MODELING AND SIMULATION EDUCATION CONCEPTS IN SYSTEM DYNAMICS OF MANAGEMENT STUDIES

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Abstract

This article describes experiences in the teaching of a modeling and simulation course for students of a school for organizational sciences. Our course consists of time continuous simulation based on System Dynamics (SD) and discrete event simulation (DES). The course is in the 3rd year and students have by then 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 discus methods of teaching SD. Of course, by definition simulation represents experimentation on a computer model. Therefore, we have also developed the simulation model in order to explicate 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 a simulation model. They were assigned to work under different experimental conditions. Experimental results were then analyzed and discussed in the students' projects. Students' contribution was 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 opinion of the course. The results show that management students, taking the course of Modeling and Simulation, thought that application of the simulation model do contributes to a greater understanding of the problem, faster finding of solutions and greater confidence in participants. All participants agree that clear presentation of the problem motivates participants to find the solution.

Keywords: group decision, learning model, system dynamics, experiment design.

Presenting Author's biography

Miroljub Kljajić graduated from the Faculty of Electronics, University of Ljubljana in 1970. He received his MS in 1972 and his PhD in 1974 at the same university. In 1970 he was employed at the Institute Jozef Stefan, Department for Biocybernetics and Robotics. Since 1976 he works at the Faculty of Organizational Sciences, University of Maribor as Professor of System Theory, Cybernetics, and Modeling and Simulation. He has been principal investigator of many national and international projects from modeling and simulation. As author and co-author he has published over two hundred scientific articles.

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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 offers a new standard of quality in management problem solving [1]. 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) [2, 3]. Experiences described in literature [4, 5], 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. Currently, the most intensive research efforts are concentrated on a combination of simulation methods and expert systems [6, 7]. Although there is a considerable amount of work devoted to simulation methodology, 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, 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 [8], 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 [9], 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 where the personal experiences of users as well as their organizational culture play an important role (e.g., in transition countries: market economy, ownership, etc.).

This article describes experiences in the teaching of a modeling and simulation course for students of school for organizational sciences. Our course consists of continues simulation based on systems dynamics and discrete event simulation DES. The course is in the 3rd year and students have already taken courses from 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 discus methods of teaching SD. Of course, by definition, simulation represents experimentation on computer model. It is typical virtual reality methodology which can alienate students from real management problems. In order to interest students in learning and understanding the subject, many authors developed business simulators of various types. One of most popular is the beer game simulator developed at MIT [10]. Therefore, we have also developed a simulation model 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' contribution was 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 fill in the opinion-questionnaire. The results show that management students, taking the course of Modeling and Simulation, thought that application of the simulation model contributes to a greater understanding of the problem, faster solution finding and greater confidence in participants. All participants agree that clear presentation of the problem motivates participants to find the solution. However, only the participants supported by simulation model without group interaction agreed that application of simulator helped to understanding of the problem. Participants who worked with simulator and group information feedback agreed that simulation model, together with application of group interaction, contributed to higher criteria function determination.

2 Business Simulator a tool to improve learning process

In order to improve our method of teaching modeling and simulation we built a business simulator aimed to present decision processes in enterprises more realistic. Students have to take active part in experiment and then make reports about results. In this way, they were motivated to regularly attending and understand lectures. However, if one wants to persuade participant 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 advantage of use 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 Fig. 1. The model described in [11] consists of production, workforce and marketing segments, which are well known in literature [10, 12]. It was stated that product price (r_1) 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 (r_3) 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 (r_4). 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 (r_2). Proper stimulation should provide reasonable productivity.

