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# Interactive learning activities for education of factory level order-to-delivery process

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**Abstract**

This paper presents interactive learning activities on both individual exercises and course implementations. The main objective is to enrich the education of production engineering both on bachelor and master level studies. The learning activities are focused on the order-to-delivery process on a factory floor as well as the related planning and scheduling tasks. The theoretical topics of the education are explained as a base for the topics of the learning activities. The core of the learning activities is a simulation model and several exercises are conducted using the simulation environment. Additional activities are added to the simulation environment to bring interactive elements to individual exercises. Similarly, the interaction elements in the course implementations are discussed. These topics are elaborated from the viewpoints of the current education and possibilities for the future development.



*Keywords:* Simulation; production; interactive

## 1. Introduction

ManuFUTURE 2030 Vision, a report from the ManuFUTURE high-level group, defines three building blocks for successful manufacturing in Europe, namely *science and technology*, *innovation and entrepreneurship* as well as *education and training* [1]. It also mentions that educational institutes should ensure that the education and training are constantly updated to cover technological evolutions. At the factories of the future multi-annual roadmap,

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modelling, simulation and forecasting are some of the key enabling technologies [2]. It can be utilized in all the phases of a factory life cycle in form e.g.of environments for learning by doing and teaching factory.

In this paper, interactive learning activities are discussed. It advances a previously introduced Virtual FMS, an engineering education environment for flexible manufacturing systems (FMS) [3, 4]. The learning activities are integrated into a simulation model. The focus is on the order-to-delivery process i.e. the chain of manufacturing processes from raw materials to finished products. The rest of the paper includes the following topics. Section 2 goes through the theoretical aspects of the learning topics of the environment that are part of the current courses related to production systems. In Section 3, the simulation exercises and their added interactive features are explained. Section 4 discusses on how the exercises can be implemented into a course execution. In Section 5, ideas of future development are discussed and the work is concluded in Section 6.

## 2. Theoretical aspects of the learning topics

The learning activities present different aspects of order-to-delivery process of discrete part manufacturing, focusing on the part manufacturing and product assemblies. In the following, the theoretical topics related to the learning activities are presented. They fall into two categories i.e. areas of design and development of production systems as well as their simulation and capacity calculations.

### *2.1. Design and development areas of production systems*

Figure 1 presents the main areas of design and development of production systems based on [5-7]. Product and production analysis represent the product portfolio as well as the volume and variation of customer orders. The portfolio represents the variation of products are offered to customers. The volume estimates how much products the customers will order while the variation explains how the volume is divided between different products. One important element in the product and production analysis is to perform make-or-buy analysis, which results in what will be manufactured at the factory and what will be procured. The product and production analysis combined with the make-or-buy analysis will give a rough level understanding for the required capacity of the factory and requirements for the procurement. Therefore, it serves as a basis for the further design and development of a production system.

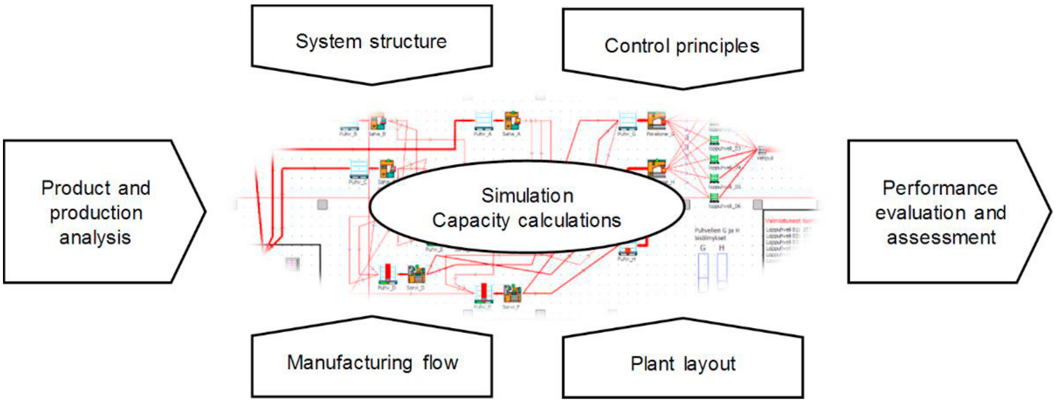


Fig. 1. Areas of production system design and development.

