Model Mediated University Course in Engineering

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Abstract: Great changes of ideas, methods and systems place new challenges for researchers, practitioners, and educators in engineering in these days. The most affecting change is for lifecycle engineering of cooperating systems operated multidisciplinary products. Product information is represented and handled in dedicated engineering system using complex model in which objects are glued by consistent system of contextual connections. Crossing disciplinary borders even at a single contextual connection is unavoidable. Groups of engineers develop and apply these models accessing modeling and other capabilities in accordance with area of industry, disciplines, and human role. Appropriately configured and cloud-based modeling assures integration of theory and practice in knowledge driven model system. The reported work is based on analysis of the above situation at the Laboratory of Intelligent Engineering Systems. Formerly published results were applied at this recent research to integrate engineering course in the above characterized industrial engineering system using appropriately configured model. This paper outlines recent advanced features of engineering modeling systems which support their application for the above purpose. This is followed by novel concept of model mediated engineering course, methodology for university course specific engineering model configuration, and possibility to realize course specific models in advanced industrial modeling system environments. The objective of work is teaching and learning method which can be applied at real industrial engineering modeling system in integration with research and industrial engineering activities.

1 INTRODUCTION

Quick development of informatics, intelligent computing, and computer technology is great challenge for educators both at teaching advancements and utilizing achievements in course program. Working with contextual object representation and system related theories, methodologies and practice is great challenge for researchers, practitioners and educators in engineering modeling. Cooperating systems operate engineering structure (ES) such as industrial product, experimental arrangement, and concept object. System based engineering modeling required higher level abstraction than it was usual in classical physical level of engineering modeling. While physical level modeling defines and connects physical components such as parts and assemblies, system level modeling requires defining and connect functional and logical level components of ES. Arbitrarily complex model of ES is capable of self-modification when any external and internal context changes.

Practice awaits results to support connection of higher education, research, and industrial processes within a single purposeful engineering model. New media is to be introduced for this purpose in the form of advanced engineering model. Although this paper provides results for application at education of engineering, similar modeling can also be utilized at other teaching areas such as archeology, anthropology, etc.

The reported results were achieved at the Laboratory of Intelligent Engineering Systems where appropriate engineering modeling environment is available. Work in this paper was mainly based on formerly published own results in organized driving chains for industrial product model (Horváth, 2017), intellectual property representation in multidisciplinary industrial

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engineering model system (Horváth, 2016), product behavior definition for requirements, functional, logical, and physical (RFLP) structured engineering model (Horváth, Rudas, 2015), and intellectual resource driven virtual engineering environment for higher education (Horváth, Rudas, 2016). Main resources from other authors were in context-sensitive synthesis of cyber-physical system model (Canedo et. al.), model-based engineering using systems engineering (SE) (Kleiner, Kramer, 2013), connection of engineering education research with learning sciences (Johri, Olds, 2011), and development of expertise at engineering education (Litzinger, et al, 2011).

The main objective of the reported work was to integrate engineering course in appropriate industrial engineering system using appropriately configured model. This paper emphasizes the relevant new features of engineering modeling systems preparing introduction of novel concept for model mediated engineering course. Rest of paper discusses methodology for university course specific engineering model configuration and possibility to realize course specific engineering model in advanced industrial modeling system. The proposed solution is considered as milestone towards deep information content based smart E-learning.

2 ENGINEERING MODEL AND UNIVERSITY COURSE

Engineering model is about characterization, connection, and behavior of engineering objects (EOs). Recently, EOs are not only tangible features, components, and units but also algorithms, mathematical procedures and functions, physical phenomena, analysis procedures, simulations, engineering calculations, experience and expertise representations, etc. (For more details see Figure 7). Real time analyses and simulations evaluate attempts to contribute models and prevent inappropriate model objects. Content of an engineering course can be included in appropriately composed deep knowledge based active model to replace passive course materials.

