SIMULATION BASED LEARNING ABOUT COMPLEX MANAGEMENT SYSTEMS
A Simulation Experiment

Mirjana Kljajić Borštnar, Vladislav Rajkovič, Miroljub Kljajić, Andrej Škraba and Davorin Kofjač
University of Maribor, Faculty of Organizational Sciences, Kidričeva 55a, 4000 Kranj, Slovenia

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Abstract: This paper describes experiences in teaching of a Modelling and simulation course at the Faculty of Organizational Sciences. The course consists of continuous simulation based on System Dynamics (SD) and discrete event simulation (DES). When enrolling the course the students have already taken courses of Mathematics, Statistics, Systems Theory, as well as Organization and Economics. The final grade of the course is derived from the student's project and written exam. Attendance at lectures is not obligatory; only the practical exercises are. In this paper, we will discuss the methods of teaching SD by using the classical approach of teaching, and by the application of a business simulator. Therefore, we have developed the simulation model in order to explicate the usefulness of the simulation in solving management problems. Students took part in the experiment with the simulation model; the obtained results were analyzed afterward in the students' projects. After the experiment, students had to complete a questionnaire on their opinion of the course. The results show that students taking the course of Modelling and Simulation thought that application of the simulation model contribute to a better problem understanding, faster problem solving and greater confidence of participants.

1 INTRODUCTION

The role of simulation methodology in the decision assessment of complex systems is constantly increasing. Human knowledge, the simulation model and decision methodology combined in an integral information system offer a new standard of quality in management problem solving (Simon, 1997). The simulation model is used as an explanatory tool for a better understanding of the decision process and/or for learning processes in enterprises and in schools. Many successful businesses intensively use simulation as a tool for operational and strategic planning as well as enterprise resource planning (ERP) (Schniederjans and Kim, 2003; Muscatello et. al, 2003). Findings in literature (Forrester, 1969; Homer, 1996) emphasize that in a variety of industries real problems can be solved with computer simulation for different purposes and conditions. At the same time, potential problems can be avoided and operative and strategic business plans may also be tested. Although there is a considerable amount of work devoted to simulation methodology, its application is lacking in practice; especially in small- and mid-sized companies. The reason lies not in the methodology itself; the real reason is in the problems of methodology transfer to enterprises and the subjective nature of decision-making. However, there are several problems, both objective and subjective, that are the reason this well-established methodology is not used more frequently.

One of the objective problems is model validation, which is very important for any model-based methodology. The validity of the model of a given problem is related to the soundness of the results and its transparency for users. According to Coyle (1996), a valid model is one that is well-suited to a purpose and soundly constructed. The second problem, the subjective one, is related to the transparency of the methodology and data presentation (Kahneman and Tversky, 1979), as well as the preferences of the decision-maker for using a certain decision style and poor communication between the methodologist and the user. The simulation methodology is a paradigm of problem solving in which the personal experiences of users as well as their organizational culture play an important

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role (e.g., in transition countries: market economy, ownership, etc.). Students are only ones who would potentially introduce simulation methodology into practice. However, how to present modelling and simulation (MS) is of enormous importance to the students, whose personal experience is limited.

This paper describes over 30 year of experience in the teaching of a modelling and simulation course for students of the Faculty for Organizational Sciences. The main objective of the course has been to show the role of modelling and simulation in management science in teaching the students the methods and techniques of modelling as well as general notation in the form of computer simulator, accompanied by presenting the field of application, effectiveness and facets at the support of business decisions. Our course consists of two parts: continuous simulation based on systems dynamics and discrete event simulation (DES). The course is in the third year and students by the time they start the course they have already taken courses of mathematics, statistics, theory of systems, as well as organizational and economic courses. The final grade of the course is derived from the student's project and written exam.

In this paper, we will discuss methods of teaching SD. Of course, by definition, simulation is experimentation on a computer model. It is a typical virtual reality method, which can alienate students from real management problems. In order to motivate students in learning and understanding the subject, many authors have developed business simulators of various types. One of most popular is the beer game simulator developed at MIT (Sterman, 2000). Therefore, we have also developed a simulation model (Škraba et. al, 2003) in order to clarify the usefulness of the simulation in solving management problems. Students took part in an experiment where they had to solve a managerial decision problem supported by the simulation model. They were assigned to work under different experimental conditions. Experimental results were then analyzed and discussed in the students' projects. Students' contributions were rewarded as a part of their final grade. Also, students were kept motivated throughout the course by special rewards for their in-class participation. After the experiment, students had to complete a questionnaire on their opinions. The results show that management students, taking the course Modelling and Simulation, thought that application of the simulation model contributes to a greater understanding of the problem in comparison to those who did not participate in the course with the business simulator. In this paper, we analyzed methods of teaching MS and the impact of the business simulator and active participation of the students during lecturing on their grades.

