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Collaborative Modeling Lab to increase Learning Engagement

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Abstract

In engineering education, modeling is one of the critical skills that students need to acquire. Models are used to help representing complex processes or systems in a way that overview and understanding of a particular aspect of these processes or systems is created. Hence, models need to be constructed in such a way that information and understanding from a complex reality can be reduced into a pragmatic assessment on the project level.
In modeling education we find a paradox. The end-result of a modeling exercise is by definition a less complex representation of the system or process that is studied. Therefore, when providing examples of a modeling effort, the true complexity of the analysis and modeling task is often underestimated. Consequently, studying worked-out examples of a modeling task, or witnessing a teacher during a modeling effort is insufficient to learn how to analyze and to model a system or a process. The difficulty of the task is only experienced and understood when students try to model by themselves. However, this is difficult to accomplish in a classroom setting as experience showed in engineering curriculums.
In this study we tested a new method for a modeling lab; a semi-structured interactive workshop in which students work in groups on large whiteboards using flexible modeling blocks. We evaluated the method using a questionnaire, and compared the final grades of the participating students with the students that did not participate. The results are encouraging.

Keywords: collaborative planning, education, engineering, modeling.

1. Introduction

Models are simplified representations of real or envisioned systems and processes. The purpose of a model is to reduce complexity in order to gain insight in a specific aspect of a system or process. We define complexity as the number of elements and the number of relations among those elements (Wood, 1986, Erickson and Siau, 2007). Models have several purposes; they are used to create overview and understanding, they are used to communicate and express relations, and they are used to demarcate systems. Models are used to help representing complex processes or systems in a way that overview and understanding of a particular aspect of these processes or systems is created. A model is usually created based on a modeling language. A modeling language is a grammar used to distinguish and represent specific types of elements and relations. Examples of modeling languages are the Unified Modeling Language (Booch et al., 1999), Structured Analysis and Design Technique (Marca and McGowan, 1987), the Entity Relationship Diagram (Chen, 1976) and System Dynamic modeling (Checkland, 1981).

Similar, in the field of policy analysis models are used to simplify and conceptualize insight in actor and system perspectives (Miser and Quade, 1985, Walker, 2000). For instance, by applying actor analysis, actors' perceived interests, means and interdependencies are represented unambiguously. Representing a complex system in a relatively small number of measurable dimensions is another modeling technique. This technique introduces factors -characteristics of the system- that can change in value like oil price, number of inhabitants of a country and water use per household per day. Causal relation modeling as a technique introduces and maps the causal relations between those factors to derive feedback loops and interdependencies.

Modeling is a key competence in engineering. In order to analyze, modify or design systems we need to gain insight in specific aspects of the system and in order to achieve this, non relevant elements and relations need to be removed. Modeling thus requires abstraction, a combination of reducing complexity of irrelevant aspects on the one hand and representing complexity of relevant aspects on the other (Smith et al., 1977). The end-result of a modeling exercise is by definition a less complex representation of the system or process that is studied. This causes a paradox when teaching modeling skills; when providing examples of a modeling effort, the true complexity of the analysis and modeling task is often underestimated. Consequently, studying worked-out examples of a modeling task, or witnessing a teacher during a modeling effort is insufficient to learn how to analyze and to model a system or a process. The abstraction skill is not visible for the students, and will be difficult to articulate for the teacher. We will describe an example from a class at Delft University.

