Collaborative Modeling Lab to increase Learning Engagement; Comparing Manual modeling with Interactive Whiteboards

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Abstract

In engineering education, modeling is one of the critical skills that students need to acquire. Modeling is a critical step in support of the design and analysis of multi actor systems. In this study we evaluate a semi-structured interactive lab exercise in which students work in groups on large whiteboards. We compared the used of electronic, interactive whiteboards, with traditional whiteboards using sticky cards as modeling blocks. We evaluated the method using a questionnaire to see whether electronic whiteboards are more engaging, and better support learning. Additionally we performed a qualitative case study to further analyze the effect of electronic whiteboards on engagement.

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 [1, 2]. 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 [3], Structured Analysis and Design Technique [4], the Entity Relationship Diagram [5] and System Dynamics modeling [6]. Similar, in the field of policy analysis models are used to simplify and conceptualize insights of actors and system perspectives [7, 8].

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 [9]. The end-result of a modeling exercise is by definition a less complex representation of the system or the process that has been studied. This causes a paradox when teaching modeling skills when providing examples of a modeling effort, as 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. Therefore, it is difficult for novices to see the interrelations and feedback loops in a system, where these seen as natural patterns for experts. This is consistent with the notion that experts have more interrelated memory representations than novices [10, 11].

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 as well as the consistency and completeness of the model, they will start acquiring 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 and learning efficiency of the students. In addition to this, it is also evaluated whether the use of interactive whiteboards has
a positive impact on engagement and whether it offers increased efficiency.

The remainder of this paper will first describe the background of collaborative and constructive learning (Section 2). Next we will present the traditional teaching approach and the new collaborative approach (Section 3). Third we will present the quantitative and qualitative research method (Section 4), and last we will present results and conclusions (Section 5).

2. Theoretical background

Although the concept of experience and analysis as important steps in the learning cycle is already recognized by Kolb [12], 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 [13]. 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 [14]). 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 [15].

3. Collaborative Modeling Approach

For the design of the lab exercises we used the guidelines of Collaboration Engineering [16] as well as the lessons from previous experience with semi-structured lab exercises with master level students. More specifically, the set-up, the goal, the process and the products of the lab exercise are described in detail to illustrate the application of collaborative modeling in modeling education for engineers.

3.1. Goals of the exercise

The exercise serves three main purposes: (a) the realization of the complexity and multi-faceted nature of policy and systems analysis 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.

3.2. Set-up of the lab exercise

We used the approach in four different classes, a first year bachelor class on analysis of business systems, a first year bachelor class with a project to apply skills in 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 trained, 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 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 lab exercise were also provided. During the lab exercise, a hand-out with a short explanation of the modeling approach was provided to every student group. Additional material was also provided during the lab exercise. This included a description of modeling tasks, of the activities required for every step of the modeling process, and background information on the case.
3.3. Traditional Whiteboards

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 having the students create separate individual models. Creating a model forces the students to negotiate their choices and to discuss disagreements and unclear aspects. 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 is important for the model to be flexible, and to support the making of corrections and changes. To accomplish similar flexibility in the manual groups, 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 and to detect flaws and problems.

In the traditional setting 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 (see Figure 1).

3.4. Interactive Whiteboards

In the interactive whiteboard setting student groups used a Smartboard (see Figure 2). 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. The interface of the Smartboard is like a “large” computer monitor but it allows for all the traditional writing on the screen given that Smartboards are touch-screens and come with a special stylus set to write on the board. The boards were slightly smaller than the normal whiteboards. The software used was Smart Ideas. This software enables modeling, and has a text recognition tool to label blocks and arrows. Alternatively students could use a keyboard. Students were able to save versions of the model for evaluation and future reference. Further, it enabled students and teachers to save the models for later feedback, and for comparison. In the interactive whiteboard setting a 5 minute demonstration was given to show how the interactive whiteboards worked and teaching assistants could help students when needed.

