

Conception and Implementation of an Introduction Course in System Dynamics and Powersim

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Abstract

As a response to the increasing need for modeling and analysis skills system dynamics at the Brandenburg University of Technology of Cottbus the Chair of Managerial Economics, Management Accounting and Control Systems developed an introduction course in "System Dynamics Modeling using Powersim" for an university wide audience.

The paper presents the specific needs, target groups, the structure of the course and first experiences with its implementation. Additionally some future targets are discussed.

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1 The Demand for System Dynamics Methodology and the Objectives of Teaching at the BTU Cottbus

Our teaching is mainly for business engineers (or industrial engineers). This is a special university master degree in Germany. Students have to learn approximate 70% of the content of business administration (to be more exact: Betriebswirtschaftslehre) and 60 % of the content in an engineering subject (machinery, construction or environmental technology). In our business teaching they have to choose two specializations among four: marketing, organization and human resources, finance and investment, accounting and control systems.

We know that one cannot build an effective control system without an understanding of business dynamics and therefore we create an demand for SD within the freedom framework of a professor or chair. Well, but our students have to learn a lot of accounting and management control as well. As a maximum we can teach 3 lectures in SD (as a good tradition the introductory lecture is given by Peter Milling.) but about one third of the corresponding exercises in the course *Management Control Systems I* (and credit points as well) are from the field of SD. Usually we have a deeper focus on SD in our special seminar preparing for the final exams. We try to give the best students an orientation on SD.

We are motivating them by two factors. First of all we introduce them in the SD network of European universities. We have exchange contracts with the universities of Bergen (Prof. Davidsen), Sunderland (Prof. Moscardini) and Bari (Prof. Bianchi) and very friendly contacts with all members of that network. With the university of Bergen we have a informal agreement: our students can get a masters degree in system dynamics at Bergen if they prepare the first part of their master thesis as a Diplomarbeit at our university under the supervision of Prof. Davidsen and me (Schwarz). So they get two degrees from two universities. If they have attended the following course they have to work at Bergen only one year instead of two.

A second motivation factor is the growing demand for SD within German companies (for instance BMW, SAP, DaimlerChrysler). SAP is now integrating Powersim in its accounting and control software. Therefore our students are motivated to work with that software package.

Interestingly in other faculties of the university is a small but growing interest as well (see table 1), especially in the environmental sciences and informatics. (By the way the chair of machine dynamics is interested in the field as well.)

Purpose \ Need	Basic Knowledge of SD	Advanced Knowledge of SD	Basic SD Modeling Skills	Advanced SD Modeling Skills
General Business Administration	X			
Managerial Control Systems	X	X		
Seminar	X	X	X	
Master Thesis	X	X	X	
Research Purpose	X	X	X	X

Table 1: Need for SD at BTU

The quantitative demand for a system dynamics education at the BTU Cottbus can be divided into the three groups. The education in Management Accounting and Control Systems is for students of Business Engineering. But the audience is changing with the actual starts of new study programs (e.g. Business Mathematics). Table 2 shows the actual interest in the system dynamics approach.

Purpose \ approx. Persons	Business Engineering	Other Study Programs	Researcher at BTU Cottbus
General Business Administration	50-60	5	---
Managerial Control Systems	10-15	2	---
Seminar	10-15	1	---
Master Thesis	1	1	---
Research Purpose	---	---	6

Table 2: Actual Demand in SD at BTU

According to the continuous growing number of students and study programs at the BTU Cottbus the potential participants may increase further.

On the basis of the different interests we decided to start an introduction course in system dynamics. It is mandatory without credit points.

2 The Structure of the Coursework

2.1 Timetable and Contents

The system dynamics approach is used in several courses to teach students a wide range of subjects, as dynamic managerial control systems, project management and dynamic behavior of interacting systems. Most of these courses are taught in the winter semester. Therefore we installed the general introduction course to system dynamics within the same time schedule. The new course stands for its own and can be engaged separately. According to the objectives of the course we do not focus only on business applications, but add also examples from social, natural, and environmental sciences. This integrating approach correspond to the philosophy of integrative study programs at the BTU Cottbus.