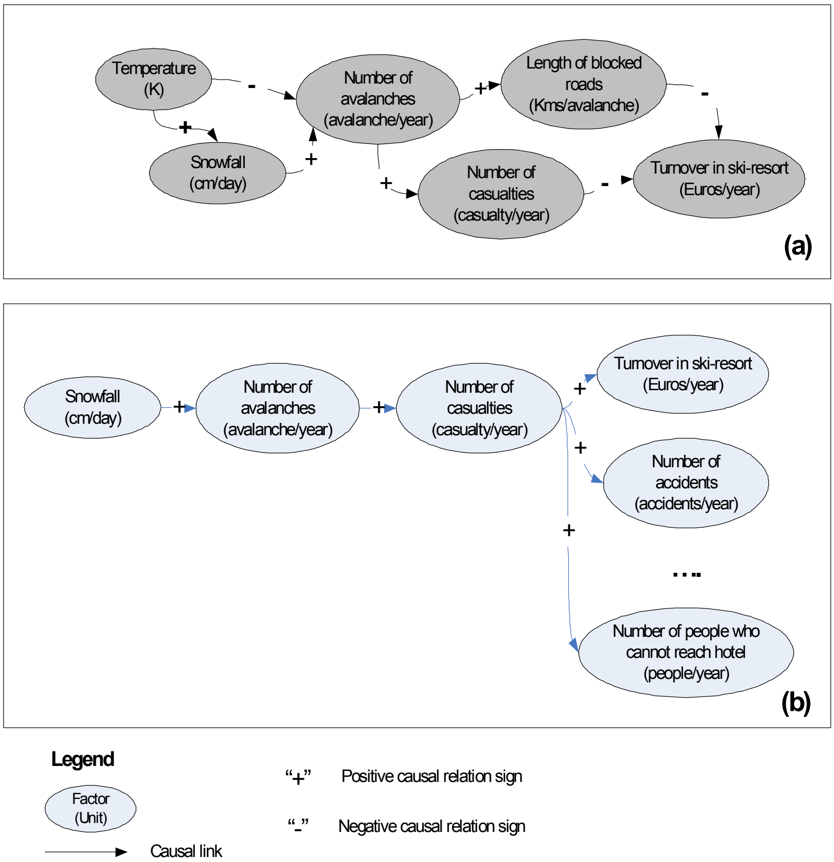

Figure 1: An example of conceptual modeling in practice with two causal relation diagrams (a) from an experienced and (b) from an inexperienced conceptual modeler (student).

"When students are confronted with the conceptual modeling technique of a causal relation diagram, we see the analogy of the Christmas tree: Adults usually see the full Christmas tree while children only get exited about the particular color of a particular decorative element. This is illustrated in Figure 1, where the dilemma between uncontrollable forces of nature (snowfall, avalanches), the effect they have on human living conditions (blockage of roads) and the effect on the local economy (turnover in ski-resort) are represented in a causal diagram. How experienced conceptual modelers depict the problem is represented in Figure 1.a while less experienced conceptual modelers like the students produce a more linear diagram with details irrelevant to the dilemma that is represented as shown in Figure 1.b. That reveals that teachers overestimate the ability of less experienced conceptual modelers to overview the whole problem."

The example shows that for novices it is difficult to see the interrelations and feedback loops in a system, where these are natural complex patterns for experts. This is consistent with the notion that experts have more interrelated memory representations than novices (Sweller, 1988, Bjork- Ligon and Bjork, 1996).

Transferring modeling skills requires true engagement of the students in the actual modeling effort. Only when students discuss the grammar of the language, the choices of demarcation and representation and the consistency and completeness of the model, they will acquire the modeling skills. For this purpose we developed a new approach for modeling in education. In this paper we present the approach and its effect on the engagement of the students.

The remainder of this paper will first describe the background on collaborative and constructive learning. Next we will present the traditional teaching approach and the new collaborative approach. Third we will present the research method, and last we will present results and conclusions.

2. Theoretical background

Although the concept of experience and analysis as important steps in the learning cycle is already recognized by Kolb (Kolb, 1984), it is extended in multimedia environments using the theory of constructivism. Constructivism is a philosophy of learning founded on the premise that, by reflecting on our experiences, we construct our own understanding of the world we live in (Fosnot, 1996). Constructivists view learning as the result of mental construction. Students learn by fitting new information together with what they already know. People learn best when they actively construct their own understanding (compare for instance the educational psychology theory of Vygotsky). Learners are encouraged to invent their own solutions and to try out ideas and hypotheses. They are given the opportunity to build on prior knowledge.

As discussed in the introduction the key problem in modeling education is the implicit nature of the skills and actions involved in the process. To articulate these implicit skills we need to engage students in the modeling effort to ensure that they experience the full scope and challenges of the task, and to help them to articulate the cognitive activities and choices involved in the task. A natural way to introduce dialogue in a task is to force students to perform the task in collaboration with other students. Hence, collaborative modeling is used as a guiding method. Collaborative learning causes explanation, disagreement and regulation of activities, which can help students to articulate and understand the skills required for modeling (Dillenbourg, 1999).