3.5. Process of the lab exercise

The spatial set-up of the lab exercise is named a solar-system lab exercise. In the place of the sun (in the center of the room) the materials provided to the students were placed. 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 lab exercise. The student groups gathered around their group boards which were placed around the materials as planets. Groups were allowed to ask questions and teachers functioned as “satellites”, 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

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1 The use of interactive whiteboards supports this flexibility.
the rationale behind the model components to make students self-improve their models. Time-pressure was created by announcing the time left twice throughout the lab exercise.

3.6. Products of the lab exercise

The bachelor students only had to ask the teacher to approve their model before leaving class. The master students however 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 taught in the course). The conceptual models created during the lab exercise were also part of the analysis and detailed presented in the appendices of the report. A presentation of the outcomes and rationale of the modeling steps was also a required deliverable.

4. Method

To assess the effect of the approach we used the following metrics:
(a) Increases learning fun (S); does the method increase the fun or joy of learning? To measure fun we measured fun, enjoyment and pleasantness of the exercise.
(b) Increases learning (L); if the method increases learning, students feel they increased their understanding of the modeling approach. To measure learning we assessed their perception of learning, increased understanding and knowing more.
(c) Increase efficacy of the modeling method (EF); 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) Increased engagement (EN); does the method engage the students to participate in the modeling task. To measure engagement we used constructs from active learning from a survey from Serva and Fuller [17].
(e) Learning efficiency (LE); 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 perceived efficiency, ease and reduced complexity of the task. We used the questionnaire in English (master students) and Dutch (bachelor students). An independent researcher translated 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. We evaluated the instrument using an exploratory and confirmatory factor analysis.

4.1. Exploratory factor analysis

Due to sample size, only factor loadings higher than .40 are considered significant [18]. The factor analysis, with Promax rotation is presented in table 1.

<table>
<thead>
<tr>
<th>Table 1. Factor analysis.</th>
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<tbody>
<tr>
<td>Factor</td>
</tr>
<tr>
<td>S1</td>
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<tr>
<td>S2</td>
</tr>
<tr>
<td>S3</td>
</tr>
<tr>
<td>L1</td>
</tr>
<tr>
<td>L2</td>
</tr>
<tr>
<td>L3</td>
</tr>
<tr>
<td>EF1</td>
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<tr>
<td>EF2</td>
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<tr>
<td>EF3</td>
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<tr>
<td>EN1</td>
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<tr>
<td>EN2</td>
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<td>EN3</td>
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<tr>
<td>LE1</td>
</tr>
<tr>
<td>LE2</td>
</tr>
<tr>
<td>LE3</td>
</tr>
</tbody>
</table>

As extraction method we used Principal Axis Factoring. For the rotation method we used Promax with Kaiser Normalization. A rotation converged in 6 iterations. All variables were included; there was no statistical reason to exclude questions. As a measure of internal validity of the scales the Cronbach’s α was calculated (see table 2). All indicating a good level of inter-item reliability [19, 20].

<table>
<thead>
<tr>
<th>Table 2. Inter-item reliability.</th>
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<tbody>
<tr>
<td>Scale</td>
</tr>
<tr>
<td>S1-S3</td>
</tr>
<tr>
<td>L1-L3</td>
</tr>
<tr>
<td>EF1-EF3</td>
</tr>
<tr>
<td>EN1-EN3</td>
</tr>
<tr>
<td>LE1-LE3</td>
</tr>
</tbody>
</table>

4.2. Confirmatory factor analysis

Further analysis was performed using structural equation modeling with AMOS 6.0. All questions are presented in the model as endogenous variables. The five factors L,S,LE, EF and EN are represented in the model as exogenous variables. To determine the fit of the model, a number of fit statistics were examined [21-23]. All statistics and their parameter are presented in table 3.
Both the values of the incremental and absolute fit indexes (GFI = 0.912, CFI = 0.966, NFI = 0.929) exceed the widely used threshold of 0.900. Only the AGFI (AGFI = 0.868) value is below the threshold, but still consistent with levels accepted in literature [24, 25]. The root mean square error of approximation of 0.064 indicates a close fitting model [26] as does the standardized root mean square residual of 0.081 [27]. We therefore concluded that the model (figure 3) was valid, and the instrument can be used to compare the learning effects of collaborative modeling lab.

