Constructing an Interactive Learning Environment (ILE) to Conduct Evaluation Experiments

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Abstract

Evaluation research on interactive learning environments (ILE) is still in its infancy. Experiences made with other instructional media (for instance, interactive video) and with non-computer-based simulation games suggest that this is to a great share caused by asking the wrong questions. In the first part of this paper, it is briefly discussed why questions about the absolute efficacy of learning environments cannot be answered generally. In the same way, comparisons with other teaching methods are not fruitful. The only evaluation approach open for rigorous experimentation is testing of ILE which are systematically varied in one factor. The second part of this paper presents a prototypical ILE that was planned to allow for controlled variation of features. This ILE can be used for evaluation purposes very easily.

The effectiveness and efficiency of interactive learning environments (ILE) is still an issue of evaluation research. In order to build a comprehensive body of knowledge, common methods and research concepts are needed. For this purpose, different definitions of effectiveness and different forms of interactive learning environments have to be discussed and evaluated.

However, more technical questions need to be solved, too. These instruments, which are used to make people learn, are not equally suited to measurement of their effects on learning. For example, business simulators usually do not allow the tracking of user input; they do not contain validated scores that represent game performance; they do not provide possibilities for adapting them to different research questions and experimental settings.

In a course project a prototypical ILE was constructed with the above mentioned issues in mind. The domain of the ILE surrounds the management of different kinds of dynamic resources of a company. The program allows the game facilitator to vary certain experimental conditions online. For instance, the experimenter can change the levels of difficulty of the learning environment by setting values of model variables. Furthermore, the structure of the ILE is flexible, that is, components can be switched on or off and various game settings are possible.

The paper starts with a brief description of different forms of effectiveness of simulation tools and possible experimental designs for obtaining empirical data. In the next section, the prototypical interactive learning environment is presented. The focus of interest lies in the opportunities for experimentation. Finally, a sample experimental setting is described.

The Effectiveness of Business Simulators and Its Evaluation

Questions of the effectiveness and efficiency of business simulators or interactive learning environments (ILE) are still an issue of research.[1] Although there are some hints that these programs promote learning (Milling 1995, p. 106) their validity has not been proven yet. Further evidence is needed, if and how business simulators can enhance decision making through learning (Bakken, Gould and Kim 1994, p. 251). Even anecdotes and observations collected over decades can be misleading and are open to systematic errors (Doyle 1997, p. 7). Accumulation of reliable results is a precondition of scientific progress (Richardson 1996, pp. 145–147). It needs common research concepts, definitions, methods and procedures.

For this purpose, a clear definition of the objects of evaluation research (i. e., the business simulators) is needed. For a primary step in this direction, see Maier and Größler 1998. The constituting, interwoven parts of business simulators are three: underlying model, human-computer interaction component, and functionality as shown in Figure 1.

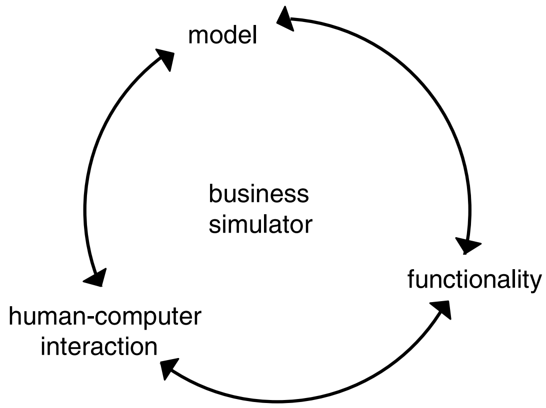

Figure 1: Three aspects of business simulators

In addition to the definition of the objects of evaluation, conceptual and technical issues concerning the rather vague term “effectiveness” must be clarified. This paper addresses the latter topic.

Business simulators are mostly used to promote learning.[2] Generally speaking, this means that they are effective if users *learn something*. In most cases, it is not clearly defined what users are supposed to learn when they fly a simulator. This is true in two ways: it is neither made explicit for the users nor have the developers or facilitators of simulators it clarified for themselves. In other words, usually interactive learning environments do not have clear learning objectives. Nevertheless, it is often stated that users should learn about the domain and about general behavior modes of complex, dynamic systems (Funke 1991, p. 208). In terms of Andersen et al. (1990, p. 38) these goals, however, would only be “meta-purposes”. Considering evaluation purposes, we agree with Andersen et al. when they continue with an appeal to make “meta-purposes” more concrete (p. 40). Without a clear statement of learning goals any evaluation becomes superfluous.