Current leading virtual engineering is result of long development process for the past four decades. Main stages of this process are summarized in Figure 1. Development computer procedure assistance of analysis, explanation, and interpretation of documented information gradually took the evaluation of documents from human. Next stage of development was introduction of model which described EOs. Annotations were still required to explain content for application. Integrated information model was milestone towards structured computer representation of EOs. Capability was restricted to mechanical, electrical, electronic, computer or software engineering. Development of object model was done towards more integration and active knowledge driven adaptive operation (Brière-Côté, A., Rivest, L., Desrochers, A., 2010). Beyond appropriate knowledge items, adaptive operation of model required consistent context structure. This allowed propagation of modifications along chains of contextually connected EOs.

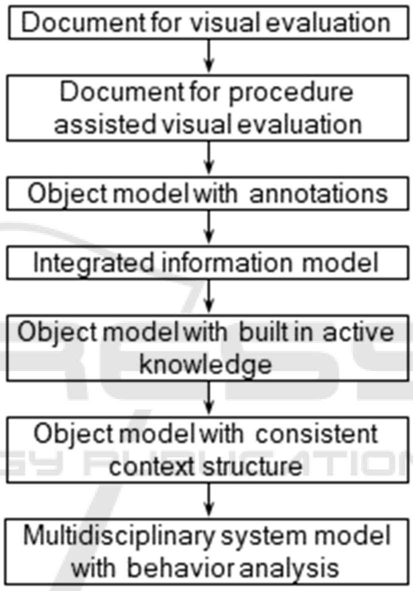

Figure 1: Main stages of engineering model development.

Several published works below strengthen real need for education program development towards virtual engineering. Paper (Johri, Olds, 2011) includes statement that engineering education research needs more support from learning sciences in theoretical and empirical work on engineering learning. Widening contexts in modeling for engineering assists development in this direction. New product lifecycle management (PLM) course concept is shown in (Eigner, M., Langlotz, M., Reinhardt, P., 2009). This work was supported by model of product engineering project. Real processes were considered in industrial context. Students cooperated using process-based case studies. Paper (Wolf, T., 2010) reports a work to assess amount of learning observed in lectures and laboratories. A graduate course on computer networks was investigated. It was concluded that amount of learning during lectures and laboratories was almost the same.

Human controls modeling procedures to generate model of contextual EOs. In this way, human contribution to model is indirect and depends on capabilities provided by modeling procedures (Figure 2). At the same time, model object generation is also affected by outside contexts. These contexts represent higher level decisions, law, standards, knowledge carriers, etc. Engineers who work on the same model complex can access modeling capabilities and model objects in group work depending on area of activity, disciplines involved, and personal role. Engineers use cross-discipline environment (Beier, G., et. al., 2013). Outside contexts are connected using information communication management capabilities. Simulation of object behaviors is provided to prevent definition of inappropriate EOs. Finally, integrated storing, simulation, and evaluation of closely connected models exclude accommodation of model which is not appropriate for cooperation with the related models.

Concept of disciple specific information unit of engineering course (Figure 3) assisted development of course representation in engineering model. Each discipline is contextual with given set of modeling capabilities. Topic must be contextual with well-defined set of EOs. Choice of EOs can be extended by user definition available in modeling systems. EO behaves as feature. Feature modifies relevant features using dedicated contextual connections of parameters in the model.

Representation of information about principles and methods is one of main challenges in definition course as ES model. Efficient teaching and learning processes are highly based on good examples. Example can be easily generated as instance of generic model. Assessment is created by purposeful contexts utilizing real time checks, analyses, and simulations. Real time response of model is novel capability and shifts assessment into a higher level.

3 MODEL MEDIATED ENGINEERING COURSE

Author of this paper think that current modeling systems are in possession of capabilities to represent all things which are needed to replace conventional courses for model-based ones. Model mediated engineering course is based on course configured engineering model (CCEM). CCEM consists of course specific purposeful contextual object model and representation of course process (Figure 4). Lecturer, student, and research, industrial, legal or other partner communicates with modeling environment through course specific access control. Clarification of partner's role is very important. Human interactions are opposed to living responses of active engineering model.