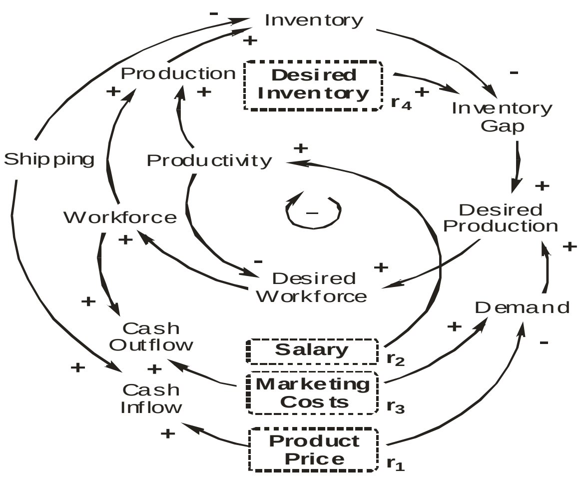

Fig. 1 Causal Loop Diagram of Production Model

Participants had the task of promoting a product, which had a one-year life cycle, on the market. They had to find the proper values of parameters ri defined in the interval $r_{min} \leq r_i \leq r_{max}$. The model was prepared in the form of a business simulator [11]. The participants changed the parameter values via a user interface, which incorporated sliders and input fields for adjusting the values. After setting the parameters in the control panel, the simulation could be processed. The end time of 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. Each participant had no limitations on simulation runs, which he/she intended to execute within the time frame of the experiment. The parameter values for each simulation run were set only once, at the start of the simulation. It was assumed that the business plan was made for one year ahead. The criteria function was stated as the sum of several ratios, which were easily understood and known to the participants. It was determined that Capital Return Ratio (CRR) and Overall Effectiveness Ratio (OER) should be maximized at minimal Workforce and Inventory costs determined by a Workforce Effectiveness Ratio (WER) and Inventory / Income Ratio (IIR). 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,

At 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 optimum 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

For 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.

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).

These results were expected. However, we also 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 condition a_1 and a_2 [13]; 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 Fig. 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.

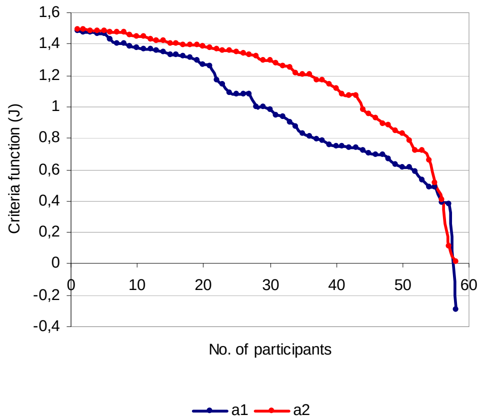

Fig. 2 Values of criteria function (J) achieved under conditions a1 and a2 ordered from the highest to the lowest

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.

Further we examined the dynamics of problem solving by observing the frequencies of simulation runs and dynamics of the average value of criteria function achieved under the two conditions. Fig. 3 shows the dynamics of the frequency of strategy testing (simulation runs) on the simulator in the timeframe of the experiment for the experimental conditions a_1 and a_2; and Fig. 4 shows the dynamics of the average value of criteria function under the two conditions during the experimental time.

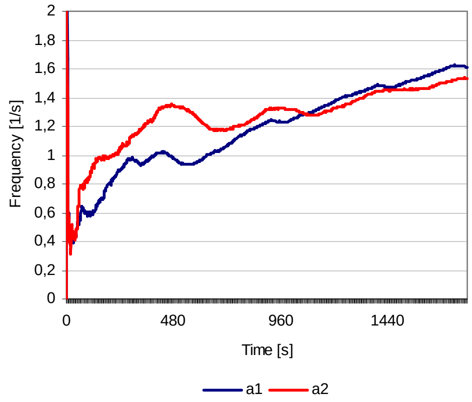

Fig. 3 Dynamics of frequency of strategy testing on the simulator of the groups' a_1 and a_2 in the timeframe of the experiment (1800 s)

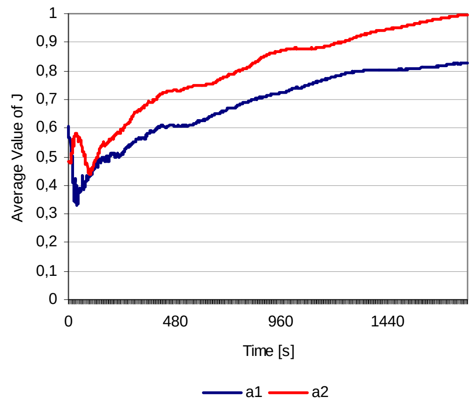

Fig. 4 Dynamics of the average value of criteria function achieved by participants under conditions a_1 and a_2 during the experimental time (1800 s)

