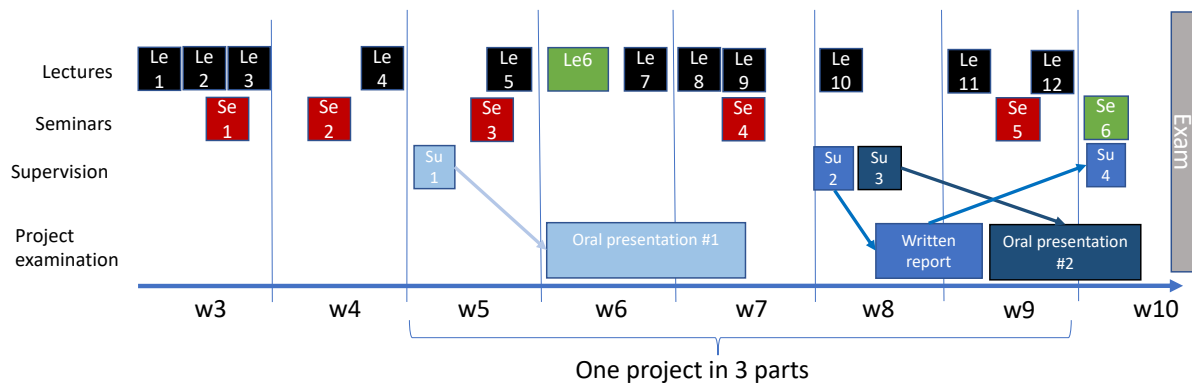The newly developed tasks were lecture 6 and seminar 6, marked green in the figure.

5. INVOLVEMENT OF THE INDUSTRIAL PARTNERS

The industrial partner Implema AB has been discussion partner in the development of all the modules and being in charge of development of module 2 in TPPE74 Design and Development of Manufacturing Operations and module 1 in TPPE91 Production System Planning and Management.

6. COURSE MODULE EVALUATION

All courses at LiU will automatically be subject to course evaluation in Evaliuate. A questionnaire will be sent to all registered students on every course when the course ends. The questionnaire contains 10 university-wide questions and some others that are specific to the faculty. Further questions can be added, if desired.

6.1. Course Module: Design and Development of Manufacturing Operations

The course evaluation opened 2021-05-31 and closed 2021-06-21.

Table 6.1: Response rate for TPPE74

Evaliuate TPPE74	Number
Number of respondents	44
Number of answers	7 (15.9 %)

For the results of the course evaluation, the results of two questions are reported. Question 9 concerns the whole course and an overall evaluation. For TPPE74 in 2021, this result was 4.57 on a scale from 1 to 5, see Figure 6.1.

9. What is your overall evaluation of the course?

What is your overall evaluation of the course?	Number of Responses
5 - Highest	4 (57%)
4	3 (43%)
3	0 (0%)
2	0 (0%)
1 - Lowest	0 (0%)
Total	7 (100%)
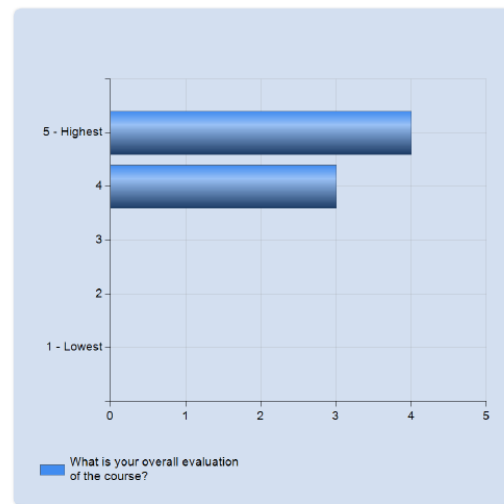
	Mean	Standard Deviation	Coefficient of Variation	Min	Lower Quartile	Median	Upper Quartile	Max
What is your overall evaluation of the course?	4.57	0.53	11.69 %	4.00	4.00	5.00	5.00	5.00

Figure 6.1: Answers for question 9 in the course TPPE74

The answers for question 14 are also relevant since the question is about how relevant the course is in the study program. For TPPE74 in 2021, this result was 4.71 on a scale from 1 to 5, see Figure 6.2.