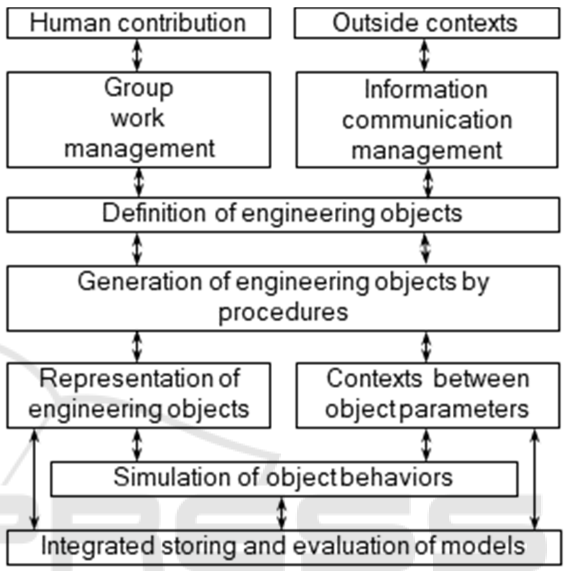

Figure 2: Outlie of engineering model and its creation.

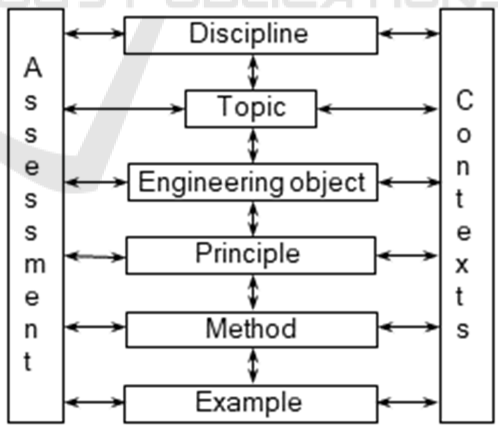

Figure 3: Information unit in engineering course.

Although active knowledge is represented in the CCEM, human knowledge that does not contradict represented active threshold knowledge is still very important. Threshold knowledge is not allowed to change during normal course processes. It can be modified only by persons with special role. This requires correct preparation from the side of lecturer and correct definition from the side of student. At the same time, change of knowledge within the allowable range is important to make what-if tests during lecture and laboratory classes. Whereas passive media cannot react, active model guarantees quality of education.

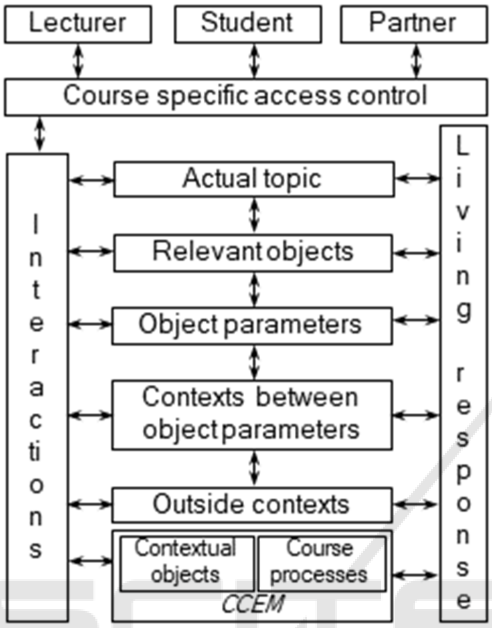

Figure 4: Engineering course in virtual environment.

During course program for lecture, seminar, or laboratory participants communicate with model to explain its content, define object in the context of existing ones, and carry out tests, analyses, and simulations to experience the behavior of modeled engineering objects. Course activities in engineering model environment are done under control of predefined course process (Figure 5). This can be modified or omitted by lecturer in accordance with the local measures for teaching and learning processes.