The system structure represents the production network consisting on the production system to be designed and the supply network for the procurements. The control principles focus on the production planning and control of both procurements and own production of a company. The manufacturing flow includes individual manufacturing processes and the chain of processes the products require. The plant layout represents the physical structure of the elements of a production system i.e. where the manufacturing resources exist.

### 2.2. Simulation in design and development of production systems

Simulation and capacity calculations differ in their complexity. Capacity calculations are sufficient when the case to be solved is a simple analytic problem. When a system has complexity, capacity calculations may offer inaccurate results. Instead, simulation can be applied into the problem [8]. In the context of the learning activities, simulation falls into a category of discrete-event simulation (DES). DES can be applied into several different application areas, such as manufacturing systems, logistics, supply chains, transportation and health care [9-12]. In this paper, the simulation related to the learning environment focuses on the areas discussed of production system design and development as well as on the logistics related to the procurement. Table 1 combines the design and development areas of productions systems based on [5-7] as well as simulation in this context discussed in [8-12].

Table 1. Example topics to investigate using discrete-event simulation.

| Area of design | Example experiments to investigate by simulation | Key performance indicators |
|---|---|---|
| Product and production analysis | Changes in production volumes and variation of existing products | |
| | New or removed products in the portfolio based on changes e.g. in customer behavior | Number of manufactured products |
| System structure | Selection of suppliers with different supply capabilities, e.g. delivery reliability | Throughput time<br>Takt time |
| | Forming product families | Cycle time |
| Control principles | Evaluation of production planning, control and scheduling principles | Work in progress |
| | Make-to-stock versus make-to-order | Delivery reliability |
| Manufacturing flow | Alternative routes for transferring products between manufacturing resources | Delivery speed<br>Batch Size |
| | Number of manufacturing resources and need for personnel | Number of resources<br>Number of workers |
| Plant layout | Sizes and locations of manufacturing resources and storage areas | Working shifts |
| | Pathways for internal factory logistics | |

The key performance indicators play an important role in evaluation of the performance of a production system. In DES, different experiments are easy to carry out to compare different scenarios. With the key performance indicators, the scenarios can be evaluated. This enables the comparison of the key performance indicators from the different scenarios for further investigation [8].

## 3. Descriptions of the learning activities

The backbone for the learning activities is a simulation model, an interactive presentation of an example factory including the theoretical aspects discussed above. It focuses on the order-to-delivery process that represents the flow of material within a factory. At the same time, it is a user interface for additional exercises. The interactive nature of the additional exercises is realized by actions of a different kind that can be launched from the simulation model. Therefore, the learning environment is used in simulation exercises as well as exercises enabling more comprehensive learning activities. The simulation exercises can be divided roughly into the following:

- Running the simulation in kiosk mode preventing user from manipulating the simulation.
- Simple simulation exercises with little or no previous knowledge of the software.
- Advanced simulation exercises where the simulation model is modified by the students.
- Advanced simulation exercises where the model is constructed based on given instructions.

The simulation exercises focus on the topics presented in Table 1. Each of the exercises concentrates on one or more of the topics. Therefore, the exercises build on each other and together they give a more comprehensive outlook to the design and development of production systems. Examples of more detailed topics of the exercises are:

- Changes in the volume and variation of customer orders in order to find to where and how much new capacity is needed. The students perform the exercise as trial and error until the goals of the exercise are reached.
- Control principles effecting on the volume of finished products. The main goal is to avoid the setup times and unnecessary transportation of products within a manufacturing plant.
- Improvement of a plant layout to minimize the movement of workers and to save the floor space of a facility.