Without elaborating this point here, it is stated that knowledge acquisition has to be evaluated by examining changes in cognitive structure and performance. Together, these two are the measures in order to account for a complete learning process

(Spender 1998, p. 15). To consider only performance or only cognitive changes is not enough (Doyle 1997, p. 8).

As far as performance is considered, business simulators are effective in the short term. If simulators are internally valid users can be supposed to perform better in controlling these instruments after a certain period of time using them. Thus, performance and behavior have changed. But gains in explicable knowledge usually are difficult to prove because the connection between this form of knowledge and controlling often is delayed and distorted. This issue led to the discussion about implicit or tacit knowledge (Broadbent, FitzGerald and Broadbent 1986; against the assumption of implicit knowledge argues, for instance, Haider 1993). The term "tacit knowledge", however, indicates that some kind of knowledge acquisition occurs.

Usually, carry-over effects to other complex systems are intended; the transfer of insights is a learning goal. Users should not only be able to control a specific simulator better, but should also perform better controlling a certain range of complex, dynamic situations. The question is, if insights, which were acquired through simulation gaming, can be transferred to real life situations (Graham and Senge 1990, p. 103–104). Chances for a learning transfer to take place increase when the individual manages to create explicit, domain-independent knowledge. Whether, on the other hand, implicit knowledge can be transferred seems questionable. Because the acquisition of explicit (or even domain-independent) knowledge could not be proved in many cases, the capability of business simulators to stimulate a learning transfer has not been confirmed yet.

Connected with the question of transferability is whether users perform better in the long run.[3] There are only few studies regarding this because methodological (and ethical) problems are enormous (Funke 1995a, p. 211). For example, a better performance over ten years after using a business simulator can certainly not solely be accounted as an effect of this use. (See Norris and Snyder 1982 for an exploratory longitudinal study.)

As another important question remains whether business simulators are more effective than other training measures. For a lot of training methods can be assumed that they influence people in the way intended. They make people learn. Nevertheless, it is obvious that some methods are better suited in certain situations (in particular, for specific learning objectives) than others. The construct of effectiveness therefore is reduced to a relative meaning.

However, the question of the advantage of one training measure over another cannot be answered in general and, most of the time, even not for a specific learning situation. For example, let us assume three groups of students: one group is using a business simulator, the second is reading a textbook, and the third is attending a lecture about the very same topic. When conducting an experiment it can be assessed which training group learned the most in relation to the learning goals set. This comparison needs a simple pre and post test experimental design (Cook and Campbell 1979, pp. 103–118) and some statistical inference (Hayes 1994).[4] Additionally, let us assume that the business simulator group performed better than the lecture group, and this group better than the reading group.[5] Can now be concluded that one of the methods applied is generally more effective than another?

It cannot, because too many disturbing and interfering variables simply cannot be controlled, for instance, the quality of the lecturer (Schulmeister 1996, pp. 374–376). The only thing which can be concluded is that in this specific situation, with the given objectives, the given training methods, the given environment, and the given people a business simulator yielded better results than a lecture or a book. Most probably, not all parameter that determine this specifics are known to the experimenter. Therefore, results must not be generalized to all uses of that simulator, book, and lecture. And it must not at all be generalized to all conceivable business simulators, books, and lectures.

The problem of such comparative studies is that the methods under observation consist of a sample of characteristics which can be varied in essentially infinite ways (Stolurow 1962, p. 520).[6] The easiest way to obtain data about a comparison of different training methods—asking users about their opinions and impressions—can lead to objectively wrong and biased results (Marchionini 1989, pp. 607–608). Hawthorne-effects must be assumed for many comparison studies (Roethlisberger and Dickson 1939).