2 BUSINESS SIMULATOR – A TOOL TO IMPROVE LEARNING PROCESS

In order to improve our method of teaching modelling and simulation and to persuade students that simulation methods in management science are not only a tool for solving already known academic problems, we built a business simulator aimed at presenting decision processes in enterprises more realistically. Students have to take active part in an experiment and then make reports about their results. In this way, they were motivated to regularly attend and understand lectures. However, if one wants to persuade participants to experiment with a stimulator, it has to be carefully prepared; the design of the experiment has to be as realistic as possible in order to show this advantage of using a simulation model in decision support. For that purpose, the business simulator has to reasonably reflect the business situation and its utility.

A simulation model developed by the SD method, which was used in the experiment, is shown in Figure 1. The model described by Škraba et. al (2003), consists of production, workforce and marketing segments, which are well known in literature (Sterman, 2000). It was stated that product price (r1) positively influences income. However, as prices increase, demand decreases below the level it would otherwise have been. Therefore, the proper pricing that customers would accept can be determined. If marketing costs (r3) increase, demand increases above what it would have been as a result of marketing campaigns. The production system must provide the proper inventory level to cover the demand, which is achieved with the proper determination of the desired inventory value (r4). Surplus inventory creates unwanted costs due to warehousing; therefore, these costs have to be considered. The number of workers employed is dependent on the production volume and workforce productivity, which is stimulated through salaries (r2). Proper stimulation should provide reasonable productivity.

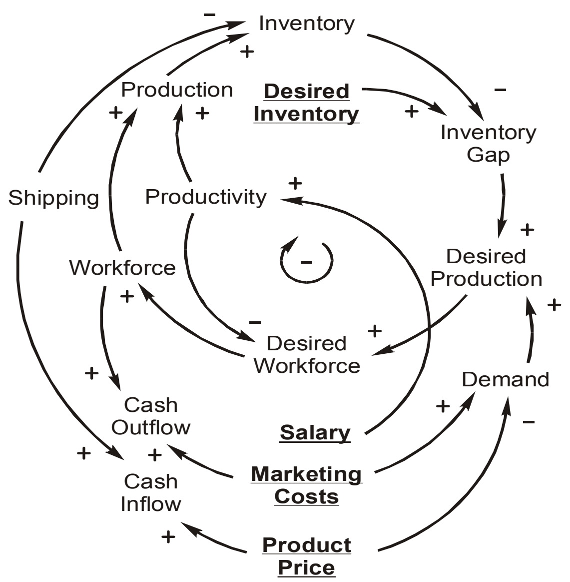

Figure 1: Causal Loop Diagram of Production Model.

The participants in the experiment had the task of promoting a product on the market, whose life cycle is one year. They had to find the appropriate value of parameters r_i defined in the interval $r_{min} \le r_i \le r_{max}$. The parameter values are shown in Table 1, where MU in the Unit column is the abbreviation for Monetary Unit.

Table 1: Parameter limitations.

Parameter	Description	Unit	Interval
r_1	Product Price	MU/product	50-200
r_2	Salaries	MU/month* people	500-2,000
r_3	Marketing Costs	MU/product	0-20,000
r_4	Desired Inventory	product	1,000-15,000

The model was prepared in the form of a simulator (Škraba et. al, 2003). The participants changed the parameter values via a user interface that incorporated sliders and input fields for adjusting the values.

After setting the parameters in the control panel, the simulation could be processed. The stop time of the simulation was set to twelve months. Output was shown on graphs representing the dynamic response of the system and in the form of a table where numerical values could be observed (Capital Return Ratio (CRR), Overall Effectiveness Ratio (OER), Workforce Effectiveness Ratio (WER), Inventory / Income Ratio (IIR), Production, Workforce, Inventory, Net Income, Shipping, Cash Inflow, Cash Outflow). Participant had no limitations of the simulation runs that he/she intended to execute within the time frame of the experiment. The criteria function was stated as the sum of several ratios, which are easily understood and were known to the participants. It was determined that Capital Return Ratio (CRR) and Overall Effectiveness Ratio (OER) should be maximized at the lowest Workforce and Inventory costs determined by Workforce Effectiveness Ratio (WER) and Inventory/Income Ratio (IIR). The simulator enabled simultaneous observation of the system response for all four components (CRR, OER, WER and IIR) stated by the criteria function during the experiment. The criteria function was dependent on the chosen parameter values and is stated as:

$$\max_{r_i \in R} J = CRR \cdot w_1 + OER \cdot w_2 - WER \cdot w_3 - IIR \cdot w_4 \quad (1)$$

The weight values were prescribed as: w_1 = 0.5, w_2 = 0.35, w_3 = 0.1 and w_4 = 0.05.

