Theory and Practice in Multi-Discipline Representations for Engineering Education

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Abstract—As a continuous development of former results in teaching of engineering using advanced computer systems, this paper is an attempt to contribute to education of engineers by an analysis and discussion of multi-discipline representation of theory and practice. A new method is introduced, explained and discussed to integrate a formerly published course modeling and a course model evaluation method with the product modeling. The purpose of this integration is the communication of demand for examples supporting given course content and on the other hand, demand for course content needed by the definition of given product objects in the product model. Integration is realized through a new element called as issue distributor. Product modeling which is applied at recent advanced product lifecycle management is considered.

I. INTRODUCTION

By the increasing of application of embedded elements in products from different areas of engineering, engineers apply multi-discipline knowledge to design, analyze, manufacture and test their products [1]. The authors of [1] state that strong academic formation still is essential for engineers, but problems are caused by preferring theory to practice. They emphasize that time expended to mathematical, physical, chemical and other basis more than the expended at laboratory experience.

Work of engineers is quickly moving into product modeling environments of product lifecycle management (PLM) systems. The authors of [9] state that intelligence is essential in the product development practice when engineer applies virtual engineering space for this activity. A main trend in product modeling is application of results of intelligent computing at product definition. Consequently, theory and practice are applied in an integrated engineering process. This need practice oriented teaching and learning of theory.

Practice in the new situation of product modeling in virtual engineering spaces needs expertise which is strongly grounded by appropriate theory. In [2], development of expertise in humans and engineering education are connected analysis of and are applied for finding instructional practices and examples of learning experiences.

The authors of [11] stated that education should cope with changing industrial environment among others because more and more knowledge was included in the product model. They introduced concept for the integration of course program and engineering system and defined expected characteristics for course model to cope with the new challenges. Structure and elements of course model was analyzed considering the product model.

This paper shows a method for handling of multi-discipline together with controlled ratio of theory and practice in higher education programs Model of multi-discipline teaching and learning of product modeling is outlined. Following this, a method is proposed in which a former course model and its practical evaluation are re-evaluated and applied for a scenario in which course modeling, its practice motivated evaluation, and product model are connected by the issue distributor. Analysis helps work of issue distributor for objects under definition for product model.

II. RELATED RESEARCH, OBJECTIVES, AND METHOD

The first question in the research which is reported in this paper was that what areas of knowledge are to be included in an education for engineers who work in virtual engineering space. Term virtual engineering space was defined and explained in [12] in order to gain a full integrated concept of a consistent product representation. This is a good environment for the education of engineers in order to a proper equilibrium of theory and practice in course programs.

In order to handle the problem by multi-discipline representations in engineering education for product development in virtual engineering space, a method was developed and introduced in this paper. This method is relied upon the model which is outlined in Fig. 1. The model works both from top to bottom and bottom to top. The first is the case of assignment control; the bottom is the case of product representation control. In the first case, product representations are found in accordance with given curriculum. In the second case, curriculum is driven by theoretical and methodological content of the product representation and the definition processes for its creation. The second case is introduced in [12] for the research program at a research-education laboratory. In this program, representative PLM system is analyzed and competencies are found in order to definition of university courses and research issues. In this way, course and research programs can be tailored to recent industrial engineering technology. This technology integrates theory, methodology, and practice in a single industrial related problem solving.

In Fig. 1, assignment for/from courses is in connection with the relevant course issues. In case of product representation driven course design, an analysis of object under definition for product model provides issues for topics of lectures and laboratory tasks by using to the so called issue distributor. In the reverse direction, task of the issue distributor is to collect issues and pass them to analysis of object under definition for product model which can work in the reverse direction too.
In order to handle more or less areas of knowledge, the authors of [1] introduced the so called engineering educational cockpit as a means of visualization of heterogeneous teaching environments. By using of this cockpit, measurement results are collected and visualized from learning management, engineering laboratory experience, group work, student projects and assessments.

III. NEW PRACTICE ASPECTS OF COURSE MODEL

In this part of the paper, a method is highlighted for the connection of theory and practice in product modeling based higher education. For this purpose, the former practice oriented evaluation in [10] of the course model concept in [8] was re-evaluated (Fig. 2). Theory and practice is handled by the same methodology in course model and its evaluation. However, they are separated in the course model because a locally approved teaching program requires this. The new contribution is integration through issue distributor and analysis of object under definition for product model. The main structure of the proposed method in Fig. 2 shows that two modeling communicate, namely the product modeling in the virtual engineering space and the classroom modeling. One of the two tasks emerged here is to extract information from an existing course model for the product model to make examples in order to explain theory and methodology on an industrially motivated example. The other task emerges in the reverse direction. Information is extracted for the demand for theory and methodology as a base of teaching topics in the course model.

The course model creation starts with the definition of the modeled objects. Objects in the teaching processes are defined such as curriculum, teaching procedures, virtual laboratories, etc. according to local needs. In a feature defined scenario, application oriented objects are applied similarly to product modeling. Procedures define collaborative functions for the participants of teaching and learning, and classroom features. Features are classified such as it was introduced in [10]. At the same time, course data sets are generated in close connection with classroom features.

The practice oriented evaluation of classroom model assures its application orientation. Sets of classroom feature definitions are extracted from course model. By using this information, generic and instance courses as well as course definition for student request are generated. This procedure works also in the reverse direction in order to produce course model entities. It is assisted by course selection, student request definition, and definition of course profiles for students or groups of students.

Figure 1. Model of multi-discipline teaching and learning of product modeling

Figure 2. Re-evaluation of practice aspect of a course model
Course models and practice oriented evaluations are connected with product model by using of issue distributor and analysis of object under definition for product model. These are planned to develop into two way working intelligent interfaces in order to theory and practice content based connection.

