AN APPROACH ON CUSTOMIZED LECTURING BASED ON A DEPENDENCY MODEL

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ABSTRACT
This paper introduces an innovative teaching approach, which provides customized curricula for students without being too resource-demanding for lecturers. Students of several disciplines attend the lecture "Complexity Management for Industrial Application". In the past, a selection of methods has been extracted from the topic of complexity management and imparted to students. This selection represents a trade-off between the different interests and needs of students. While some of them are familiar with a specific method, the same method may overburden students from other disciplines. Some methods may even be irrelevant regarding the students' future scope of work. Thus, the static structure of the current lecture concept and the individual student characteristics are conflicting and limit the effectiveness of teaching.
We developed an approach for matching the subject matter to the specific needs of students by using "Structural Complexity Management". This methodology is designed for acquiring, analyzing, and optimizing the dependencies within complex systems. Our approach results in an arrangement of selected teaching units in lecture blocks, group tutorials and exercises led by tutors. At first, lessons, methods and competences and their mutual dependencies are modeled. Subsequently, students' interests and needs are linked to the model. Then we compute customized lists of lessons, which represent the individual educational objectives of students. Finally, superimposing and optimizing all customized lists result in the course arrangement.

Keywords: Structural complexity management, customized lecturing model, dependency models, innovative teaching approach, customized curricula

1 INITIAL SITUATION AND CHALLENGE

"Structural Complexity Management" is an interdisciplinary challenge. At the Technische Universität München (TUM) this is offered in a lecture to students of different educational backgrounds. The topic can be classified as a lecture on technical/methodical competences [1]. This definition is important, as "competencies only get meaning in a specific context […]" [2]. The lecture consists of 60 methods which build upon one another. At the moment the lecture is arranged as a static sequence of lecture blocks and supervised exercises for the sutdents.
Methods have been selected from the general topic for lecturing. This selection represents a trade-off between interests and needs of students. Whereas some students are familiar with a specific method, the same method may overburden students from other disciplines. Some methods are even irrelevant regarding the students' future challenges in industry. Thus, the static structure of the current lecture and the individual student characteristics are conflicting and limit the effectiveness of teaching.
So far, limited resources prevented a full customization of the lecture. The challenge is to develop an approach towards an efficient use of available teaching capacity while maximizing the degree of customization. In other words, the challenge is to realize lean customization of knowledge transfer.

2 OBJECTIVE

"A current movement in many engineering-related universities […] is seeing a necessary rethinking, reorganization, and relaunch of engineering curricula" [3]. Our contribution to this movement is the re-design of lectures by lean customizing students' curricula. "Lean" means to keep efforts affordable on a large scale, which is described as one of the challenges in competence-based education [4]. "Customization" means varying the content and sequence of teaching units due to individual needs in the student group. In order to reach the objective, the chronological sequence (network) of lessons has to be anticipated. The sequence expresses that LESSON A must be understood before LESSON B can be taught.