The following figure presents the timetable in the winter semester 1999/2000.

unit	date	subject	block I	block II
	12.10.	no class		
1	19.10.	introduction to System Dynamics	C	---
2	26.10.	causal loops - structure and behavior	C	---
3	02.11.	problem analysis using causal loop diagrams	C	---
4	09.11.	basic terms of system dynamics modeling	C	---
5	16.11	Powersim: a modeling- and simulation software (the surface)	C	E
6	23.11	modeling of dynamic behavior of systems using Powersim	C	E
7	30.11.	analysis of dynamic behavior of systems	C	---
8	07.12.	use of dynamic behavior	C	E
9	14.12.	basic dynamic functions in Powersim	C	E
	21.12.	no class		
10a	04.01.	use of table functions	C	
10b		table functions in Powersim		C
11a	11.01.	the delay concept	C	
11b		delays in Powersim		C
12	18.01.	system dynamics archetypes	C	---
13	25.01.	conceptualization and modeling of a small complex system	C	E
	02.02.	no class (preparation week – managerial control systems I)		
	09.02.	no class (preparation week – exam in managerial control systems)		

L = lecture (90 min) E = exercises (90 min)

Table 3: Timetable of the SD Introduction Course

In total we have 15 units of lectures and 5 units of supervised exercises. The first four units define the basic framework of the course – the underlying theory, the general procedure to develop a system dynamics model, from the definition of the problem, the collection of data up to the causal loop diagramming and the transformation of the CLDs into a graphic system dynamics model.

The following thirteen units (no. 5-11b) concentrate on specific themes, divided into a theoretical lecture, its realization using the Powersim Constructor, and some examples and modeling hints.

The last three units bring us back to a more global view of system dynamics modeling. First the archetypes (see Senge 1990) are referred in detail. They are used to go through the

whole process – from problem definition to prototyping a computer model – after dealing a lot of hours with the methodological details. For this purpose some small case studies have been prepared.

Second the same process is presented for a more complex system. At that point case studies, research projects or even manager flight simulators can be introduced to the audience. In 1999/2000 we chose one of our actual research projects – a make-or-buy decision making problem - as the example in the class and discussed enhancements in the exercises. We think that this is a good possibility to attach the student’s interest to use system dynamics in his own studies.

2.2 Literature and other Material

There are a lot of points in the system dynamics approach that has to be rethought and redone several times before they fit. Listing to the lectures can only be the first step to understand system dynamics. Reading some important sources is the second. Because system dynamics literature is not very widespread we offer the students two literature lists:

- a short reading list (see table 4)
- a longer reference list (see table 5)

unit	subject	literature
1	introduction to System Dynamics	Forrester (1961, pp. 13-19; 43-66) Forrester (1972, pp. 9-18) Niemeyer (1977, pp. 25-30; 52-55) Vester (1990, pp. 17-35)
2	causal loops – structure and behavior	Goodman (1974, pp. 3-28; 35-51) Forrester (1972, pp. 88-91) Vester (1990, pp. 53-65)
3	problem analysis using causal loop diagrams	Kim (1992) Richardson (1986) Richardson (1997)
4	basic terms of system dynamics modeling	Forrester (1961, pp. 81-85) Niemeyer (1977, pp. 217-226) Roberts et al. (1983, S.223-242) Richardson, Pugh (1981, pp. 18-25;61-66)
5	Powersim: a modeling- and simulation software (the surface)	Seppänen (1996, pp. 15-46)
6	modeling of dynamic behavior of systems using Powersim	---
7	analysis of dynamic behavior of systems	Vester (1990, pp. 37-52; 105-110)
8	use of dynamic behavior	---
9	basic dynamic functions in Powersim	Richardson, Pugh (1981, pp. 115-132)
10a	use of table functions	---