Participants of Group a_2 started the search for the best business strategy with high frequency in the first eight minutes (480s) of the experiment and slowed down by the end of the experiment, while participants of Group a_1 started testing the strategies rather slowly and increased the pace by the end of the experiment time (30 minutes). This suggests that the participants of Group a_2, who were expecting to share their work with other decision-makers in their group after the first eight minutes, were more motivated than the participants of Group a_1 who merely had to submit their strategies to the server and were left to their own devices. However, the cumulative frequency of the simulation runs recorded at the end of the experimental time was similar in both the groups ($Fcum_{a1}$=2925; $Fcum_{a2}$=2930), yet the average value of criteria function remains higher in Group a_2 throughout the experiment, which we can observe from the Fig. 4. This difference in first eight minutes, where we expected that group had the some condition with such experiments (the pretest - post-test design) cannot be explained. Therefore, we conducted a new experiment according to Solomon Four-Group Experimental Design.

3 Solomon Four-Group Experimental Design

By means of Solomon Four-Group Experimental Design, we expected to estimate the effect of group belonging (as a result of the introduced group information feedback) and pretest effect (as a result of facilitation of the group decision process) on decision-making. Fig. 5 shows the model of the production process as a black box with input parameters r_1, r_2, r_3 and r_4 (where r_1 is Product Price, r_2 Salary, r_3 Marketing Costs and r_4 Desired Inventory) and criteria function J as the output under conditions a_1, a_2, a_3, and a_4.

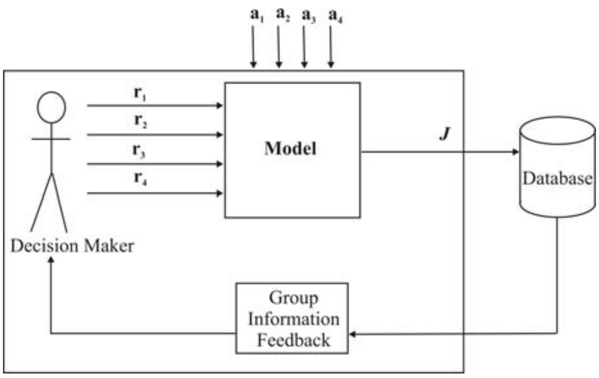

Fig. 5 Business model with input parameters under different experimental conditions

The experimental conditions were:

a_1) individual decision-making process supported by a simulation model with testing after 8th, 16th, 24th and 30th minutes, assumes that each participant submitted the best-achieved set of parameter values $\{r_1, r_2, r_3, r_4\}$ to the network server at the end of each time interval; pretest - posttest design.

a_2) decision-making process supported by simulation model and group information feedback with testing after 8th, 16th, 24th and 30th minutes. Each participant submitted the best-achieved set of parameter r_i to the network server at the end of each time interval. Information about the best-achieved parameter values was fed back into the group support system. The participants got feedback on the defined strategies of all the participants in the group $Ri = \{r_1, r_2, r_3, r_4\}$; $i = 1, 2, \ldots n$ as well as the aggregated values in the form of parameter mean values $\{\bar{r}_1, \bar{r}_2, \bar{r}_3, \bar{r}_4\}$. For example, if the considered parameter was Product Price and there were ten participants involved in the decision process, then all ten values for Product Price, recognized as the best by each participant, were mediated via feedback as well as the mean value of Product Price. The mean value provided the orientation for the parameter search and prevented information overload. In addition to criteria function as the results of decision making at different conditions, simulation frequency in order to follow decision makers' activity was also analyzed.

a_3) individual decision-making process supported by a simulation model without a pretest (testing after 30th min.) assumed the individual assessment of the decision-maker when determining the model parameters values $\{r_1, r_2, r_3, r_4\}$ by maximization of the criteria function using the SD model. At the end of the experiment, the subjects submitted the best-achieved parameter values to the network server; posttest design.

a_4) decision-making process supported by a simulation model and continuous group information feedback without the pretest (testing after 30th min.). Each participant submitted the best-achieved set of parameter values $\{r_1, r_2, r_3, r_4\}$ to the network server at the end of experiment. However, information about the instantaneous optimization of the group is always at subjects' disposal; posttest design.