Figure 3. Model factor analysis.

5. Research results

To get a first indication of the effect of interactive whiteboards on learning we compared the results of students working with and without smart boards using an Independent Samples Test. The assumptions for a t-test are the following:

- There is a continuous scale used for each dependent variable: we used a 1-7 Likert scale.
- Random sampling: this assumption is not met, while we did not choose the participants, they participated as part of a course.
- Independence of observation: this assumption is violated as well, as participants collaborated in groups during the sessions. Statistics manuals suggest the use of a more stringent alpha. We used a significance level of .01.
- Normal distribution: for a sample size of 30+ violation should not pose a problem.
- Homogeneity of variance: We used Levene’s test for equity of variances, this assumption was in some cases violated, in those cases we used the test in which equal variances are not assumed.

The groups we compared consisted of 146 students working with interactive whiteboards versus 64 working with manual tools (see Table 4).

Table 4. Independent-samples t-test

<table>
<thead>
<tr>
<th></th>
<th>Fun</th>
<th>Learning</th>
<th>Efficacy</th>
<th>Engagement</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean of Sigma smartboard</td>
<td>14.2</td>
<td>13.4</td>
<td>13.3</td>
<td>14.7</td>
<td>12.8</td>
</tr>
<tr>
<td>Mean Score 1-7</td>
<td>4.7</td>
<td>4.5</td>
<td>4.4</td>
<td>4.9</td>
<td>4.3</td>
</tr>
<tr>
<td>Standard deviation smartboard</td>
<td>3.5</td>
<td>4.1</td>
<td>4.2</td>
<td>3.7</td>
<td>4.0</td>
</tr>
<tr>
<td>Mean of Sigma manual</td>
<td>15.0</td>
<td>14.9</td>
<td>12.9</td>
<td>15.7</td>
<td>13.9</td>
</tr>
<tr>
<td>Mean Score 1-7</td>
<td>5.0</td>
<td>5.0</td>
<td>4.3</td>
<td>5.2</td>
<td>4.6</td>
</tr>
<tr>
<td>Standard deviation manual</td>
<td>2.7</td>
<td>3.6</td>
<td>3.2</td>
<td>3.2</td>
<td>3.3</td>
</tr>
<tr>
<td>Sig. α 0.01</td>
<td>.129</td>
<td><strong>.009</strong></td>
<td>.463</td>
<td>.074</td>
<td>.043</td>
</tr>
<tr>
<td>Eff. size</td>
<td>.0112</td>
<td>.0328</td>
<td>.0026</td>
<td>.0153</td>
<td>.0196</td>
</tr>
</tbody>
</table>

From the results (Table 4), we learned that the lab exercise was considered to be fun, it contributed to learning and it was engaging. Confidence in the modeling technique and efficiency 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. Also learning to work with the interactive whiteboards took some time. Actually the lower score on efficacy indicates that the lab exercise helped the students in understanding the complexity of the modeling task and reduces the risk that students underestimate the modeling effort.

The comparison showed that there is only a significant difference between
interactive and manual whiteboards for learning. Surprisingly, the interactive whiteboards showed a lower score for this. Another factor that is significant on an alpha .05 criterion is efficiency. Again manual is considered more efficient, probably due to the start-up investment in learning to work with the text-recognition software.

5.1. Opportunities for further improvement

Our experience with both the traditional and the interactive whiteboard in the collaborative lab exercises revealed that there is opportunity for further improvement and learning:

(a) Concerning the set-up of the lab exercise: The group size should not be larger than 5, when the group becomes larger, some students become more passive. During the lab exercise 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.