Few more words should be devoted for student profile based selection of course using generic and instance course. Generic course model similarly to generic product model is the medium for flexible course definition. In case of course model, generic representations contain constraints. Constraints are applied among others to include mandatory elements from conditions of accreditation and decisions at institutions.

IV. ISSUES IN THEORY AND PRACTICE IN MULTI-DISCIPLINE

Multidiscipline teaching and learning scenario in engineering is based on content level connection between course and product modeling through the issue distributor. Issue distributor is assisted by analysis of object under definition for product model. These two connecting elements (Fig. 3) are characterized by two way work.

In the proposed teaching and learning method, the role of a suitable laboratory with virtual system of task oriented functionality is inevitable. Paper [3] is about a software tool to assist the laboratory resource management tasks. Preparation activities for laboratory sessions in automation discipline are automated. The aim was to reduce the configuration and to make teaching personnel more autonomous.

Importance of the remote operated laboratory experiments and the visualization systems for monitoring and operating is emphasized in [5]. In order to solve known problems in establishing software for this purpose, an XML–based Graphical User Interface Language is proposed in order to flexible automation of software development and to utilize the available models. A distance laboratory with clearly defined learning outcomes verification is introduced in the topic of motion control system in [7].

Other important issue in the proposed method is flexible reconfiguration of teaching programs. Authors of [4] propose reconfigurable educational platform in order to fast reconfiguration of teaching matter topologies. Improved hands-on training gives strong theoretical concepts while practical elements such as measurements are involved.

Additional actual issue that gains possibilities to handle is environment for student demand. Paper [6] introduces the Enhanced Individualized Learning Environment (EILE) in order to utilize benefits from e-learning and virtual reality methodologies. Performance of students from different higher education institutions are compared for progress, motivation, attitudes, and satisfaction at the application of the proposed environment.

In the method of this paper, an issue distributor receives and produces topics of lectures and laboratory tasks. When receives, it synthesizes theory and practice related elements of a topic and makes topic content analysis. When produces, the tasks are topic separation into theory and practice related elements and definition of topic content. Consequently, issue distributor receives results for product model definition and produces results from teaching topic definition. Ratio of theory and practice content can be controlled according to the type and level of education program. Analysis of object under definition for product model is a two direction sequence of activities. Product model object and contexts are created or received. Object analysis utilizes or produces course model information in the product model. Roles of context content analysis, method analysis, and human activity analysis are similar.

![Figure 3. Issue distributor and analysis of object under definition for product model](image)

A solving tool such as the above method must be realized in the future higher education program implementations because virtual space based engineering practice can not cooperate with conventional teaching and learning systems. Beyond the problems in information
exchange and its media, virtual spaces apply strong
information technology and mathematical background that
requires new thinking in both higher education and
industry. At the same time, main value of education comes
from experience and personal capabilities of lecturers and
laboratory personnel that must be considered.

V. KNOWLEDGE AS INTEGRATING CONTENT CARRIER

An old recognition by integrated product and course
model motivated researchers is that the real integrating
factor is the common knowledge content [8]. In order to
show this connection for industrial problem solving, a
typical solution chain and the knowledge extraction are
illustrated in Fig. 4. Product development tasks are
initiated at the project level of the product development.
Group work methodologies are applied. Problem solving
tasks are handled by product modeling by using of
methods and tools for the realization of solution chain. A
possible chain is shown in Fig 4. It starts with a hypothesis
on the problem then a theory is selected or made. The next
step is to define questions what, why, and how. Definition
of function, knowledge, objects must answer these
questions in the solution chain.

![Diagram of Solution Chain and Knowledge](image)

In the current knowledge intensive product modeling,
high level, comprehensive knowledge is defined in
product model. An advantage of the knowledge which is
utilized at product development is that it is both theory
and practice oriented. Solution chain elements produce
widely applicable knowledge. A theory and practice
related element is extracted for the curriculum and stored
in the model for related course objects and knowledge
background in course model. This extraction is available
both from solution chain and from model for related
product objects and knowledge background in product
model. Direct knowledge extraction from solution chain
produces content which is placed neither in product model
nor in knowledge ware of PLM system.

VI. CONCLUSIONS AND FUTURE RESEARCH

While recent products inherently require engineering to
be organized in a multi-discipline environment, education
of engineers must be fitted to this trend. Behind multi-
disciplinary, the other important recent issue is trend for
integration of theory and practice in product modeling.
Because modeling widespread for definition and analysis
purposes in almost all fields of human activities, education
for engineers must consider modeling and analysis type
solution at the handling of curriculum related tasks. In this
paper this situation is analyzed, main issues are discussed,
and a method is provided.

After a lookout to related opinions and results by other
experts, a former course modeling method and the
formerly applied practical evaluation of this modeling is
re-evaluated and utilized to make connection towards
product modeling. Two way connections are aimed. To
achieve this, an issue distributor is applied together with
an analysis for its connection to the product modeling.
Issue distributor synthesizes theory and practice related
elements of a topic and makes topic content analysis. At
the same time, it also produces topic separation into theory
and practice related elements together with definition of
topic content. It receives and produces results in
connection with product model and teaching topic
definitions.

Integration of two strongly knowledge based modeling
and analysis methodologies would join to the general
integration of systems. Knowledge representations in both
of the methodologies can be applied as carrier of
knowledge between the two modeling. A model base
solution would support advanced functions such as student
specific profile based definition and control of the theory-
practice ratio in teaching program.

Future research is planned to conceptualize and define
functions, functional elements, and information exchange
entities for the connection of course and product
modeling.

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