Fig. 6 shows the random assignment into four decision groups from the population of senior management students. The first two groups in Fig. 6 represent the pretest - posttest design (decision groups are facilitated and measured four times during the experiment, after 8th, 16th, 24th, and at the end after 30th minute). The last two groups represent the posttest only design. All four groups were supported by the simulation model of a business system. One of each two groups (a_1 and a_2) had additional group information feedback at their disposal. Thus, we could asses whether the interaction between the pretest (in our case this also means facilitation of the group decision process) and the treatment (group information feedback) exists. At pretesting, the subjects were directed by a facilitator. They were told to submit their best chosen parameter values into the network database. After the submission, they continued with the search for the optimal combination of the parameter values. However, the decision-making process of the two groups working without pretests was continuous and without facilitation. All measurements were automatic and group information feedback was available at all times. For this purpose, we developed a new interface for data acquisition and processing.

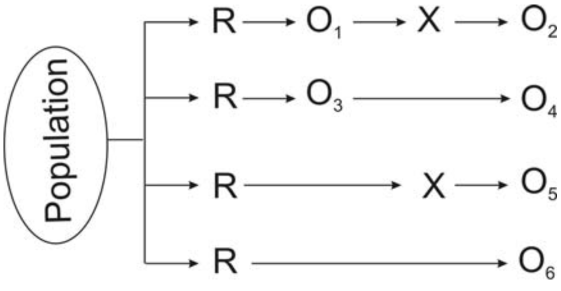

Fig. 6 Solomon four-group experiment design (R means random, O_i means observed, and X treatment)

3.1 Subjects and Procedure

Senior graduate students from the University of Maribor participated in the experiment in order to meet the requirements of their regular course work. The students were randomly assigned to eight groups with 14 to 15 subjects, who were then assigned to work under one of the four experimental conditions: a_1, a_2, a_3, and a_4. The subjects who participated in the experiment became accustomed to the business management role facing the stated objective, which was in our case presented in the form of criteria function. The presentation of the decision problem was prepared in the form of a uniform 11-minute video presentation, which differed only in the explanation of experimental condition, at the end of each video presentation. The problem, the task and the business model were explained. The structure of the considered system was presented and the main parameters of the model were explained. The evaluation criteria for the business strategies were also considered. The work with the simulator was thoroughly explained in the video. A printed version of a problem description was also provided for each subject. The participating subjects were familiar with SD simulators; therefore, working with the simulator was not a technical problem. Subjects were awarded by a bonus grade for their participation in the experiment.

4 Results of the Solomon four-group experiment

For the purpose of results analysis, the criteria function was optimized by Powersim SolverTM using genetic algorithms. The optimal value of the criteria function was thus set to 1.5. The highest values of criteria function were selected by the participants of Group a_2 ($\hat{J}_{a2} = 1{,}237$, $\sigma_{a2} = 0{,}210$), followed by the results of Group a_1 ($\hat{J}_{a1} = 1{,}170$, $\sigma_{a1} = 0{,}338$) and the results of Group a_4 ($\hat{J}_{a4} = 1{,}157$, $\sigma_{a4} = 0{,}290$); the lowest results were gathered by Group a_3 supported by simulation model ($\hat{J}_{a3} = 1{,}147$, $\sigma_{a3} = 0{,}272$).

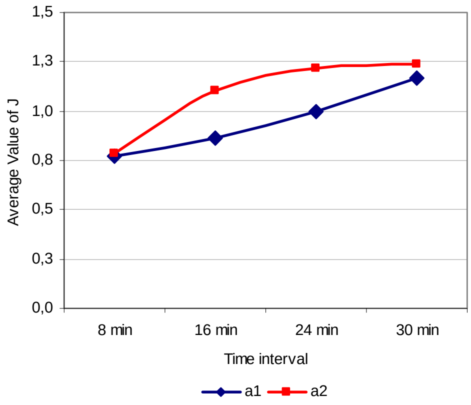

Fig. 7 Average value of criteria function at the observed time intervals (8^{th}, 16^{th}, 24^{th} and 30^{th} minutes)

Fig. 7 shows values of criteria function achieved by the participants under experimental conditions: a_1, a_2 at the end of each time interval. The results of Friedman's ANOVA test confirmed that criteria function values increase during the experiment time (χ_{a1}=30.57, p_{a1} =.000; χ_{a2}=27.30, p_{a2} =.000); therefore, we can conclude that learning takes place during the decision-making process.

