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Development of a measurement tool for sd-based learning activities in business subject matters

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Abstract

One consideration is that learning with System Dynamics is helpful for learners. It presumably supports the understanding of complex subject matters. Especially in the context of learning activities in school it seems to be an appropriate instructional alternative to avoid e.g. isolated or inert knowledge. Moreover researchers are exploring the effectiveness of various sd-based learning approaches e.g. exploring given models versus building models (ALESSI 2000).

The development of an diagnostic instrument for sd-based learning approaches is the core problem in the study (Hillen 2004). Trying to find out not only what concepts students learn, or how much they learn, the question evolved on what level (higher order thinking) students are able to express their learning residue. A well-known taxonomy is Bloom's one. According to FORRESTER this seems to be insufficient because of the missing perspective to dynamics.

To express an appropriate policy or to be aware of policy concepts is probably an essential competence for apprentices in business subject matters. This meets the demands in business life. Existing diagnostic approaches often stress declarative knowledge, sometimes structured knowledge too. The policy concept sensu FORRESTER (1968) interpreted as a quality of knowledge represents the basis of the developed diagnostic approach. Moreover the use of the policy concept avoids a break between the learning and the measurement approach. To take this concept into consideration can be seen as an advancement to existing concepts of knowledge respectively for measurement approaches.

Introduction

Besides knowledge and skills for handling routines there is a growing need for the ability of qualified office staff, to cope with complex processes (DÖRNER 1997). It has to be stressed that the occupation with complexity leads to the necessity of an elaboration via the student's mental model (figure 1). Moreover the dynamic which is inherent in such subject matters is often neglected. The aim is primarily to enable students to grasp such a dynamic complexity, to detect typical patterns of dynamic behavior, and to act due to these insights. The approaches to cope with this objective make use of modeling and simulation (FORRESTER 1968). A modeling assignment provides a learning environment which can foster students to think and handle in and about complex business subject matters.

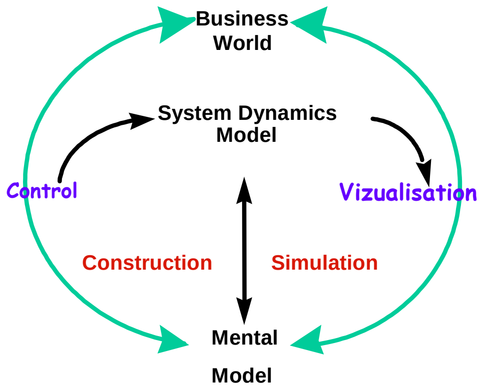

Figure 1: Elaboration via the mental model

The application of system dynamics in learning environments
A traditional view concerning learning processes is the taxonomy of Bloom.
A closer look to these different learning phases shows that the most critical and important step, the synthesis (5) starts just at the top of the hierarchy.

(5) synthesizing to assemble parts into a whole.
(4) analyzing to break material into constituent parts
(3) applying facts to generalizations
(2) comprehending meaning
(1) learning facts

One consideration for the application of the System Dynamics methodology in learning environments is to contrast this traditional orientation viz. the taxonomy of Bloom. NANCY ROBERTS (1978, S. 836) points out that most pupils do not reach this last fifth but important stage:

> "…putting it all together- should be placed *at the beginning* of the educational sequence. The problem is that 'higher order thinking' in the best case take place at the end of the learning process. ROBERT refers to BRUNER (1963, S. 26), "... claim on structure and principles in teaching is that ... one's able to narrow the gap between 'advanced' and 'elementary' knowledge."

With the modeling approach it is possible to counter these effects. The underlying structure of phenomena can be detected in a holistic view at the beginning of the learning process. System dynamics activities support and foster a systemic learning approach. The second deficit mentioned above is the absence of dynamic aspects in traditional learning environments. Workbooks or generally the print media are less apt for representing behavior or changes over time. In this respect J. W. FORRESTER, stresses that a mere static view to the structure is not enough (1992, S. 10):

> „The structure should show the dynamic significance of the detail – how the details are connected, how they influence one another, and how past behavior and future outcomes arise from decision-making policies and their interconnections."

Research background

In the application of these System Dynamics based learning environments this study refers to Salomon's 'cognitive tool' approach. His idea is that cognitive tools can extend the reach of mind. In this sense I pursue the embedding of the system dynamics approach in a learning environment to enable and support learning activities of students to business subject matters. Concerning these intentions the following hypotheses for the learning process and the learning effects are defined.