The most important affairs between model and participants are summarized and related in Figure 5. Suppose that an actual concept is explained at a given stage of course process. Concept is related to one or more objects in engineering model. Engineering model is object model. Object consists of its class, place in taxonomy, parameters, contextual connection between parameters, and procedures to handle parameters. Object orientation is one of the cornerstones of information technology.

According to experience at the Laboratory of Intelligent Engineering Systems, object orientation of engineering model can be well utilized at teaching. In this way, object parameters and their contextual connections are revealed and explained. Active model facilitates built in and user defined tests, analyses, and simulations using appropriately configured objects, parameters, and contexts.

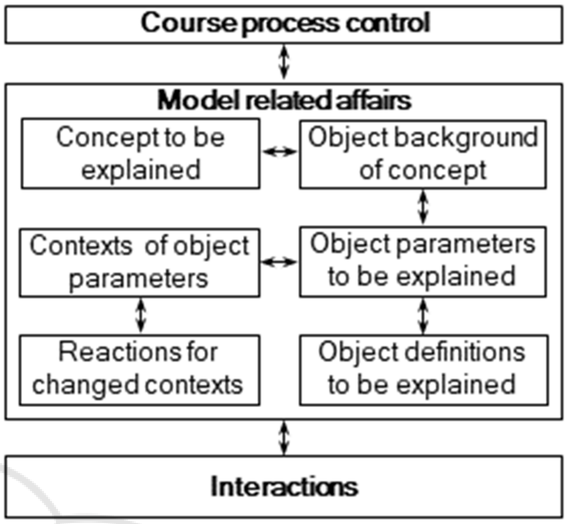

Figure 5: Engineering model at course.

Capabilities can be applied at generation of arbitrary defined ES with the restriction by existing active knowledge and role-based access. Model must have consistent context structure. Trivial and other effective contexts are enforced by modeling procedures including contexts of selected capability, engineering object, and interacting human.

Among wide range of capabilities for description and representation engineering objects, their parameters, and contextual connections shape related modeling capabilities are shown in Figure 6. Mathematical representation of arbitrary shape can be composed using engineer understandable features. On this physical level of model definition shape feature is contextual with geometry, topology, and attributes. Shape feature behavior means for example that the shape is either on mechanical or on electrical component of ES. Features build shape of ES component. Inter shape features define relative placing and movements of ES components. Behaviors of EC components and their groups can be analyzed in case of certain mechanical, heat, magnetic or other loads using numerical mathematics. Knowledge features are applied using driving contextual connections with target object parameters.

On functional and logical levels of ES model functional and logical components are connected by ports into structures. These models are virtually executable when behavior representations are available in components.

System based product development forced industrial companies to apply engineering system which included modeling capabilities for research including scientific configurations, contexts, analyses, experiments, simulations, and procedures. Research specific functions are available such as design of experiments, definition of optimizing and other algorithms, and methods from computation intelligence. Engineering model allows placing research results in wide context for evaluation and verification. Research capabilities highly increase relevance of engineering modeling systems to doctoral research for PhD degree. Laboratory of Intelligent Engineering Systems prepares engineering modeling environment for research jointly with the Doctoral School of Applied Informatics and Applied Mathematics at the Óbuda University.

4 UNIVERSITY COURSE SPECIFIC ENGINEERING MODEL

CCEM is an engineering model which is active at course related activities during lectures, seminars, laboratories, classroom tests, and individual work. Course specific engineering model defines and organizes objects according to content of course program. This supposes that objects in subject material of engineering education can be included in engineering object (EO) representations.

Figure 7 is an attempt to summarize EO categories which are well proven in advanced engineering modeling systems and can be applied at course specific modeling. EOs are included in model of ES for ES components, for knowledge applied at definition and modification of components, and for tools which are used regarding the above two groups. Figure 7 tells us that conventional teaching content includes elements which can be processed into EOs in engineering model. Grouping engineering objects in Figure 7 serves only analysis of engineering model for the application at university course. Well proven modeling methodology is available to include any EO on Figure 7 in engineering model where it is active through its contextual connections.