In addition to the simulation exercises, several ways can be used to add interactive elements to the simulation exercises. The elements can be based on images, videos and text. Images can be still images or 360° images, which can be used to show the surroundings of a certain point in space. The images can also be 3D-models that can be zoomed, panned, and rotated. Videos can be enhanced with different activities by adding e.g. information and questions for the video playback. It can be set that students cannot continue the video before taking required actions, such giving a right answer to a question. When the intention of an exercise is based on reading text, images and videos can be used to enrich the textual content.

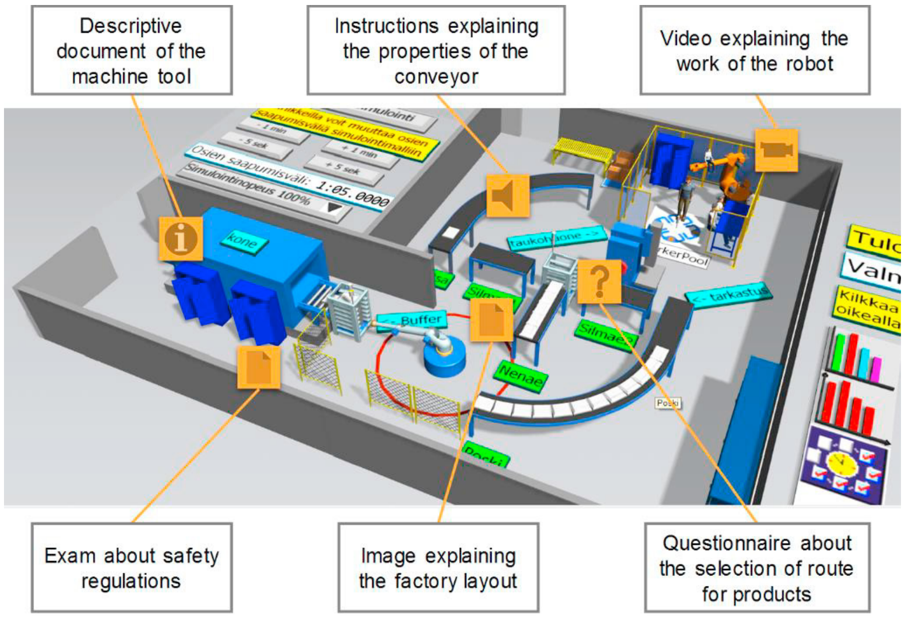


Fig. 2. Examples of additional exercises integrated into a simulation model.

All types of elements can have clickable hotspots to provide additional information. The hotspot is basically a link to another element that can be any type of element, even another simulation model. Figure 2 shows examples of interactive elements in a simulation environment. These have different combinations of elements making them interactive learning activities for the students. *The descriptive document of a machine tool* includes information about the machine tool relevant to the course topics. It can include textual descriptions with images to support the text. *The instructions explaining the properties of the conveyor* uses images and videos to support the textual explanation. *The video explaining the work of the robot* is interactive i.e. it can have additional elements such as textual information and questions. *The image explaining the factory layout* utilizes the hotspots to explain the characteristics of the layout. The exercise elements can include additional activities that the students will perform. *The exam about safety regulations* of a robotic cell includes needed information to complete an exam with the information available at the same time. *The questionnaire about the selection of a route for products* can be used like an exam. In this case, the work is not assessed but instead the teacher gains knowledge how the students interpret what is taught.

## 4. Utilizing the learning activities in course implementations

The learning activities will be used in different courses from a bachelor level introductory course of production engineering to advanced courses related production systems and simulation. In the following, the inclusions of the activities are discussed. The number of attending students varies from under 20 to over 100. Therefore, the actual implementation and how the learning activities are utilized will differ between the courses.

### *4.1. Description of a course including interactive exercises*

Figure 3 presents an example of the timeline and the structure of a course, based on [13], consisting of the steps *beginning and activation of prior knowledge*, *basic knowledge and directing interest*, *deepening knowledge through interaction* as well as *summing up and assessment*. The focus changes during the course execution between interaction and course content. At the beginning a course an orientation is held where the learning objectives, course structure and schedule as well as assessment criteria are explained. In this step, the practical information of the course schedule and learning topics are given to the students.