Also, efficiency matters. For example, do people learn faster (with less cost) when using a business simulator instead of reading a book about a subject? The argumentation can be equivalently transformed applying the universal rule of efficiency: given the same cost of two learning measures, does one measure yield better results than the other?[7]

Back to the example, let us assume the students used the business simulator for one hour, read the book for half a day, and attended the lecture lasting 45 minutes. Given the same ranking of effectiveness as above, it is not clear which method is more efficient. Imagine that the simulator group outperformed the lecture group just one percent in relation to the learning goals. Does this small advantage justify the cost of a longer learning time? Statements about efficiency can only be made if equal cost for the three methods are supposed. That is, one hour usage of simulator costs as much as half a day reading and as attending a 45 minutes lecture.[8] In this case, the business simulator indeed would be more efficient than the lecture and the textbook.

However, because of the problems of measuring relative effectiveness, this statement is limited to the specific situation, with the given objectives, the given training methods, the given environment, and the given people. Again, these results must not be generalized in a way that the simulator is more efficient than book or lecture in any case. And, once more, it must not at all be generalized to all conceivable business simulators, books, and lectures.

In summary, the (absolute) effectiveness of business simulators is trivial in a short-term view, given that suitable learning goals are specified. The (relative) effectiveness and the efficiency of these tools in comparison to other training methods can hardly be measured out of methodological reasons (Clark 1983, p. 450). The same holds true for longitudinal studies. What remains is the evaluation of different features of business simulators or different ways of the use of simulators. In this case, forms of simulation tools can be compared that differ in just one variable. This allows rigorous experimentation.

Systematic variations of exactly one characteristic of business simulators permits to find effective characteristics by which business simulators can be improved. (These characteristics are located in all three aspects of business simulators; see Figure 1 above. See also Wolfe 1985, pp. 275–281, for a comprehensive list of features of business games, which can easily be applied to interactive learning environments.) Design-guidelines for simulators can be verified using this experimental approach (if the guidelines are operational. See, for instance, Thurman 1993, p. 87, for a list of design issues and implications.) It becomes possible to identify features of business simulators which make them effective in a particular learning situation.

Thus, comparisons of interactive learning environments that differ in one feature are meaningful and useful. Such research uses business simulators as objects of interest *and* methods to obtain empirical data. At this point, one can also consider the double function of the used simulation tool in many experiments: it serves as a treatment as well as being a means to measure the results of such a treatment. Methodological problems concerning this point have not been discussed widely so far. See also Funke (1993, pp. 315–316), for a criticism aiming in the same direction and the claim for a clear distinction between knowledge acquisition and knowledge application.

In conclusion, the search for characteristics of business simulators which are effective for specific groups of users in specific situations can take over the place of a search for the absolute value of simulators. Because, as Bosco (1986, p. 15) pointed out in an analogy, "the question 'Are books effective in providing instruction' does not lead to a categorical answer. Rather, the answer to this question depends upon content of the book, the way it is being used, the objectives of instruction, etc." Therefore, consequences of the use of business simulators depend on various factors.

When conducting any kind of evaluation research not only characteristics of the learning tool business simulator have to be taken into account. What also needs to be considered are characteristics of the users and situational determinants business simulators are used in (Funke 1995b, pp. 250–251). See Figure 2 for an extension of Figure 1.

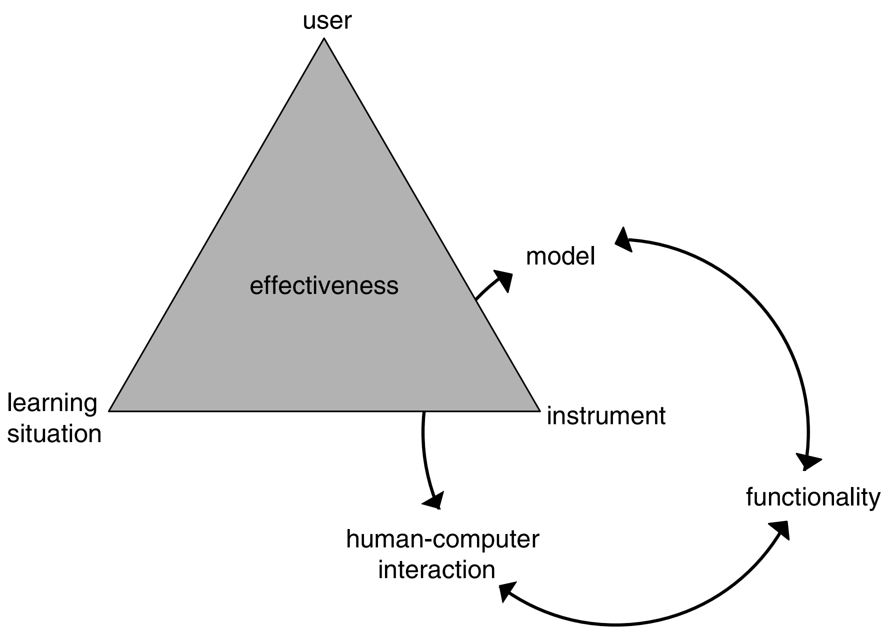

Figure 2: Components of evaluation research about the effectiveness of business simulators