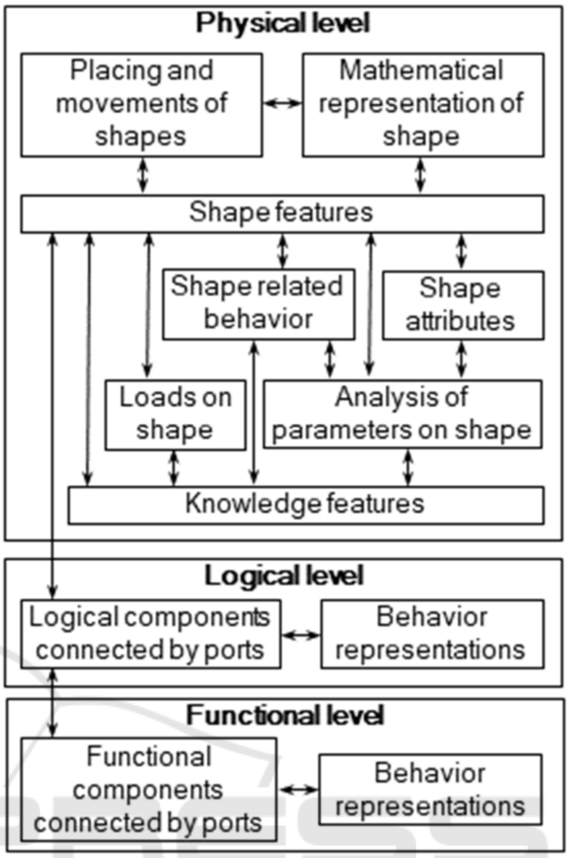

Figure 6: Shape related modeling capabilities.

Representation of ES component part consists of geometry for curves and surfaces, topology for structure of geometry in boundary, and form features for definition of shape boundary using series of engineer understandable modifications. The result is solid body representation which has contexts from curves and surfaces. Engineering connection connects solid bodies using definitions of placing constraints, degrees of freedom, and connecting means. Material engineering object may be very complex including formulas and other means to calculate properties at different conditions. Physical parts and their connected units are visible. When ES definition starts on the level of systems and multidisciplinary modeling is required, port connected functional components drive port connected logical components. At the same time, definition of physical level components needs contexts from the logical level components. Functional and logical components are in ES wide structures.

The second group of EOs (Figure 7) is knowledge. Significance of knowledge in engineering model was increased during the past decade because reusable knowledge representations drive generation of model objects at frequent modifications of EOs and contexts during lifecycle of ES. In this scenario, principles are recognized behind relationships and phenomena, methods for definition engineering objects, and behaviors of modeled EO components and structures, and experience and expertise serve as knowledge contexts of relevant EOs.