The goal of the participants was to maximize the criteria function in Equation 1. The criteria function represents the business goal, which is explicitly stated in our case in order to achieve a proper level of experimental control with regard to the results obtained.

3 SIMULATION EXPERIMENT

The simulator enabled simultaneous observation of the system response for all variables stated by the criteria function during the experiment. In total, 147 subjects, senior university students randomly scheduled into three groups, participated in the experiment. The experiment was conducted under three experimental conditions:

a_0) Determination of strategy on the basis of a subjective judgment of the task

Under this condition, a subject had to make an individual judgment about the best possible strategy on the basis of the presentation of the model by the Causal Loop Diagram (CLD) and the stated Criteria Function. The participants had 30 minutes to determine the appropriate values of decision parameters and record their decisions on paper.

a_1) Individual decision-making supported by the simulation model

Under this condition, each subject was supported by the simulation model, which provided feedback information about the anticipated business outcome. There was no limitation on the number of simulation runs a particular participant executed on the simulation model within the experimental time. After each predetermined time interval (8+8+8+6 minutes), participants had to forward their selected business strategy to the network server and continue the search for the optimal business strategy. Participants had to make a final decision about the best business strategy and forward the selected decision parameter to the server after 30 minutes.

a_2) Decision-making supported by both the simulation model and group feedback information

Under this condition, the simulation model was connected to the GSS, which enabled the introduction of group feedback information into the decision process. Under experimental condition a_2, each individual subject was supported by the simulation model, which provided feedback information on the anticipated business outcome. Under this condition, subject interaction via computer mediation was enabled. Participants were able to examine the chosen business strategies (decision parameter values) of other participants in the decision group after the strategies were forwarded to the network server. Therefore the participants could look into the "group's achievements" after the 8th, 16th and 24th minutes. There were no limitations on how many times they could seek group feedback. Group feedback information was presented in the form of a table, which contained input parameter values selected by each participant anonymously, and the average values of the parameters with the standard deviation.

3.1 Simulation Experiment Results

The hypothesis that model application and group feedback information positively influence the convergence of the decision process and contribute to higher criteria function values was confirmed at the p=.01 level. More precisely, the results of the decision process gathered when group feedback information was introduced revealed that criteria function values of Group a_2 were higher than in cases where the decision was based only on individual experience with a simulation model (a_1) and the lowest criteria function values were achieved on the basis of subjective judgment (a_0).

However, we expected that the results gathered after the first eight minutes would not differ for the groups working with simulator (a_1 and a_2) where the same conditions were in force in the first eight minutes: individual use of simulator. Because groups were randomized and homogenous, we expected no difference in participants' use of simulator. However, we found that the frequency of simulator use in first eight minutes was significantly higher in Group a_2 than Group a_1. In the second year, we repeated the experiment with the next class, but only with conditions a_1 and a_2 (Škraba et. al, 2007); the results were similar. The results of the decision process conducted under experimental conditions a_1) N_{a1}=58 and a_2) N_{a2}=58 are shown in Figure 2. On the Y-axis, the values of the criteria function for each participant are ordered from the highest to the lowest. On the X-axis, the number of participants is presented.

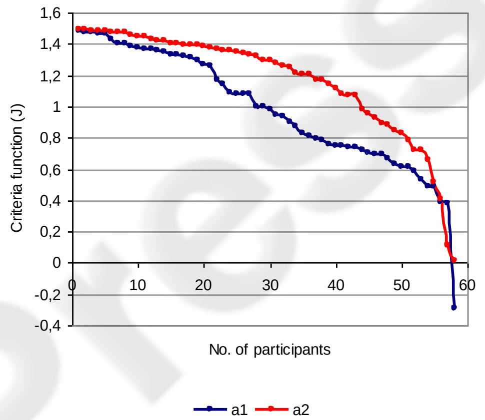

Figure 2: Values of criteria function (J) achieved under conditions a_1 and a_2, ordered from the highest to the lowest.

The single factor ANOVA showed that there are highly significant differences among Groups a_1 and a_2 on a p=.006 level of confidence. However, we again found that the frequency of simulator use in first eight minutes was significantly higher in Group a_2 than Group a_1. Therefore, the following year we omitted the exercise on the business simulator in the process of teaching with students in order to prepare tools for a new experiment according to Solomon Four-Group Experimental Design. That automatically means that students are not obliged to participate in lectures.

4 OPINION QUESTIONAIRE SNALYSIS AND EXAM RESULTS

Evidence of the students' grades from the course of modeling and simulation, where students took part in simulation experiment were high (first attempt: average grade=7.08, Std. Deviation=1.78; n=118) and student was motivated to visit lectures and seminars. In the course for which experiment was omitted, the attendance of lectures was rather poor (attendance was not obligatory) and the grade was lower (first attempt: average grade=3.38, Std. Deviation=1.96; n=91). It must be emphasized that the final grade of the course is derived from the student's individual project (40%) and a written exam (60%). The written exam consists of six standard question prepared in advance and selected by chance for all students, regardless of whether they had attend lectures or not. Therefore, the analysis of the results could be considered an unbiased one.