Results show that the subjects' decisions did not differ after the first eight minutes, when the same conditions were in place. This was confirmed by Mann-Whitney test (U=415) at p=.762. After Group a_2 had received the group information feedback, they quickly approached the optimum criteria function value. The biggest increase in criteria function values is observed after the first time group information feedback was introduced (after 16^{th} minute), confirmed by Wilcoxon test (z=-2.995, p=.002). Criteria function values significantly increase after the 24^{th} minute (confirmed by Wilcoxon test, z=-3.165, p=.001), but hardly changed towards the end of the experiment (in the last eight minutes). This was confirmed by Wilcoxon test (Z=-.660, p=.510). However, the group without group information feedback (a_1) slowly continued to approach the optimal solution and significantly improves their results in the final phase of the experiment (after the 24^{th} minute). The Wilcoxon test confirmed that criteria function values significantly improved after each experimental phase (z_1=-2.584, p_1=.009; z_2=-2.259, z_2=.023; z_3=-2.869, p_3=.004). This means that Group a_2 took eight minutes less to solve the decision-making problem than Group a_1. Results prove that learning occurs in the decision-making process supported by the simulation model. On the basis of analysis, we can conclude that the introduced group information feedback into the decision-making process contributes to a higher convergence of the decision group and helps to speed decision problem solving.

The main goal of the Solomon four-group experiment design was to determine whether interaction between the pretest and treatment exists. There is no single test that can be used on the data acquired by this experiment design [14], that is why we chose to use several statistical tests to determine the possible influence of pretests (facilitating) and treatment (group information feedback).

Testing the hypothesis that the interaction between testing and treatment exists, we calculated the differences between the criteria function of the pre tested groups and post-tested only groups and compared those differences. If there were no differences, we concluded that only the treatment influences the criteria function value. If the differences were significantly different, then we can conclude that interaction between pretest and treatment exists.

On the basis of the t-test the main contribution to the values of criteria function is the use of simulator ($t=3.654$, $df=29$, $p=.001$). Contribution of interactions between testing and treatment is significant ($t=1.965$, $df=34.16$, $p=.058$). However, the pretest and treatment alone are very small and insignificant.

Fig. 8 shows frequency of simulation runs at pretest and posttest (8^{th} and 30^{th} minute) for all four experimental conditions. It is noticeable that the frequency of Group a_2 (pretest treatment group) in the first eight minutes is slightly higher than the frequency of the pretested non-treatment Group a_1, and that both have higher frequencies of the two non-pretested groups (a_3 and a_4). Towards the end of experiment time, all groups show equidistant increases of frequency, except Group a_2 (pretest plus treatment). The groups' frequency of simulation runs is almost constant.

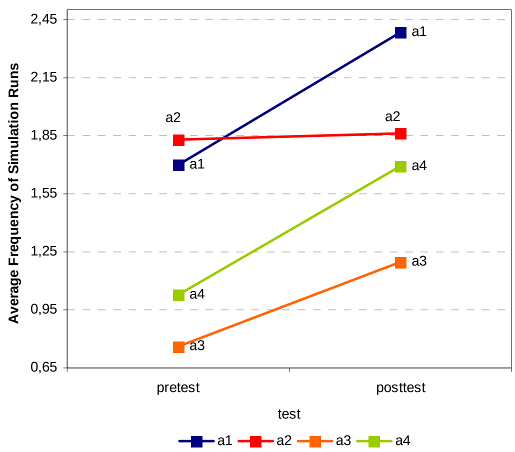

Fig. 8 Solomon test for frequency of simulation runs

From Fig. 8, we can conclude that pretest influenced the number of simulation runs performed. It is also evident that group information feedback impacts the number of simulation runs performed. We have conducted the two-way ANOVA which confirmed that treatment alone (group information feedback) does not influence the frequency of simulation runs ($F=.000$, $p=.9982$), pretest (facilitation of the decision process) influences the frequency of simulation runs ($F=6.895$, $p=.01$), and interaction between the pretest and treatment together influence the frequency of simulation runs ($F=4.076$, $p=.046$).

5 Learning model of decision making supported by simulator

In order to explain the influence of individual information feedback (assured by the simulation model) and group information feedback (brought into the decision-making process by group support system) on the efficacy of problem solving, we have developed a CLD model of learning during the decision-making process. The model shown in Fig. 9 was modified according to [15] and consists of three B and one R loops.