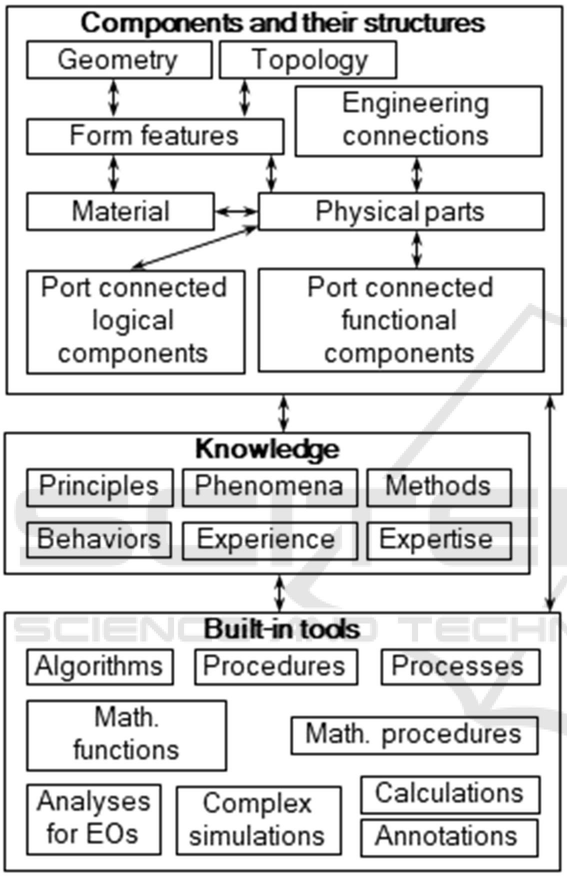

Figure 7: Engineering objects.

The third group of EOs (Figure 7) includes tools which are applied at handling the other two groups. Tools are algorithms for optimizing and other purposes, object parameter related procedures, modeling and other processes, numerical and other mathematical functions and procedures, dedicated analyses for various EO parameters, structures of contextual simulations, and engineering calculations. Significance of mathematics was increased with need for more sophisticated ES models. Paper (Machado, J. A. T., et. al., 2016) introduces method to include approximate-analytical mathematical method in engineering solutions. Annotations communicate passive information between participants. They contain document entities in engineering model and are attached to any EO representation.

Figure 8 illustrates objects and their contextual connections in the proposed model. Suppose that we analyze objects O_1 and O_2. Each has three parameters. Contextual connection C2 is defined between parameters of O_1 and O_2, while C1 and C3 are defined between parameters of O_1 and O_2 and other objects. Proper operation of engineering model requires consistent structure of these contextual connections. Methods are researched for analysis of consistency (Horváth, L., 2017). Notice at any lack of contextual connection is inevitable.

Figure 9 serves better understand of key procedures around EO. Suppose that an EO represents some actual subject matter for teaching and learning. Course model includes parameters for characterization of EO and related definition procedures which are to be explained. This must be correct representation of content collected among others from conventional passive notes, presentations, and other teaching materials. When model is adequately defined, its exploration shows the required content. Full parametrized generic engineering model is required for this purpose. Parameters for characterization of the contextual EO representations and the applied definition procedures are to be explained.

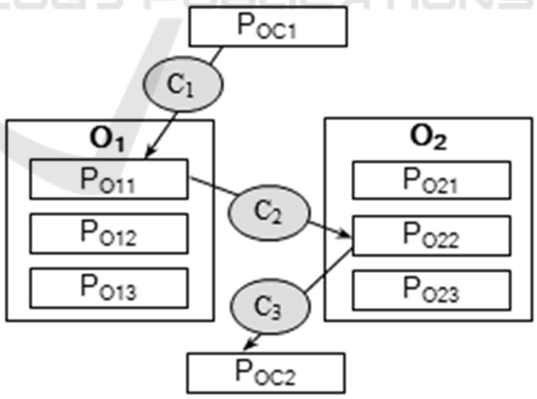

Figure 8: Objects and connections.

Access to course purposed engineering model using role-based authorization (Figure 9) has key importance. Participants access model by course specifically configured control of authorization. Change and definition of objects, their parameters, and contexts are possible in accordance with actual mode. Mode may authorize for modification only during a session, including new model version in the system, or development of the course specific engineering model.

5 IMPLEMENTATION ISSUES

Development and maintenance of the above model is challenging task and needs expertise in engineering, teaching, and modeling. The main benefits are the availability high amount inherently active knowledge in the modeling system and that considering of this knowledge is enforced by modeling procedures. Despite advanced modeling capabilities and built in knowledge, quality of model and success of model-based course still highly depends on participant qualities.