Are Interactive Learning Environments Ready for Experimentation?

The rest of this paper deals with the more technical questions which need to be solved in order to conduct evaluation experiments as described above. Business simulators, which are used to make people learn, are not equally suited to measurement of their effects on learning. They do not provide possibilities for adapting them to different research questions and experimental settings. Usually, simulation tools are not build to allow an easy variation of variables, which are of interest to the researcher. Only the variation of exactly one factor permits controlled experimentation.

Following is a list of possible features of an "experimentation-friendly" business simulator: It allows

- to manipulate model variables which determine the difficulty of a scenario (for instance, initial values of levels, delay times, etc.),
- to set arbitrary time intervals (over-all gaming time, time per decision period, etc.),
- to select different levels of transparency of the underlying structure of the model,
- to let or let not user test their decisions in a "strategic mode",
- to have roles in competitive games played by humans or the computer (following different decision rules),
- to display different performance scores,
- to switch on or off different kinds of user-interfaces (that is, different modes of human-computer interaction, various modes of presentation of results and background information), and
- to track all user input.

Certainly, not in every evaluation study all of these features are needed. Nevertheless, a business simulator having these features would be a powerful instrument. It could serve for experimentation about effectiveness. But it could also be used for experiments in psychological research. In combination with better documented and validated models as the basis of a simulator, some of the issues mentioned against the use of simulators for this purpose (for instance, Süß, in print) would be less serious any more. For example, through experimentation with distinct kinds of scores valid and reliable ones could be found. Such a powerful tool would combine chances to study dynamic decision making, knowledge mediation, and psychological processes (Doyle 1997, p. 9).

Although, in general, these forms of experiments are possible with any business simulator it has hardly be done until today. One reason for this is a lack of interest in and knowledge about the topics described. Another reason, however, are technical difficulties in the implementation of such features. The rest of this paper shows the design and prototypical implementation of an interactive learning environment with some of the above listed features. It could serve as a guideline and reminder for other business simulators.

A Business Simulator to Manage the Resources of a Company

In a course project, the task was to create a prototypical ILE with the evaluation issue in mind.[9] The program should allow the game facilitator to vary certain experimental conditions in an easy way. In the rest of this section, the ILE is described from a user's point of view and the managerial background is presented. The next section contains examples and further possibilities how this ILE could be used to conduct evaluation experiments and shortcomings of the prototype.

Research in the field of strategic management suggests that firms obtain competitive advantages by implementing strategies that exploit their internal strengths, while neutralizing external threats and avoiding internal weaknesses. For a long time, management has tended to focus too narrowly on the position of products and market share as a basis for competitive advantage. On the contrary, the resource-based approach emphasizes that resources *within* the company have to be deployed to protect and to consolidate the company's market position. It goes back to 1984 when Wernerfelt's article „A Resource-Based View of the Firm" was published.

"Resources" refers to financial, physical, human, technological, and organizational resources of the company. They can be divided into *tangible* resources (for instance, equipment and raw material) and *intangible* resources (for instance, reputation, staff morale, and staff loyalty). To be a strategic asset and a sustainable source of competitive advantage, the company's resources have to be difficult to imitate and substitute.

Resources as seen by Dierickx and Cool (1989) are accumulated and depleted over time. Morecroft illustrates this idea in his article „The Rise and Fall of People Express: A Dynamic Resource-Based View" (1997) and shows that the described approach can be well represented by a system dynamics stock and flow structure as shown in Figure 3.