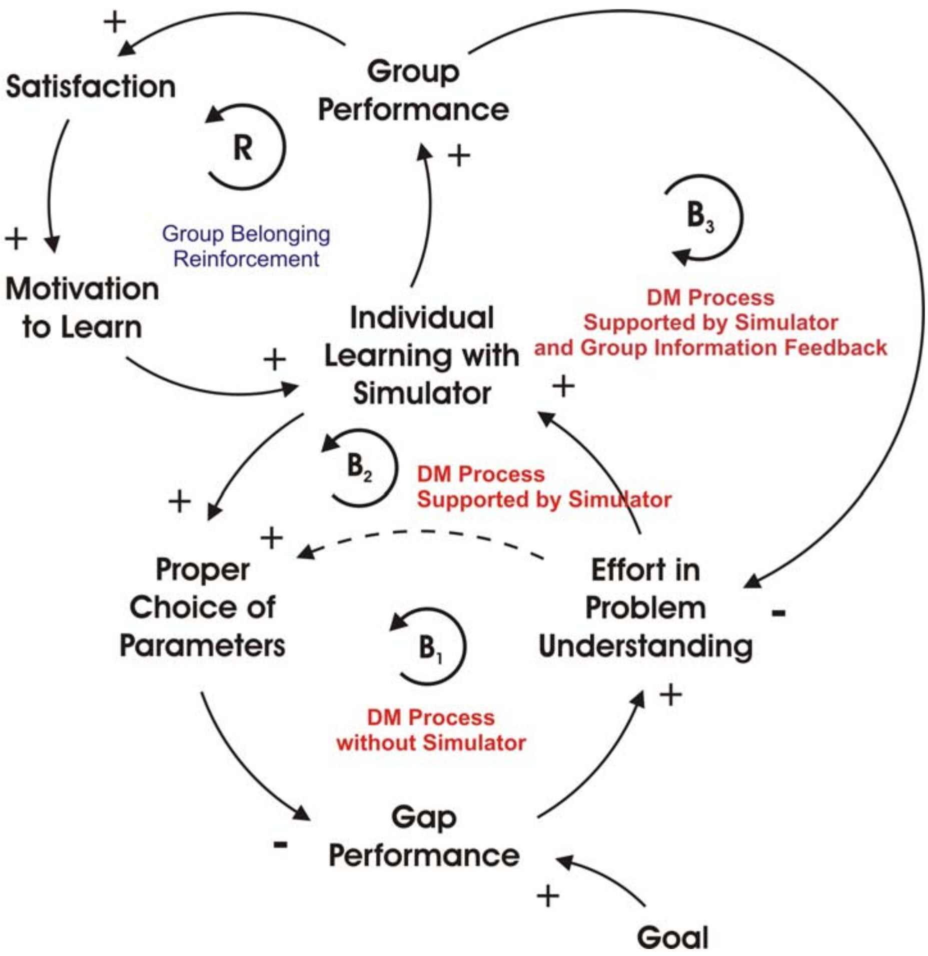

Fig. 9 Learning model of decision group under various decision-making conditions

Loop B1 represents a decision-making process supported by just a formal CLD model (in Fig. 1), paper and pen; described in [16, 11]. The decision maker solves the problem by understanding the problem and the task. The higher the gap between the goal and performance, the more effort should be put into understanding the problem. Loop B2 represents the decision-making supported by a simulation model and corresponds to experimental conditions a_1 and a_3 (groups supported by just individual feedback information of a simulation model). The higher the gap between the goal and performance, the higher the frequency of simulation runs. The search for the optimal parameter values is based upon trial and error. The more simulation runs that the decision maker performs, the more he or she learns (on an individual level), and the smaller is the gap between performance and goal (in our case the optimized criteria function). The correlation between frequency of simulation runs and criteria function value was confirmed (p_{a1}=.014; p_{a3}=.017). We named this loop “Individual Learning Supported by Simulator”. Loop B3 represents direct contribution of group information feedback, while loop R suggests reinforcing effects of group influence on problem solving With Groups a_2 and a_4 (groups supported by individual feedback information of a simulation model and group information feedback provided by group support system). The decision maker of loop B3 understands the problem and the goal. He or she is supported by simulator and group information feedback. While the use of simulator supports individual learning, the introduced group information feedback enhances group performance. Consequently, the increased group performance reduces the need to experiment on the simulator. In other words, a decision maker supported by group information feedback has broader view of the problem, insight into new ideas and less need to put less effort in problem solving. Conversely, the group information feedback stimulates group members to actively participate in problem solving so that they perform more simulation runs in the process of the search for the solution [17]. When the group is satisfied with its performance, the frequency of simulation runs decreases. Loop R can be further explained by interaction between group information feedback and facilitation of the decision-making process. As we have observed in [17], the group information feedback together with facilitation contributes to higher feedback seeking behavior and higher commitment to problem solving. Facilitation in this case serves as motivation and orientation towards the goal. Subjects of Group a_2 had to make their decisions three times during the experiment before they submitted their final decisions, while their colleagues of Group a_4 were left to work their own pace and had to make their final decision at the end of the experiment.