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.

Limitations are first of all in the number of students in the interactive whiteboard group (n 64). Since many other factors affect the outcomes of the modeling exercise more data are required to further verify the conclusions. A second limitation is that groups were overlapping; a first year group did the exercise several times both with traditional and interactive whiteboard support, so some students filled out the questionnaire two or three times.

(b) Concerning the process of the lab exercise: 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.

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 interactive whiteboards require a short investment in learning to use the text recognition functionality. We will experiment with the use of wireless keyboards instead. Further, the software used was not available for students for further use. This will change, which makes the models more useful for self study after the lab exercise.

For the instructors the use of the interactive whiteboards had considerable advantages; the models made were much clearer, readable, and therefore it was easier to give feedback. Further in two cases the students had to use the model for a report, once the software is available for them after the modeling exercise, this will save them considerable time.

We expect additional advantages in using the interactive whiteboard for modeling instruction where students can see how the model is developed. Also the tools give us the opportunity to work with assignments that build the modeling skills in a more gradual path, starting with filling in the details of an existing model, and working towards a full modeling effort.

6. Additional case study

To further study the effect of the Smartboard intervention we decided to do a qualitative case study for a group of master students. In this case study we did not run the questionnaire, but instead observed the students consciously during their modeling task. The lab exercise realized with policy analysis master level students. The students were offered a project-related framework to ease their modeling and conceptual mapping was provided to them. This framework included three ready-made files of Microsoft Visio uploaded in the Smartboards for the policy analysis students to use during the lab exercise that was held in June 2008. Apart from this framework, a three-page manual for Smartboard and use of Microsoft Visio with Smartboard were provided to the students.

The use of Smartboards eased the interaction and collaboration of the policy
analysis students. All the group members participated actively and the corrections could be made more flexibly using Smartboards than using traditional whiteboards.

During the conceptual modeling lab exercise of June 2008, we realized that Smartboards not only ease the collaboration of students, enable fast iterations and validations of the models students construct but also inhibit strategic behavior of students such as free riding in projects. We experienced that one group of students chose not to work with the Smartboards in the class but instead worked with paper. Giving this freedom to them while monitoring their progress, we faced the following situation: only two out of the six students of the group were actively involved in the modeling exercise while the others were not involved at all. They consciously chose not to work with the Smartboard claiming that traditional way of working is more inspiring for them. However, we suspected based on our observation that not working with the Smartboard had a free riding motive.

Smartboard as a collaboration tool is easy and user-friendly even to students less skilled or familiar with technology. Even groups that were skeptical about using the Smartboard were convinced that the Smartboard interface provides the option to save the work on conceptual models in a very simple and fast way.

Concerning the learning process that took place with the aid of the Smartboard, we observed that first versions of the conceptual models (causal relation diagrams and goal tree hierarchies) were constructed within the first 2 hours of the lab exercise. We found that reflection on choices and improvement of the conceptual models were realized faster and with increased interaction of the group members. Iterations of reflection and modification of the conceptual models lasted longer than expected: It took 3 additional hours to finalize and hand in both conceptual models.

Summarized we observed that the Smartboards increased the interaction of the students during the task, which in turn fostered learning.

7. Conclusions and further research

This study shows that using a collaborative approach in modeling education fosters engagement and interaction and therewith helps the students to understand the complex skills required to create a representative model from a case description. While this relation is not yet confirmed by the data, the instrument to verify this has been developed but further data collection and improvement of the approach to improve usability of the Smartboards is required. The study showed that using a collaborative approach, the modeling paradox in education can be solved. Further research could involve the development of design patterns for collaborative modeling, a more in-depth analysis of group dynamics to further understand the effect of factors such as group size and task complexity on learning engagement and effectiveness. Especially focus on inactive students is important in this respect. Further it would be interesting to measure the effect of the smartboard lab exercise more directly using a pre and post test of modeling skills.

References