3. Methodology

For the design of the workshops we used the guidelines of collaborative planning as well as the lessons from previous experience with semi-structured workshops with master level students. Given that the first year master students are challenged to go through all the steps of a policy analysis exercise so as to construct a model and use it to assess policy alternatives, the model structuring process is of high importance. The bachelor students learned the modeling skills in the context of a business system and a simulation course, as part of an analysis and design cycle.

More specifically, the set-up, the goal, the process and the products of the workshop are described in detail to illustrate the application of collaborative modeling in modeling education for engineers.

Goals of the exercise:

The exercise serves three main purposes: (a) the realization of the complexity and multi-faceted nature of policy problems in an engineering context, (b) the learning by doing of analysis and modeling methods, and (c) the training of rigor in modeling through use of the consistency rules in modeling, by using conceptual modeling and consistency validation.

Set-up of the workshop: We used the approach in three different classes, a first year bachelor class on analysis of business systems, a second year bachelor class on discrete modeling, and a first year masters' class on policy analysis. In the first case, the lab session was conducted twice for two different modeling languages; SADT modeling and UML class diagram modeling, in the second case, these same methods were used, and in the third case conceptual models (a causal model and a goal-hierarchy model) and quantitative models were made by the students. In each case the session was voluntary; participation gained no study credits and had no direct effect on the student's marks. The students worked in small groups of 3-7 students. The first year students spent 1-2 hours on each model, the second year and master students had to make 2 models in 2 hours.

The students were provided with a description of the main dimensions and challenges of the topic in the form of a short case description as well as a description of the outcomes of the modeling exercise. A presentation of the case and an explanation of the rules of the workshop were also provided. During the workshop, a hand-out with a short explanation of the modeling approach was provided to every student group. Additional material was also provided during the workshop . This included a description of modeling tasks, of the the task-lists for every step of the modeling process, and debates, technologies, and points of skepticism that have been published..Every student group was given specific color sticky cards that were used as blocks of the model components and a couple of markers and a wiper. Every group had its discussion board and whiteboard to post its conceptual model and final model.

The whiteboard was chosen as a means to communicate and negotiate ideas about the model within the group to develop a joint model, rather than separate individual models. Creating one model forces the students to negotiate about choices and to discuss disagreements and unclear aspects. In this respect, the modeling blocks posted on the whiteboard enable all students in the group to view the model and to detect flaws and problems. Furthermore change awareness should be created; student should see that others change the model. For this purpose the model should be large enough to enable 3 to 7 students to see and change it. Additionally it would be useful for the model to be flexible, and easy to make changes. For this purpose we created the whiteboard models with sticky cards, so elements of the model can be easily replaced or removed and relations (usually lines) can be wiped out and altered. The whiteboards were approximately 1x1.5 meter, so sufficiently large to allow all group-members to see the model.

Process of the workshop: The spatial set-up of the workshop is named a solar-system workshop. In the place of the sun (in the center of the room) were placed the materials provided to the students. These materials comprised the reading materials for extra information (journal articles, leaflets, newspaper articles, press releases) and some whiteboards/handouts with the modeling steps and modeling language for students to view during the workshop. The student groups gathered around their boards and whiteboards were placed around the materials as group-planets. Groups were allowed to ask questions and teachers as “satellites” were visiting one group after the other to answer questions, to indicate flaws in the models, to guide negotiations between students and to involve non-active students into the discussions. Teachers did not directly point out mistakes in the models but asked questions on the rationale / argument behind the model components to make students self-improve their models. Time-pressure was created by announcing the time left twice throughout the workshop.

Products of the workshop: The master students were asked to deliver a brief (up to five pages) but comprehensive policy analysis study where different policy options needed to be formulated and assessed using the models (and applying all the steps of policy analysis as taught in the course). A presentation of the outcomes and rationale of the modeling steps was also a requested outcomes of the workshop. The bachelor students only had to ask the teacher to approve their model before leaving class.