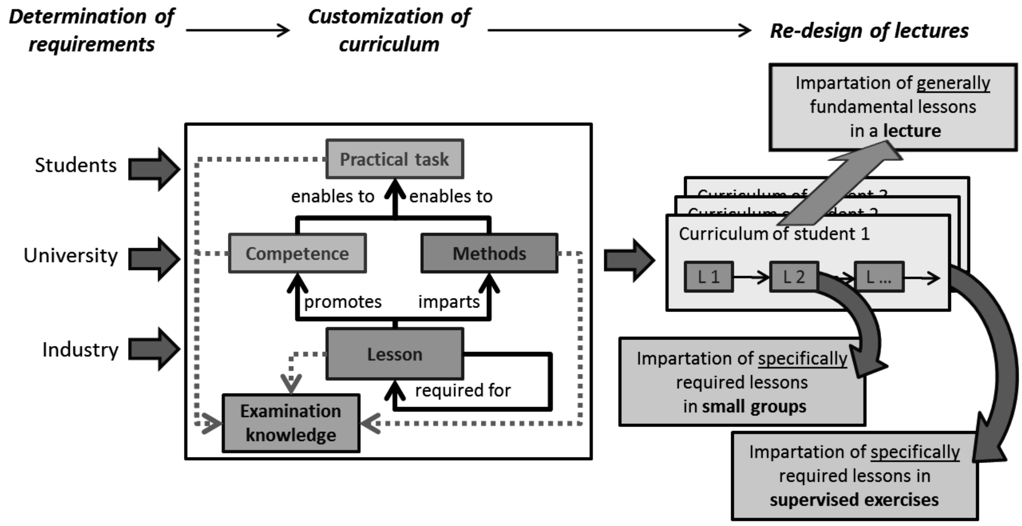

Figure 1. Concept of lecture re-design

Figure 1 illustrates the objective. Three stakeholders determine the requirements for the course: students, university and industry. The structure of the curriculum shows that lessons impart methods, lessons promote competences, and both together enable students to fulfill practical tasks. Our lecture re-design delivers customized curricula per student. Those curricula then get superimposed for deriving an optimized lecture concept. Small group exercises as well as spefically supervised exercises shall amend the lecture blocks for imparting knowledge due to the specific demands.

3 APPROACH

We developed an approach enabling lecturers to match the subject matter with the specific needs of students using the methodology of “Structural Complexity Management” [5]. We applied this to the lecture "Complexity Management for Industrial Application”. Figure 2 shows the main steps of our development as well as inputs and outputs.

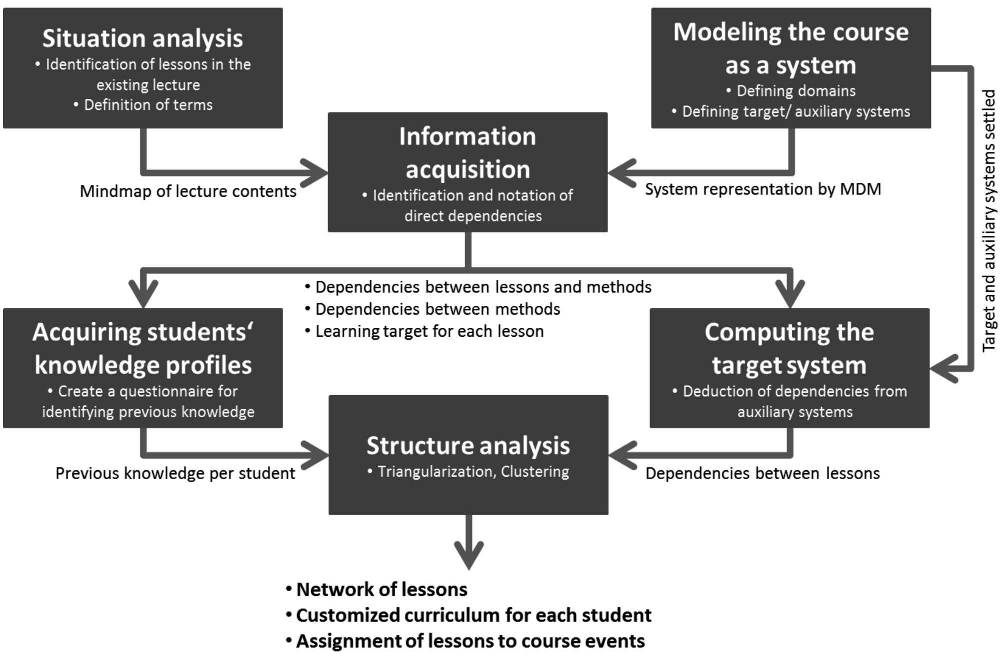

Figure 2. Approach based on “Structural Complexity Management”

We model the course by elements (classified in domains). Elements like methods, lessons and students’ foreknowledge represent the core of the system. These domains are linked by relations,

which allow answering questions like: Which competences can be gained by which lesson? The result is a description of lecture contents and resulting knowledge about methods.
Students' interests and needs are linked to the structure of lecture contents. This allows identifying the lessons required by every student based on prior knowledge. This step results in customized lists of lessons, which represent the set of students' educational objectives.
Finally, we superimpose all customized lists and deduce the course arrangement. If, for example, 80% of the students require one specific lesson, this will be taught in a (central) lecture. If only 20% of the students require another lesson, this will be imparted in a group tutorial. We can sequence the lessons based on their dependencies ("Which lesson is required as prior knowledge for another lesson?"). The approach helps determining the content and schedule of a lecture focused to the competences of all participating students.

3.1 Situation Analysis

In this step the lessons of the considered lecture are identified. A lesson is a contiguous amount of teaching material consisting of different modules such as introduction, theoretical part, practical part and repetition. In addition, a potential test is included at the end of a lesson. The order of lessons varies according to the lessons' objective. A verbalized learning target gets assigned to each lesson. This learning target helps deriving competences, which have to be acquired.