14. The course was relevant to my education.

The course was relevant to my education.	Number of Responses
5 - Yes, absolutely	5 (71%)
4	2 (29%)
3	0 (0%)
2	0 (0%)
1 - No, not at all	0 (0%)
Total	7 (100%)
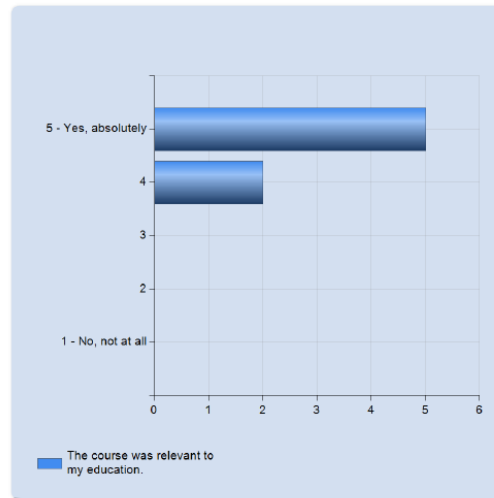
	Mean	Standard Deviation	Coefficient of Variation	Min	Lower Quartile	Median	Upper Quartile	Max
The course was relevant to my education.	4.71	0.49	10.35 %	4.00	4.50	5.00	5.00	5.00

Figure 6.2: Answers for question 14 in the course TPPE74

6.2. Course Module: Production System Planning and Management
The course evaluation opened 2021-03-22 and closed 2021-04-11.

Table 6.2: Response rate

Evaliuate TPPE91	Number
Number of respondents	120
Number of answers	24 (20 %)

For the results of the course evaluation, the same two questions are reported as in the previous section (in Swedish). Question 9 concerns the whole course and an overall evaluation and for TPPE91 in 2021, this result was 3.71 on a scale from 1 to 5, see Figure 6.1.

9. Vilket helhetsbetyg ger du kursen?

Vilket helhetsbetyg ger du kursen?	Antal svar
5 - Högst betyg	4 (17%)
4	13 (54%)
3	4 (17%)
2	2 (8%)
1 - Lägst betyg	1 (4%)
Summa	24 (100%)
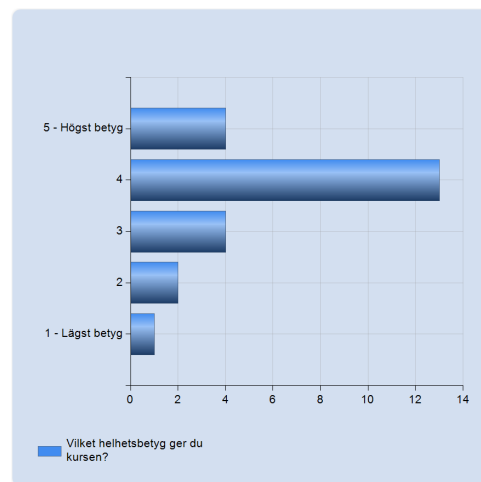
	Medelvärde	Standardavvikelse	Variationskoefficient	Min	Undre kvartil	Median	Övre kvartil	Max
Vilket helhetsbetyg ger du kursen?	3,71	1,00	26,94 %	1,00	3,00	4,00	4,00	5,00

Figure 6.3 Answers to the question "What is your overall evaluation of the course?" in the course TPPE91

Finally, the answers for question 14 with the statement "The course was relevant to my study program". For TPPE91 in 2021, this result was 4.13 on a scale from 1 to 5, see Figure 6.4.

1. Kursen är relevant för min utbildning.

Kursen är relevant för min utbildning.	Antal svar
5 - Ja, absolut	11 (46%)
4	7 (29%)
3	5 (21%)
2	0 (0%)
1 - Nej, inte alls	1 (4%)
Summa	24 (100%)
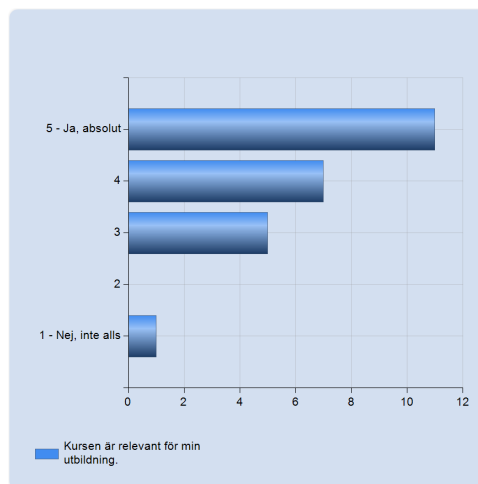
	Medelvärde	Standardavvikelse	Variationskoefficient	Min	Undre kvartil	Median	Övre kvartil	Max
Kursen är relevant för min utbildning.	4,13	1,03	25,08 %	1,00	3,50	4,00	5,00	5,00

Figure 6.4 Answers to the statement "The course was relevant to my study program" in the course TPPE91