The participant's opinions about their involvement in the experiment were solicited with questionnaires. Participants filled in the questionnaires via a web application. Questions were posed in a form of a statement, and agreement to the statement was measured on a 7-point Likert type scale, where "1" represents very weak agreement, "4" a neutral opinion, and "7" perfect agreement with the statement. The average value of an answer and its standard deviation to the statements in the opinion questionnaire are shown in Table 2.

Table 2: Average agreement and its standard deviation to the statements in the opinion questionnaire.

		Experimental Condition	
Q	Short descpription of a question	a1	a2
1	general quality of the experiment	5,733 *(0,785)*	5,724 *(0,996)*
2	presentation of the decision problem	5,733 *(0,980)*	5,552 *(1,183)*
3	understanding of the decision problem	5,833 *(1,392)*	5,690 *(1,256)*
4	simplicity of the use of simulator	6,600 *(0,498)*	6,586 *(0,733)*
5	contribution of simulator to understanding of the problem	5,067 *(1,484)*	5,931 *(1,132)*
6	evaluation of the time for solving the problem	5,167 *(1,683)*	5,931 *(1,307)*
7	motivation for solving the problem	4,733 *(1,530)*	4,966 *(1,149)*
8	benefit of participation in the experiment in the course	5,833 *(1,020)*	6,034 *(0,981)*
9	organization of the experiment	6,400 *(0,894)*	6,483 *(0,949)*
10	contribution of the simulator to the quality of decision	5,900 *(1,269)*	6,276 *(0,797)*

From Table 2, it is evident that participants expressed high agreement to most of the statements. In fact, only Statement 7, regarding motivation for participating in the experiment, was evaluated a bit lower. In other words, it was closer to the neutral point, but not negative.

We performed an ANOVA test to explore the differences in opinions among the four experimental conditions. The ANOVA test also showed high agreement in opinion between groups. The groups' opinions differ significantly only in two questions: 4) simplicity of use of the simulator ($F=3.067$, $p=.031$), and 5) contribution of simulator to understanding of the problem ($F=3.274$, $p=.024$), both of which can be explained by different experimental conditions requiring a slightly different user interface and thus different levels of person-computer communication.

From the opinion questionnaires, we can make some general observations:

a) 99% of the participants agreed on the general quality of the experiment.

b) 84% of all participants agreed that the use of simulator contributed to understanding of the problem.

c) 63% of all participants agreed that they were motivated for solving problem.

d) 88% of all participants agreed that they benefited from participating in the experiment.

e) 92% of all participants agreed that use of the simulator contributed to better decision-making.

These are cross-group averages and represent the overall agreement to the statements. We can say that, in general, students were satisfied with the experiment as a method of teaching and the use of simulation in decision support.

5 CONCLUSIONS

This article describes experience in teaching of modeling and simulation course for students of the Faculty of Organizational Sciences, University of Maribor. The course consisted of theoretical lectures, practical training and participation in the experiment. Special emphasis was made on the motivation of students to actively participate in the course and in the experiment. In order to participate in the experiment, students had to actively participate in both the theoretical and practical parts of the course. The experiment was performed on the business simulation model in order to clarify the usefulness of the simulation in solving management problems. The goal was to acquire knowledge of learning in a group decision process supported by a system dynamics model and group information feedback. The criteria function was explicitly defined in order to increase the level of experimental control. It was found that model application and group feedback information positively influence the convergence of the decision process and contribute to higher criteria function. More precisely, the results of the decision process gathered when group feedback information was introduced were better than in cases where the decision was based only on individual experience with a simulation model and the worst results were achieved on the basis of subjective judgment. However, group feedback and the facilitator are extremely important during complex problem solving. The results show that management students taking the course of Modeling and Simulation thought that application of the simulation model do contribute to a greater understanding of the problem, faster solution finding and greater confidence in participants. All participants agreed that a clear presentation of the problem motivates participants to find the solution.

According to the authors' subjective evidence of students' grades from the course of modeling and simulation, there is a significant difference between classes of students taking part in simulation experiment (higher motivation to visit lectures as well as seminars); in the course where the experiment was omitted, the attendance of lectures was rather poor.

All participants agree that clear presentation of the problem motivates participants to find the solution. So, in the future, the use of realistic yet sufficiently simple business models is essential, if one wishes to close the gap between business processes understanding and the role of modeling and simulation in problem solving. A similar conclusion was found in (Ståhl, 2007).

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