3.2 Modelling the course as a system

According to a general system definition [5] core elements and their interrelations have to be identified (see also Figure 1). A system boundary needs to be drawn to distinguish between inner-system elements and surrounding elements. Information can be noted in a system graph, which is easy to create. We classify system elements into three sections: input, output and main system. However, as system graphs can become rather complex with increasing numbers of elements and interrelations, we implemented information into a Multiple-Domain Matrix (MDM) [5]. Using the MDM method, the user is supported in reviewing all system relations, as the scheme of a matrix can be systematically processed (in contrast to a system graph). An exemplary MDM can be seen in Figure 4.

3.3 Information acquisition

The following three direct dependencies have to be acquired in Design Structure-Matrices (DSM) and Domain Mapping Matrices (DMM) for restructuring the current sequence of the lecture (aggregated in a MDM in Figure 3). The upper right field represents the DMM "Lesson imparts method". In the lower left field the DMM "Lesson applies method" is implemented. The DSM "Method requires method" (lower right corner) gets computed using the DMMs for deduction of indirect dependencies [5], as it will be described in section 3.5.

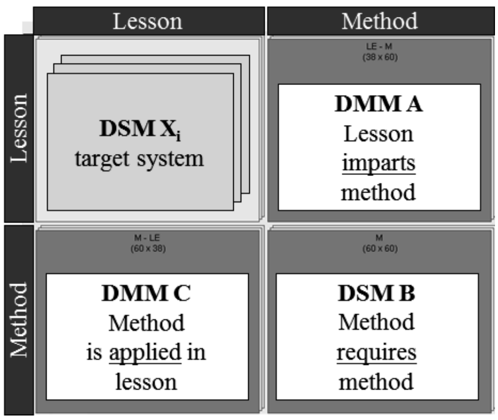

Figure 3. Multiple-Domain Matrix for systematic description of system dependencies

Direct dependencies between system elements are collected by implementing a 1 to the associated matrix cell. For example, if a method is introduced for the first time, it gets noted by a 1 linking the method and the lesson in DMM A (upper right DMM in Figure 3). In the DMM "Method is applied in lesson" a 1 means that students should know the method, as it's e.g. required for application to a specific problem. In the DSM "Method requires method" a 1 specifies that the method is required for introducing another method. For example, knowledge about graphs with elements, nodes and relations is required for introducing the clustering method.

3.4 Acquisition of students knowledge profiles

A questionnaire was developed for asking students about their knowledge concerning the methods of the lecture in question. Analysis of the questionnaire results in the relevant students' knowledge profiles. Students have been supposed to classify their level of skill per method into three categories, representing the abilities to quote, explain or even apply a method or approach.

Based on the analysis of the questionnaire we can deduce which lessons need to be imparted in which way in the final lecture concept. For example, if 16 out of 20 students possess the same level of prior knowledge as basis for one method, the associated lesson can be imparted in frontal lecture format. If, however, 4 students out of 20 can quote a method, while all other students are already able to apply it, imparting the required knowledge for these four students should take place in a supervised exercise. Thus, students obtain the chance to catch up with their fellow students and subsequent lessons can be imparted to the entire group.

3.5 Deduction of indirect dependencies

Indirect dependencies need to be deduced (from previously acquired direct ones) in order to derive the sequence of lessons. LESSON A can be required for LESSON B in two ways: Firstly, LESSON A might introduce methods that are applied in LESSON B. Secondly, LESSON A might introduce methods which are required to introduce a new method in LESSON B. A matrix (DSM) containing this information can be obtained by superposing two matrices (DSMs), which have to be deduced from the acquired direct dependencies.