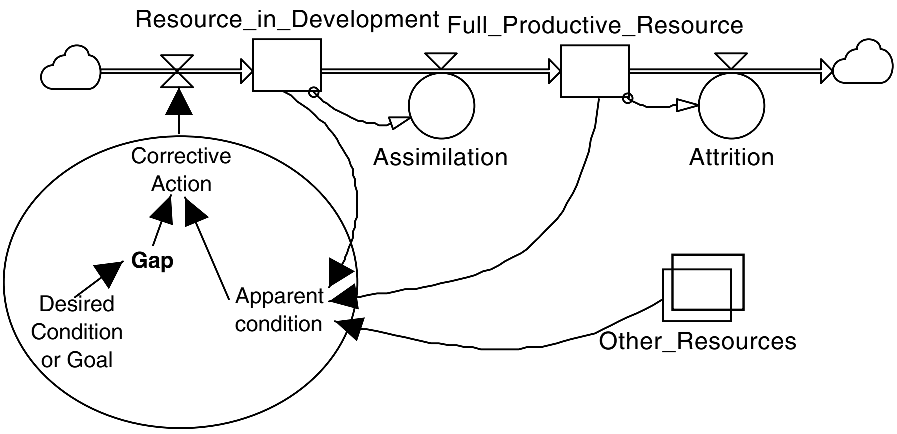

Figure 3: Stock and flow diagram of a strategic resource (after Morecroft 1997, p. 582)

Furthermore, Morecroft joins Dierickx and Cool's point of view that „a key dimension of strategy is the task of making appropriate choices about strategic expenditures with a view to accumulating required resources and skills" (p. 580) and classifies resources in *managed* and *unmanaged* resources. Unmanaged resources are often difficult to locate within the firm because they are invisible at the operating level. Furthermore, most unmanaged resources are intangible and therefore difficult to measure.

The purpose of the presented ILE is to improve the management skills of the user and to support learning about the resource-based view. In the business simulator four different sectors and resources have to be managed; each of them with different characteristics. (See Figure 4.)

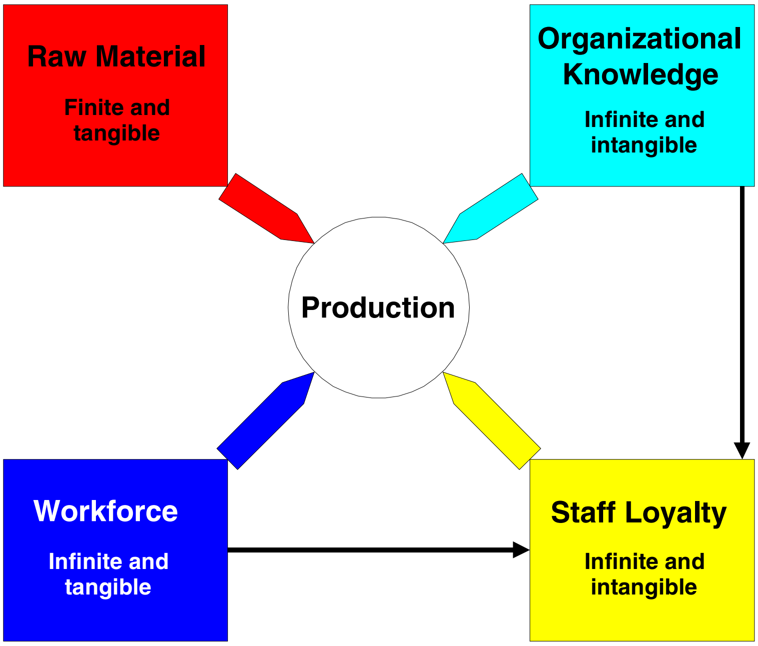

Figure 4: Resources used as examples in the ILE

"Raw material", "workforce" and "organizational knowledge" can be directly influenced by investments. The intangible resource "staff loyalty" is changed due to the state of the resources "workforce" and "organizational knowledge". The number of goods produced serves as performance indicator.

To broaden the users' view of resources, the simulation also includes a finite natural resource (raw material). Users have to pay attention to the depletion of this resource and decrease the dependency of production on raw material over time.

Learning objectives connected with the resource-based view are:

- to know about the accumulation and depletion of resources,
- to distinguish between tangible and intangible resources,
- to learn about finite and infinite resources,
- to understand that a "dominant logic" (that is, concentration on some resources) can lead to unforeseen results over time (Prahalad and Bettis 1986),
- and to manage resources in a competitive environment.