Assessment of the products of the workshop: The models (both conceptual / qualitative and quantitative) were assessed by judging the consistency of the resulting model with modeling conventions or rules (Dean et al., 2000) and by completeness and validity (Dean et al., 2000, Hengst, 2005). Furthermore a model should have communicative qualities; in should increase shared understanding and insight into the system or process that is being modeled.

To assess the effect of the approach we used the following metrics:
(a) Increases learning; if the method increases learning, students feel they increased their understanding of the modeling approach. To measure learning we assessed learning, increased understanding and knowing more.
(b) Learning efficiency; if the method contributed to learning efficiency, students feel they learned the skills faster than through traditional learning (class or self-study). We measured the efficiency, ease and reduced complexity of the task.
(c) Increase efficacy of the modeling method; if the method increases self efficacy with respect to the modeling method, students feel confident they master the modeling method. To measures efficacy we measured confidence, mastering the method and ability.
(d) Increases learning fun; does the method increase the fun or enjoyment of learning. To measure fun we measured fun, enjoyment and pleasantness of the exercise.
(e) Increased engagement; does the method engage the students to participate in the modeling task. To measure engagement we used constructs form active learning from a survey from Serva and Fuller (Serva and Fuller, 1999).

We used the questionnaire in English (master students) and Dutch (bachelor students) We had an independent researcher translate the questionnaire, and translated this back. Inconsistencies were resolved in discussion among the translators. The questionnaire used 3 questions for each factor in the evaluation.

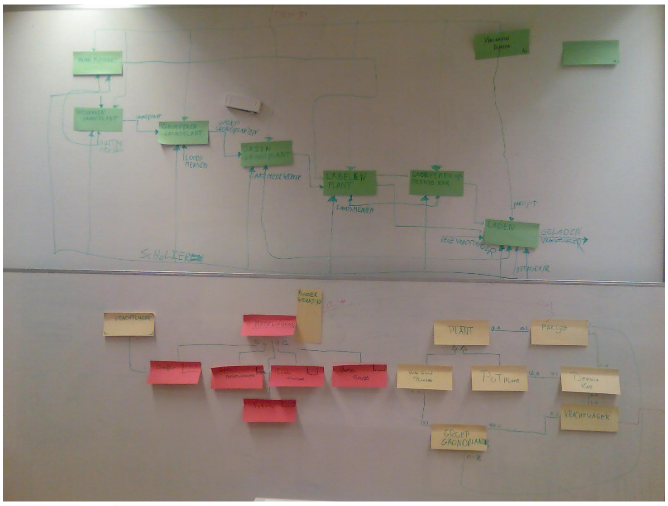

Fig. 2a Conceptual models drawn by a student group.

Fig. 2b Snapshot of groupwork of students during the workshop.

4. Research results

Below we present the results of the questionnaire.

Table 1: Workshop assessment results on a scale from 1-7

	average	stdv	n
fun	4.97	1.03	154
learning	4.93	1.32	152
confidence	4.27	1.16	153
engagement	5.20	1.38	154
efficiency	4.61	1.32	152

From the results (Table 1) we learned that the workshop was considered to be fun, that it contributed to learning, and that it was efficient. Furthermore, as we expected, the students felt engaged in the exercise. Confidence in the modeling technique was scored less convincing; we think this is because the feedback on the quality of the models they made was not in terms of a grade, and because they made the model in groups while they need to eventually learn to create the model alone. Actually the lower score on confidence indicates that the workshop helped the students in understanding the complexity of the modeling task and reduces the risk that students underestimate the modeling effort. We observed the following opportunities for improvement and learning:

- The group size should not be larger than 5, when the group becomes larger, some students become more passive. During the workshop we inspected that in groups larger than 5, active students dominated the process and some students were acting as free-riders and were not involved. In one of the groups, free-rider behavior resulted in slowing down the progress of the modeling process and in the indecisiveness of the group when constructing the model.

- The use of the sticky cards helped the students to correct their model: The sticky cards were used by all the groups to construct and revise their model. Sticky cards proved easy to use and easy to replace.

- The use of the whiteboard made sure that the students could all participate in the effort, and made it easier for the teachers to ‘look over the shoulder’.

- Encouraging self-verification using the modeling rules increased learning. In this way the students would actively verify their model using the modeling rules, detect errors and correct them in discussion with the group.