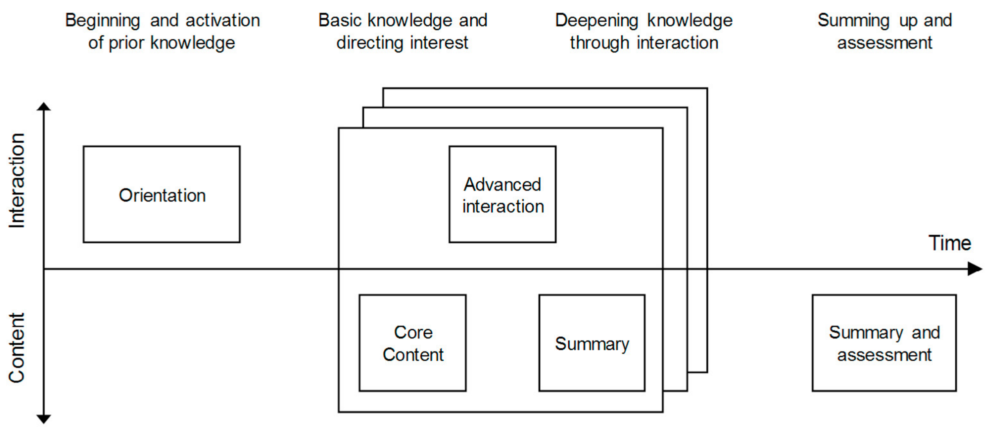


Fig. 3. Basic structure and timeline of a course.

All the exercises follow roughly the next two steps presented in Figure 3 i.e. the basic knowledge and directing interest as well as deepening knowledge through interaction. The exercises also follow the operational framework for teaching design consisting of intended learning outcomes, teaching and learning activities as well as assessment tasks [14]. First, the focus is in the core content of an exercise. Typically, this step includes the detailed instructions of the exercise are introduced and the students follow the instructions individually or in groups. It is important that in this step the intended learning outcomes are considered. This ensures that the students will explore correct and relevant topics. The teaching and learning activities are part of the core content. During the advanced interaction, the teaching and learning activities are continued. The roles of the teacher and students should be different in this step. For example, students present their findings to the teacher or both to the teacher and other students. After the interactive part of the exercises, the work will be summarized. This may include example solutions provided by the teacher. The students should return the reports of their finding based on the core content and advanced interaction. For good learning results, students can also perform self-reflection about what they have learned. For the assessment purposes of the exercises, the summary should include elements that can be evaluated. At the end of the course, the whole course content is summarized. The assessment can be done all in one at the end of the course. One can also choose to assess the exercises individually during the course.

### 4.2. Benefits of the interactive exercises

Exercises in virtual simulation environments do not have such limitations that exercises using physical premises. The exercises can be implemented more freely as they exist only in the virtual world. Existing exercises can be modified and new exercises implemented regardless of the physical world. The interactive elements can be used freely to suit the learning outcomes of the exercises. Exercises in the virtual environment are scalable i.e. multiple students can perform the exercise concurrently with their individual instances. The limitation of the concurrent instances can be limited if the exercises should be completed in certain classrooms or because of the number of the software licenses.

## 5. Future Work

Currently the exercises focus on teaching related to production systems. The courses have connections to the teaching of product development as well as sales and marketing in the form of lectures. These connections could be strengthened with exercises demonstrating the effect deriving from other functions of a company. This would give the students more understanding on where and why certain needs for change in production happen. Similarly, more detailed design issues in the areas of production automation and manufacturing technologies could be added. Changes in technologies could be investigated on how they effect on the factory level performance indicators.

## 6. Conclusions

Interactive learning activities for engineering education was discussed in the context of design and development of production systems. Current focus on the topics of the order-to-delivery process were explained as the theory related to the existing courses. The main point was the utilization of interactive elements in individual exercises as well as in course implementations. Examples of the interactive elements were explained and how the interaction could happen during the steps of a course. The future work of the learning activities was discussed to expand the exercises topics in the context of production systems as well as detailed design issues of production. Because the exercises happen in simulation environment, the possibilities for future development are basically limitless.

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