(a) Students can get access to business knowledge in a *deeper* mode by the simulation and modeling approach.

(b) Students acquire different qualities of knowledge by expressing it via the System Dynamics notation and the verbal (natural) language.

(c) Students acquire different qualities of knowledge by working in an approach of active modelling compared to the use of given models (micro worlds).

Deeper mode in this approach means more elaborated knowledge in the sense of well-structured knowledge additionally enclosing inherent aspects of dynamics.

Measurement tool

Knowledge about the SYSTEM	Category 1	Concepts
	Category 2	Simple linear structured knowledge
	Category 3	Chained linear structured knowledge
	Category 4	Chained l. structured knowledge with exogenous time delays
	Category 5	Knotted structured knowledge
	Category 6	Knotted structured knowledge with exogenous time delays
	Category 7	Circular structured knowledge
	Category 8	Circular structured knowledge with exogenous time delays
POLICY Concepts	Category 9	Action knowledge
	Category 10	Action knowledge with exogenous time delays
	Category 11	Simple policy concepts
	Category 12	Simple policy concepts with exogenous time delays
	Category 13	Constraint complex policy concepts
	Category 14	Complex policy concept

Figure 2: System of knowledge categories

The defined and operationalized categories refer to the definition or comprehension of policy concepts in accordance with the System Dynamics methodology (figure 2). The qualities of knowledge are differentiated in knowledge about the system - that means concepts, structural knowledge and its interrelations -, and complex concepts which are described as knowledge about policies. These results have been compiled via a verbal protocol analysis approach. The second approach is to compare the qualities of knowledge when students are working with given models in contrast to actively creating their own models. This will not be discussed further in this paper (Hillen 2004).

Data - data formats and coding

Data have been collected (n = 89 students) in vocational and economics education over a time-horizon of 2 years on the processes of active modeling with instructional support by means of worksheets. The consequence is that you get two different representation formats (data) described as learning explicates[1]. These are verbal explicates and sd-based explicates (models).
A system dynamic-model is a graphical explicate constructed by a student. The coding process use the categories of knowledge mentioned above (figure 2). The coding process takes every variation, step or change by an individual student (B2101342) during the construction process into consideration except from repetitions. This can be explained by the mental model approach (JOHNSON-LAIRD 1988). A mental model is viable till a 'new information' does not 'fit' and in consequence leads to its reconstruction or extension. New information can be 'evoked' by different means. One is through questions via worksheets. Complementary the structural organization can serve as an elaboration process and as well as the simulation itself which could lead to cognitive dissonance by unexpected simulation results (behavior over time graphs). Figure 3 shows the fourth stage of a constructed model on the business subject 'Marketing'.