6 Opinion questionnaire analysis

Participant's opinions about their involvement in the experiment were solicited by questionnaires. Participants filled in the questionnaires via a web application. Questions were posed in a form of a statement and agreement to the statement were 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 answer and its standard deviation to the statements in the opinion questionnaire are shown in Tab. 1.

Tab. 1 Average agreement and its standard deviation to the statements in the opinion questionnaire

		Experimental Condition			
Q	Short descpription of a question	a1	a2	a3	a4
1	general quality of the experiment	5,733 *(0,785)*	5,724 *(0,996)*	5,867 *(0,900)*	5,483 *(1,022)*
2	presentation of the decision problem	5,733 *(0,980)*	5,552 *(1,183)*	5,833 *(0,791)*	5,379 *(1,208)*
3	understanding of the decision problem	5,833 *(1,392)*	5,690 *(1,256)*	5,733 *(0,944)*	5,448 *(1,378)*
4	simplicity of the use of simulator	6,600 *(0,498)*	6,586 *(0,733)*	6,067 *(1,143)*	6,103 *(1,113)*
5	contribution of simulator to understanding of the problem	5,067 *(1,484)*	5,931 *(1,132)*	5,833 *(1,085)*	5,586 *(0,867)*
6	evaluation of the time for solving the problem	5,167 *(1,683)*	5,931 *(1,307)*	5,100 *(1,710)*	5,138 *(2,031)*
7	motivation for solving the problem	4,733 *(1,530)*	4,966 *(1,149)*	5,100 *(1,494)*	4,345 *(1,471)*
8	benefit of participation in the experiment in the course	5,833 *(1,020)*	6,034 *(0,981)*	6,133 *(1,010)*	5,483 *(1,089)*
9	organization of the experiment	6,400 *(0,894)*	6,483 *(0,949)*	6,333 *(0,661)*	6,310 *(0,712)*
10	contribution of the simulator to the quality of decision	5,900 *(1,269)*	6,276 **0,797*	6,333 *(0,884)*	5,793 *(0,940)*

From Tab. 1, 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 showed high agreement in opinion between groups as well. 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 ($F=3.274$, $p=.024$), which can both be explained by different experimental conditions requiring slightly different user interface and thus different levels of man-computer communication.

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

1. 99% of the participants agreed on the general quality of the experiment.
2. 83% of all participants agreed that the decision problem was correctly presented.
3. 68% of all participants agreed that they understood the presented decision problem.
4. 93% of all participants agreed that the simulator was easy to use.
5. 84% of all participants agreed that the use of simulator contributed to understanding of the problem.
6. 70% of all participants agreed that there was enough time for decision making.
7. 63% of all participants agreed that they were motivated for solving problem.
8. 88% of all participants agreed that they benefited from participating in the experiment.
9. 97% of all participants agreed that experiment was well organized.
10. 92% of all participants agreed that use of the simulator contributed to better decision-making.

These are the across 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.

7 Conclusion

This article describes experience in teaching of modeling and simulation course for students of 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; they were awarded by 60% of their final grade based on course participation. 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. A Solomon four-group experiment was examined.

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. A causal loop diagram model of learning during decision-making process by means of simulation model was developed. The results show that management students, taking the course of Modeling and Simulation, thought that application of the simulation model does 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' grade from course of modeling and simulation, there is huge difference: three classes of students taking part in simulation experiment were much more motivated to visit lectures as well as seminars. Conversely, the course where experiment was omitted, the attendance of lectures was rather poor (attendance is not obligatory). So, in the future, use of realistic yet sufficiently simple business models is essential, if one wishes to close the gap between business processes and the role of modeling and simulation.

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