The first DSM is obtained by mulitiplying the DMM "Lesson imparts method" (DMM A) with the DSM "Method requires method" (DSM B) and with the DMM "Method is applied in lesson" (DMM C) (abbreviations refer to Figure 3). The equation is:

$$DMM\ A\ x\ DSM\ B\ x\ DMM\ C = DSM\ X_1. \qquad (1)$$

Information in DSM X_1 can be interpreted as: "LESSON A introduces methods that are presumed to impart methods from LESSON B, while LESSON B is based on LESSON A." (I)

The second DSM is obtained by multiplying the DMM "Lesson imparts method" (DMM A) with the DMM "Method is applied in lesson" (DMM C). The equation is:

$$DMM\ A\ x\ DMM\ C = DSM\ X_2. \qquad (2)$$

Information in DSM X_2 can be interpreted as: "LESSON A introduces methods which are applied in LESSON B, while LESSON B is based on LESSON A." (II)

Information gained by the superimposition of DSM X_1 and DSM X_2 can be interpreted as: "LESSON A introduces methods, some of which are the basis for introducing or applying other methods, which are imparted in LESSON B. (III)

3.6 Structure analysis

The superimposed DSM gets rearranged by Triangularization [5]. Triangularization means to generate a sequence of elements, which allows processing the elements without (or only with minor) iteration. Thus, the result of a Triangularization is similar to an executable Gantt chart. Furthermore, Banding [5] was applied to the superimposed matrix in order to obtain the desired sequence of lessons. Banding means that lessons included in the same band are independent from each other and they can be imparted in arbitrary sequence. The result of the structure analysis is an improved sequence for imparting all lessons of the course. This sequence represents the basis for customization; even if a student does not require all lessons, the sequence of the remaining ones is still valid.

4 USE CASE

We applied the basic approach (Chapter 3) to the content of the existing lecture "Complexity management for industrial application". The status of results will be presented in the following sections.

4.1 System definition and modelling

Figure 4 provides an overview of the system structure in MDM notation. The domains “Lessons” and “Methods” represent the core of the system and therefore are highlighted. But it should be mentioned that further domains have been acquired for describing the system in greater detail.

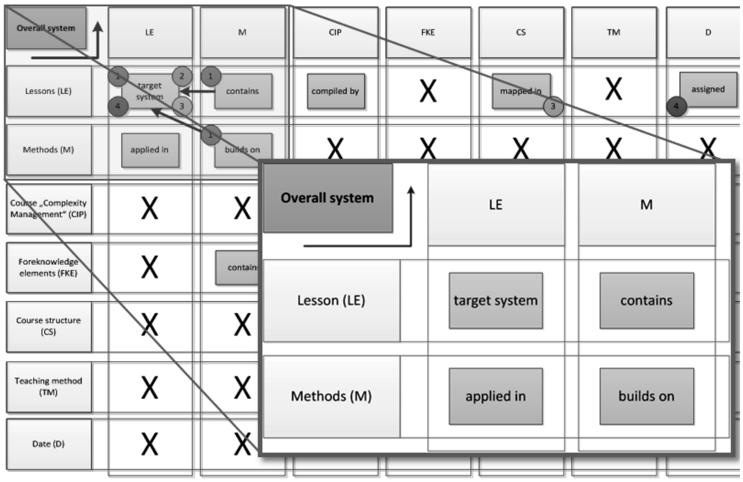

Figure 4. Overall system in MDM notation and system core

4.2 Information acquisition

The existing documentation of the lecture was subdivided into lessons, which possess a learning objective. An example for a learning objective is: “*The students know about the importance of quality in data-acquisition in order to assure the significance of the results*.” (learning objective of lesson 47). Each lesson represents an element of the domain “Lesson”. As well, all methods of the lecture were catalogued and represent the elements of the domain “Methods”.

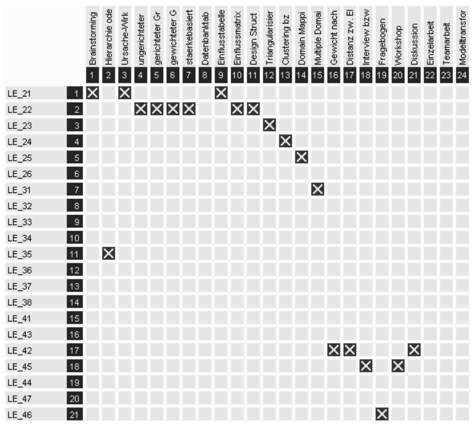

Figure 5. DMM “Lesson imparts method”

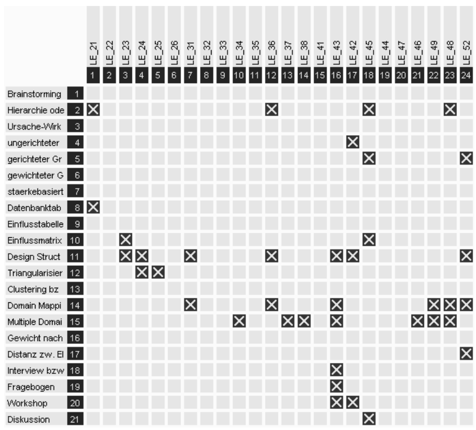

Figure 6. DMM “Lesson applies method”

Figure 5 and Figure 6 show matrices, which contain result of the data acquisition. A cross represents a dependency between the two elements, in the sense of the relation described below the figures. The DMM in Figure 5 indicates in which lesson a method is introduced, whereas the marks in Figure 6 describe in which lesson a method is applied. In addition, a DSM was acquired, which indicates which methods students need to know before other methods can be introduced (figure not shown).