10b	table functions in Powersim	---
11a	the delay concept	Forrester (1961, pp. 21-36; 86-92)
11b	delays in Powersim	Niemeyer (1977, pp. 227-236) Richardson, Pugh (1981, pp. 103- 115)
12	system dynamics archetypes	Senge (1990, pp. 378-390) or Senge (1996, pp. 455-471)
13	conceptualization and modeling of a small complex system	---

Table 4: The Reading List

Forrester, J.W. (1961). <i>Industrial Dynamics</i> , Productivity Press, Cambridge.
Forrester, J.W. (1972). <i>Grundzüge einer Systemtheorie</i> , Gabler Verlag, Wiesbaden.
Goodman, M. (1974). <i>Study Notes in System Dynamics</i> , Wright-Allen Press, Cambridge.
Kim, D. (1992). Guidelines for Drawing Causal Loop Diagrams. <i>The Systems Thinker</i> , no. 3, 5 - 9.
Niemeyer, G. (1977). <i>Kybernetische System- und Modelltheorie - system dynamics</i> , Vahlen Verlag, München 1977.
Richardson, G., and Pugh A. (1981). <i>Introduction to System Dynamics Modeling with DYNAMO</i> , Productivity Press, Portland.
Richardson, G. (1986). Problems with causal loop diagrams. <i>System Dynamics Review</i> , 2, no. 2, 158 - 170.
Richardson, G. (1997). Problems with causal loop diagrams revisited. <i>System Dynamics Review</i> , 13, no. 3, 247 - 252.
Roberts, N. et al. (1983). <i>Introduction to Computer Simulation - A System Dynamics Modeling Approach</i> , Productivity Press, Reading and others.
Senge, P.M. (1990). <i>The Fifth Discipline</i> , Currency Doubleday, New York and others.
Senge, P.M. (1996). <i>Die fünfte Disziplin</i> , 2 nd ed., Klett-Cotta Verlag, Stuttgart.
Seppänen, E. (1996). POWERSIM - A Tool for Building System Dynamics Models Version 2. <i>Economic Systems Reports</i> , no. 3/1996, 1-104.
Vester, F. (1990). <i>Unsere Welt - ein vernetztes System</i> , dtv Verlag, München.

Table 5: The Reference List

All the literature is available at the Chair. Some sources are available in German as well as in English. Of course these literature cannot support all needs of this course. Therefore we developed special slide shows for most of the units. They will be published later.

Additionally the students have full access to several other system dynamics resources at the Chair of Managerial Economics, Management Accounting and Control Systems:

- around 60 internet pages of system dynamics resources (all in German and English)¹
several downloadable system dynamics exercises²
- management flight simulators (Peoples Express[®], Beefeater^{®3} and some learning labs from the University of Bergen).
- a system dynamics literature database and
- the related archive which has been collected in the last five years. The archive itself contains around 1,500 literature sources.

For the modeling the students have access to a modern computer pool where they can use Powersim Constructor[®] 2.51⁴ not only within the lecture and exercises.

3 First Results and Further Targets

Introducing the course *Introduction to System Dynamics and Powersim* last winter semester for the first time and without any advertisement we had 21 students and two doctoral students taking part. In the course *Managerial Control Systems I* we had 55 participants doing the system dynamics home work exercises.

The future targets will be to attract more students to both – to the system dynamics course as well as to do further work in system dynamics (e.g. seminar thesis's and/or master thesis's). According to the positive response from other institutes at the BTU Cottbus, the diffusion of the system dynamics approach is another objective.

¹ German version: <http://www.wiwi.tu-cottbus.de/Controlling/index.htm>
(click on: *Forschung – System Dynamics*)
English version: <http://www.wiwi.tu-cottbus.de/Controlling/indexe.htm>
(click on: *Research – System Dynamics*)

² German version: <http://www.wiwi.tu-cottbus.de/Controlling/index.htm>
(click on: *Studium/Lehre – Controlling I*)

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⁴ *Powersim Constructor* is a registered trademark of Powersim AS, Isdalstø, Norway.