- Working in groups made students realize the complexity of the problem and the effort required to reach to a consistent and negotiated view of the system and consequently translate this into a model.

5. Conclusions and further research

This study shows that using a collaborative approach in modeling education increases engagement and therewith helps the students to understand the complex skills required to create a representative model from a case description. In engineering education, modeling is one of the critical skills that students need to acquire. The study showed that using a collaborative approach, the modeling paradox in education can be resolved. Collaborative modeling has been introduced in a number of modeling courses in the curriculum of students of the various programs at the school of Technology Policy and Management of Delft University of Technology. In recent courses Smartboards have been used to replace the paper-whiteboard materials. Smartboards are electronic whiteboards, they are large enough to enable group-modeling and yet the modeling effort can be fully virtual. Smartboards enable recording of the model and the modeling effort.

In future research we will further think about the methods required to give useful feedback to the students during and after the modeling exercise. For this purpose modeling in a virtual mode is very useful. In this way it would be possible to save versions of the model for evaluation of the evolvement of the model. Further, it would enable students and teachers to save the models for later feedback, and for comparison. Also the blocks of the model can be offered in advance, which will save the students time that can be spent on the actual modeling skills rather than on analysis tasks. Naturally a future research project will be to compare experiences with both the pen-and-paper version and the virtual modeling tools.

REFERENCES

BJORK- LIGON, E. & BJORK, R. A. (Eds.) (1996) *Memory Handbook of Perception and Cognition,* San Diego, Academic Press.

BOOCH, G., RUMBAUGH, J. & JACOBSON, I. (1999) *The Unified Modeling Language User Guide,* Indianapolis, Addison-Wesley.

CHECKLAND, P. B. (1981) *Systems Thinking, Systems Practice,* Chichester, John Wiley & Sons.

CHEN, P. P.-S. (1976) The Entity Relationship Model - Towards a Unified View of Data. *ACM Transactions on Database Systems,* 1**,** 9-36.

DEAN, D. L., ORWIG, R. E. & VOGEL, D. R. (2000) Facilitation Methods for Collaborative Modeling Tools. *Group Decision and Negotiation,* 9**,** 109-127.

DILLENBOURG, P. (1999) What do you Mean by 'Collaborative Learning'? In DILLENBOURG, P. (Ed.) *Collaborative-Learning: Cognitive and Computational Approaches.* Oxford, Elsevier.

ERICKSON, J. & SIAU, K. (2007) Theoretical and Practical Complexity of Modelling Methods. *Communications of the ACM,* 50**,** 47-51.

FOSNOT, C. T. (1996) *Constructivism: Theory, Perspectives, and Practice,* New York, Teachers College Press.

HENGST, M. D. (2005) Collaborative Modeling of Processes: What Facilitation Support does a Group Need? *Eleventh Americas Conference on Information Systems.* Omaha, Nebraska, USA, AIS Press.

KOLB, D. A. (1984) *Experiential Learning,* Englewood Cliffs, NJ, Prentice Hall.

MARCA, D. A. & MCGOWAN, C. L. (1987) *SADT: Structured Analysis and Design Technique,* New York, McGraw Hill, Inc.

MISER, H. J. & QUADE, E. S. (Eds.) (1985) *Handbook of Systems Analysis,* New York, John Wiley & Sons, Inc.

SERVA, M. A. & FULLER, M. A. (1999) The Role of Media Use and Active Learning in Higher Education: the development of an instrument to determine the dimensions of teaching. *International Conference on Information Systems* Charlotte, North Carolina, Association for Information Systems.

SMITH, J. M. & SMITH, D. C. P. (1977) Database Abstractions: Aggregation and Generalization. *ACM Transactions on Database Systems,* 2**,** 105-133.

SWELLER, J. (1988) Cognitive Load During Problem Solving: Effects on learning. *Cognitive Science,* 12**,** 257-285.

WALKER, W. (2000) Policy Analysis: a systematic approach to supporting policymaking in the public sector. *Journal of Multi Criteria Decision Analysis,* 9**,** 11-27.

WOOD, R. E. (1986) Task Complexity: Definition of the construct. *Organizational Behavior and Human Decision Processes,* 37**,** 60-82.