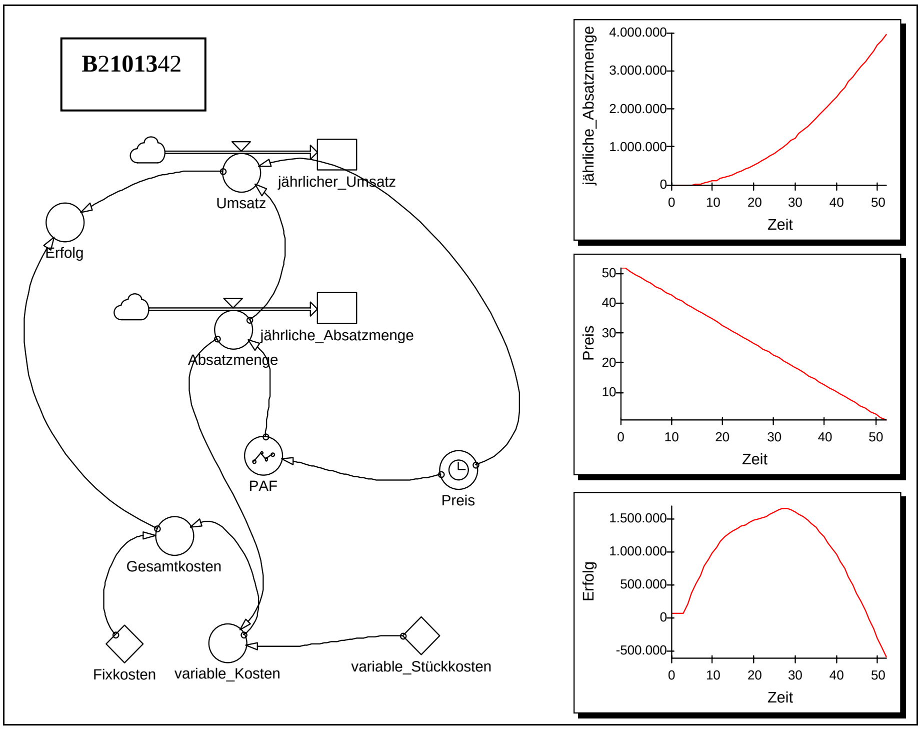

*Figure 3: Model state 4 of the student **B2101342***

[1] Learning explicates are 'products' of the learning processes over time which are supported by using the described learning approaches.

Other explicates of students learning processes and results are their verbalisations on the filled out worksheets (figure 4).
The coding processes take place by using the same categories in figure 1.

TN:	2101342				
LS:	Marketing expressiv				
		Data	Coding Unit		Coding Unit
	Question	*Students explanation*	*Reason*	*category*	*Reason*
	1	variable Stückkosten, Fixkosten, Preis-Absatz-Funktion	relevante Begriffe werden genannt		
Code:				*1*	
	2a (G)	Graf (Absatz, Preis, Umsatz)	Funktionaler Zusammenhang über Graf aufgestellt		
Code:				3	
	2b	Der Absatz steigt mit sinkendem Preis. Der Umsatz steigt mit sinkendem Preis, da der Absatz damit stärker steigt.	lin. Zusammenhang mit Polarität in Wirkungskette		
Code:				*3*	
	3	*Niveau:* Preis			

Figure 4: Encoded worksheet with categories

Learning explicates and interpretation of data

The qualitative learning results become derived via a 'content analysis' (FRÜH 2001) by a coding process respecting System Dynamics criteria for 'higher order thinking' (STERMAN 2000).
The inter-rater-reliability was measured with the following formula. The inter-rater reliability coefficient was 0,787.

$$CR = \frac{2\,\ddot{U}}{C_1 + C_2}$$

CR = Coder-Reliability
Ü = Quantity of similar codes
C_1 = Quantity of codes of Coder 1
C_2 = Quantity of codes of Coder 2

The results in figure 5 reveal in both representational formats appropriate[2] explicated concepts to the business subject 'Personnel'. The verbal explicates derived from the worksheets indicate many declarative concepts.
The learning explicates to the system dynamic-models additionally hold higher order concepts (policies).

[2] Only appropriate concepts to business subjects are taken for the coding process

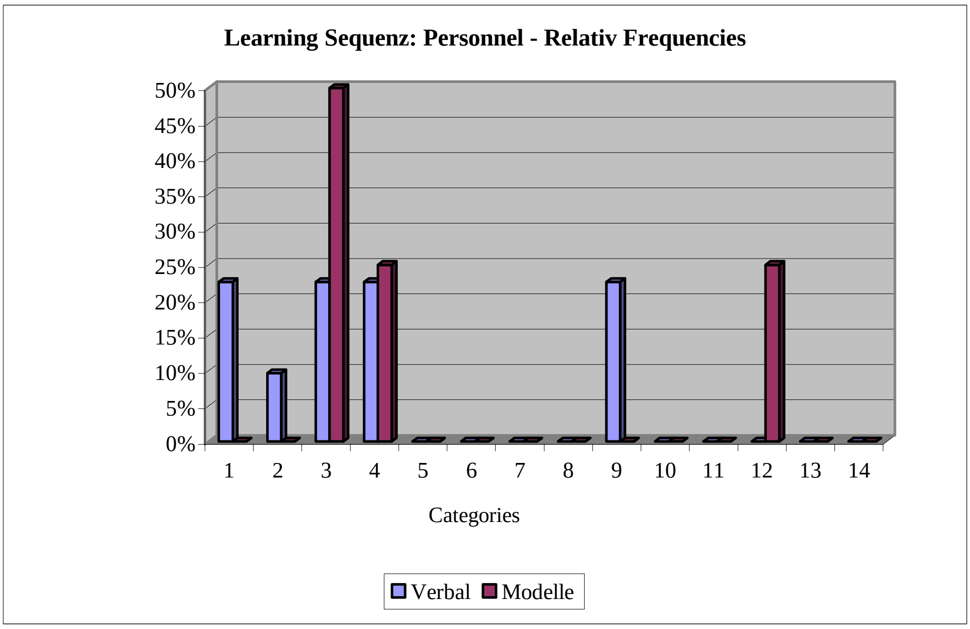

Figure 5: Comparison of the verbal and computer based explicates

Explanations to figure 5:

- Students describe or explain nearly the same what they have modelled (category 4).
- Many verbal concepts (category 1) are indicated and none are found in the system dynamics-models. This does not mean that students who are working with system dynamics models do not possess declarative knowledge. The coding system is hierarchical structured. That means declarative concepts are integrated in the structural knowledge. Declarative concepts are coded only implicit. The System Dynamics application support students less to define explicit declarative knowledge. Worksheets foster students to define more declarative concepts.
- The category 12 indicates knowledge about policy concepts respecting exogenous dynamic aspects. The System Dynamics application leads to higher order concepts.

Conclusions

Looking to the total of the learning sequences (figure 6) some questions about the contribution of an sd-based learning approach in learning processes can be answered.
The different notations support the acquisition of knowledge (knowledge about the system or knowledge about policy concepts) but in different respect. In the lower categories the acquisition of knowledge is predominantly expressed by 'verbal explicates', in the higher categories (policy concepts) the learning explicates are expressed by the sd-models. The result of the non parametric sign test shows a statistical difference between the both representational formats and a higher coding for sd-based explicates ($p<0.001$).

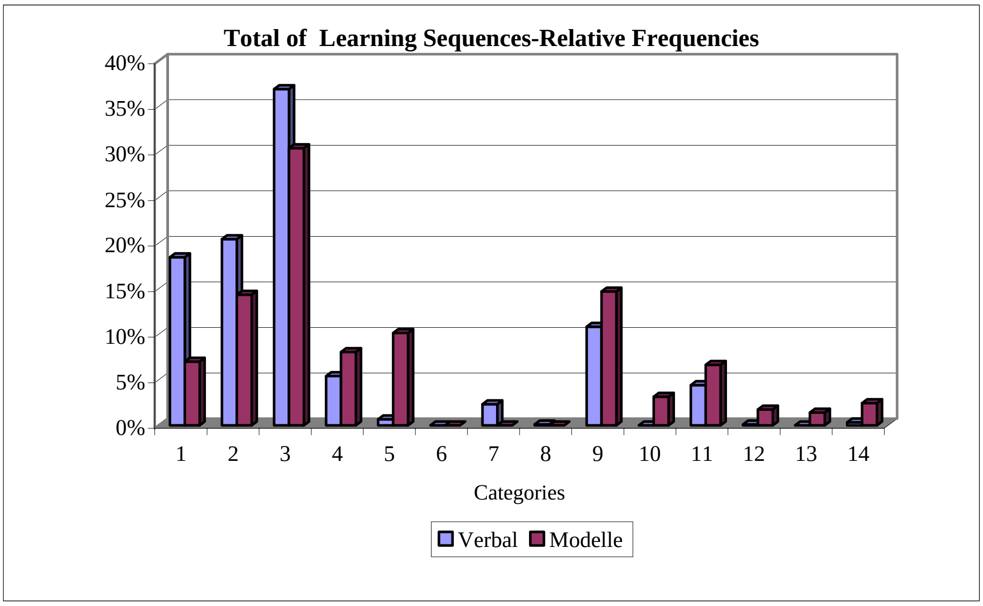

Figure 6: Total of the learning explicates in both notations

Other covariates are taken into account: The expertise of teachers with System Dynamics and the individual perception of the students concerning their learning environment. One remarkable result is that the expertise of the teacher has a leverage effect. The perception of the learning environment and the learning explicates results are correlating positively with the teachers expertise independently of the chosen methodical approach (Hillen 2004).

Existing diagnostic approaches often stress declarative knowledge, sometimes structured knowledge too. The policy concept sensu FORRESTER (1968) interpreted as a quality of knowledge represents the basis of the developed diagnostic approach. Moreover the use of the policy concept avoids a break between the learning and the measurement approach. To take this concept into consideration can be seen as advancement to existing concepts of knowledge respectively for measurement approaches.

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