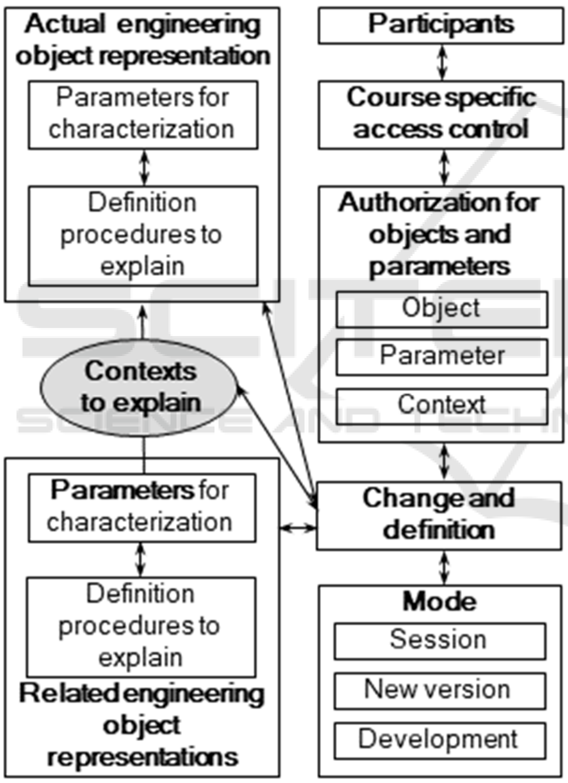

Figure 9: Scenario around an actual engineering object.

Implementation of course model supposes availability of comprehensive, reliable, and proven engineering modeling system which is in possession of correct active knowledge, allows for local knowledge in model, and supports system level multidisciplinary generic representation of ESs.

Work in a user group which is configured within very complex and increasingly smart engineering modeling system is still a challenge even for professionals. The question may be emerged in reader that how teachers and students can cope with the difficulties of working in such environments. Anyway, students must be prepared for this type of work in the future.

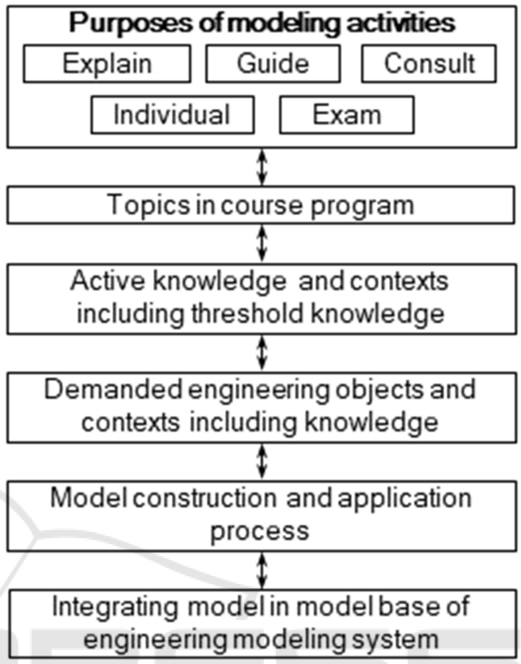

Figure 10: Main steps of model design.

Essential work of implementation is design of the demanded course specific engineering model. Main steps of design are sketched in Figure 10. First task is to decide and characterize the purposes of modeling activities. Following a student-oriented schema, purposes are explanations of teaching content, guiding student at learning and individual work, consult student, individual work of student for classroom tests and assignments, and examinations. The next step is definition of topics in course program and relevant active knowledge and contexts. Threshold knowledge is defined as knowledge which will be enforced by the modeling procedures. Original threshold knowledge can be extended by user definitions in modeling system. Following this, the demanded engineering objects and their contexts are defined. Knowledge items are considered as engineering objects in accordance with Figure 7. The rest tasks are definition of model construction and application process and placing the planned models in an actual engineering model system.

The Laboratory of Intelligent Engineering Systems has been experimenting with real-world courses in modeling environment for ten years. This activity prepares experiments with CCEM courses. A new and most recent engineering modeling environment is under preparation at this laboratory.

Challenge may be lack of the required modeling expertise. Moreover, system and multidisciplinary engineering organized teaching subjects may be strange for teaching personnel.