4.3 Deduction of dependencies and structure analysis

Dependencies between lessons have been computed and analyzed according to the description in Chapter 3. The result of matrix multiplication and matrix superimposing (section 3.5) is shown in Figure 7. Figure 8 shows the matrix after applying the methods Triangularization and Banding (section 3.6) for reordering the matrix alignment.

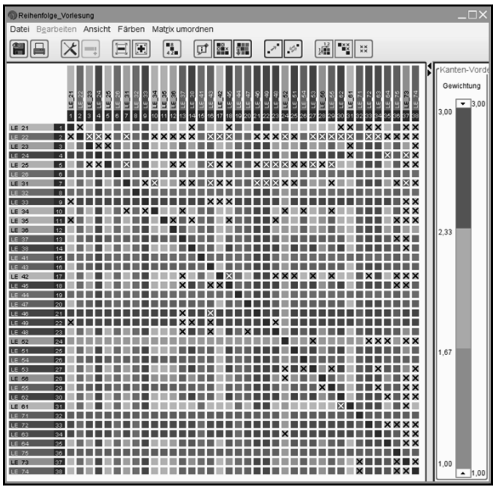

Figure 7. Indirect dependencies between lessons

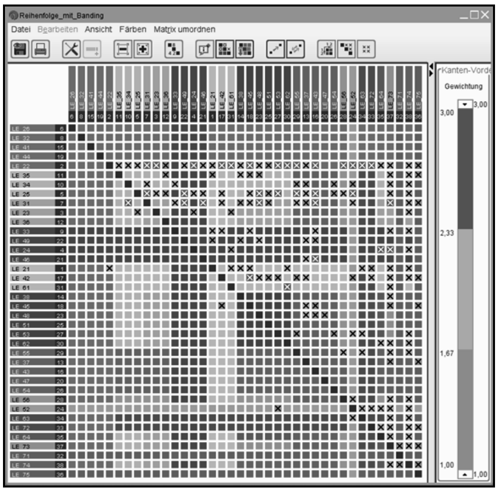

Figure 8. Indirect dependencies between lessons after sorting the matrix

According to the indication in section 3.5, the background colors of the matrix entries in Figure 7 and Figure 8 describe the matrix-multiplication they result from: (I) yellow, (II) green, (III) red. But the matrix only provides an overview over all dependencies. Valuable insight can be obtained, if the column (predecessors) and row (successors) of a specific lesson are investigated in detail.

4.4 Customized curriculum

We evaluated the acquired knowledge profiles and compared this student specific level of skill per method with a presumed level of skill, specified in advance. All gaps were summed up and we created a unique number of required methods per student. Figure 9 shows an extract of who must acquire a certain lesson. The number per lesson indicates how many methods have to be taught. The rows of the table represent the customized curriculum per student; a lesson must be imparted if the corresponding number is larger than 0.

Students	Lessons												QTY of req. Methods
Surname, prename	21	22	23	24	25	31	33		64	72	73	74	
Müller, Petra	2	2	3	2	2	2	1	...	1	5	6	3	48
Schmidt, Hans	0	0	1	1	0	1	1		1	5	3	2	25
Schneider, Inge	0	0	2	2	2	1	0		1	4	4	2	26

Figure 9. Customized curriculum; non-zero numbers indicate a need for imparting lessons

5 CONCLUSION AND FUTURE WORK

Concerning the presented approach the following tasks have to be mastered in the future: Firstly, an automated evaluation of the knowledge profiles needs to be developed to efficiently cope with a high number of students. Secondly, the customization approach could be used for enhancing the course e.g. with advanced methods, approaches or special background information, if the majority of students are aware of certain methods. Thirdly, a standard set of lessons should be identified in the future, which represents the basic curriculum for students depending on their chosen master program.

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