Fantastic advancement is that current modeling procedures do not allow generation of obviously erroneous model entities. At the same time, this requires highly prepared teaching personnel. Anyway, this is expected at university level. Appropriately formed working team on the Internet can help with remotely working members having the necessary expertise.

6 CONCLUSIONS

Moving engineering activities to virtual systems is a long history. Comprehensive projects with fully integrated engineering would be impossible without smart engineering modeling. This also means that involving latest engineering technology is unavoidable in higher education programs.

This paper shows a pioneer concept and methodology to realize subject matter for university course in the form of purposeful engineering model. Working with this model student will experience engineering work where knowledge will be active, and representations will "live" as it can be expected in the contemporary info-communication world. Author thinks that the only solution is application of industrial professional engineering modeling system in a laboratory which is available at all types of teaching and learning.

Teaching engineers must follow advances which are towards wide application of virtual environments to integrate active knowledge. This paper is a contribution to these efforts.

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REFERENCES

Kleiner, S., Kramer, C., 2013. *Model Based Design with Systems Engineering Based on RFLP Using V6*. In Smart Product Engineering, Springer, pp 93-102.

Canedo, A., Schwarzenbach, E., Faruque, M. A. Al., 2013. Context-sensitive synthesis of executable functional models of cyber-physical systems. In *ACM/IEEE International Conference on Cyber-Physical Systems*, Philadelphia, PA, USA, pp. 99-108.

Johri, A., Olds, B. M., 2011. *Situated Engineering Learning: Bridging Engineering Education Research and the Learning Sciences*. In Journal of Engineering Education, Vol. 100, No. 1, pp: 151–185.

Litzinger, T. A., Lattuca, L. R. et al, 2011. Engineering Education and the Development of Expertise. In *Journal of Engineering Education*, Vol. 100, No. 1, pp. 123–150.

Horváth, L., 2017. New Method for Definition of Organized Driving Chains in Industrial Product Model. In *ICIT 2017, 2017 IEEE International Conference on Industrial Technology*, Toronto, Canada, IEEE, pp. 1183-1188.

Horváth, L., 2016, Representation of Intellectual Property for Multidisciplinary Industrial Engineering Model System. In *ISIE 2016, 25th International Symposium on Industrial Electronics*, Santa Clara, California, USA, IEEE, pp. 328-333.

Horváth, L. Rudas, I. J., 2015. Product Behavior Definition for Element Generation in RFLP Structure. In *New Trends on System Sciences and Engineering*, Amsterdam, IOS Press, pp. 485-498.

Horváth, L. Rudas, I. J., 2016. Intellectual Resource Driven Multipurpose Virtual Engineering Environment. In *IEEE 14th International Symposium on Applied Machine Intelligence and Informatics*, Herlany, Slowakia, IEEE, pp. 69-74.

Eigner, M., Langlotz, M., Reinhardt, P., 2009. Case study based education in Product Lifecycle Management. In *11th International Conference on Engineering and Product Design Education*, Brighton, United Kingdom, pp. 215-220.

Wolf, T., 2010. Assessing Student Learning in a Virtual Laboratory Environment. In *IEEE Transactions on Education,* Vol. 53 No. 2, pp. 216-222.

Brière-Côté, A., Rivest, L., Desrochers, A., 2010. Adaptive generic product structure modelling for design reuse in engineer-to-order products. In *Computers in Industry*, Vol. 61, No. 1, pp. 53–65.

Beier, G., Figge, A., Müller, R., Rothenburg, U., Stark, R., 2013. Supporting Product Development through Cross-Discipline Dependency-Modeling-Novel Approaches for Traceability-Usage. In *Lecture Notes on Information Theory*, Vol.1, No.1, pp. 21-28.

Machado, J. A. T., Babaei, A., Moghaddam, B. P., 2016. Highly Accurate Scheme for the Cauchy Problem of the Generalized Burgers-Huxley Equation. In *ACTA Polytechnica Hungarica*, Vol. 13, No. 6, pp. 183-195.