The business simulator presented here was created using Powersim®. Figure 5 shows the main screen of the application with some information about the meaning of different parts of the screen.

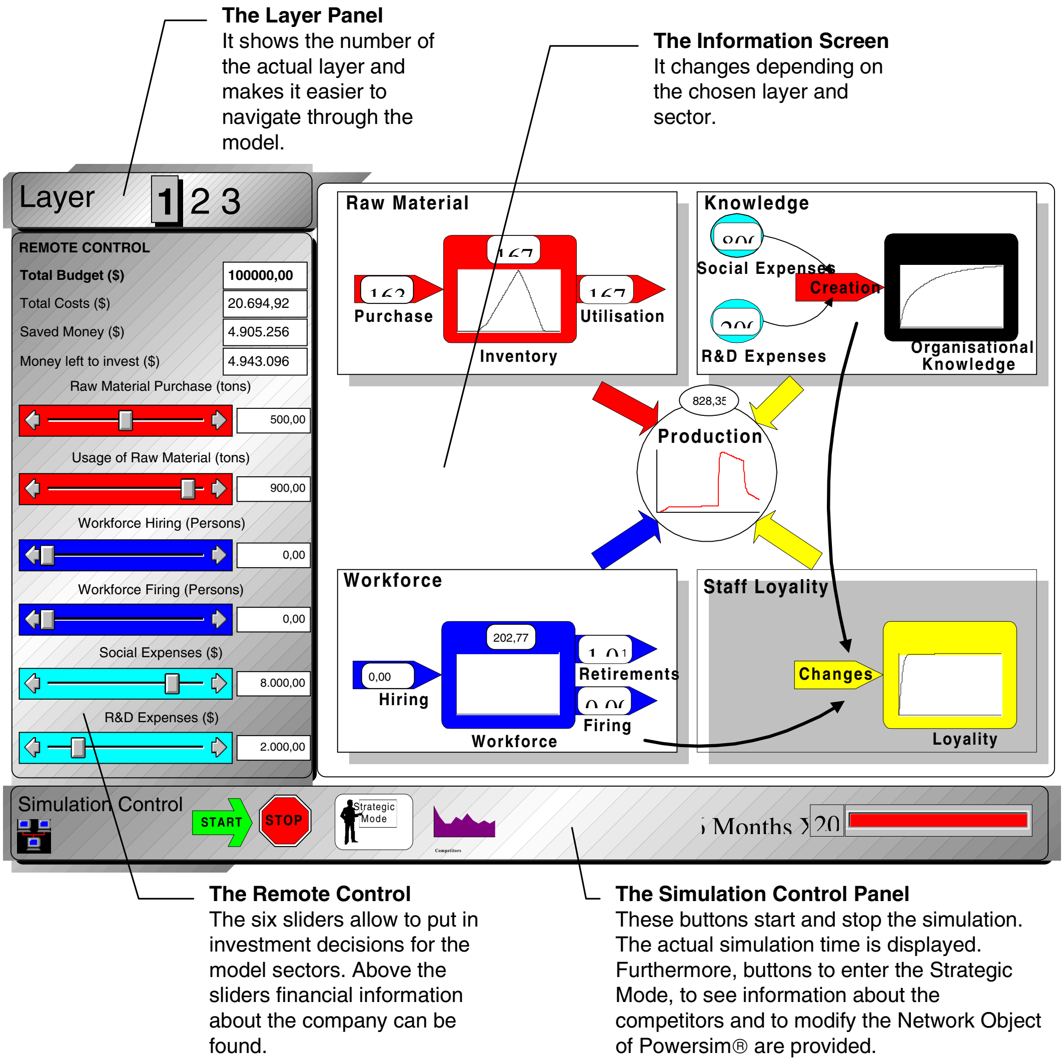

Figure 5: Main screen of ILE

The human-computer interaction component of the business simulator comprises three different layers of detail. The first layer (depicted in Figure 5) contains general information and an overview of the model. It is useful to gain insights about the relationships of the different model sectors. The second layer serves to provide a deeper understanding of a sector. It displays all information that is required to understand how the sector works. The third layer goes down to the smallest detail. The user can gather information about the utilised system dynamics structure and all contained variables. Figure 6 illustrates the different layers.

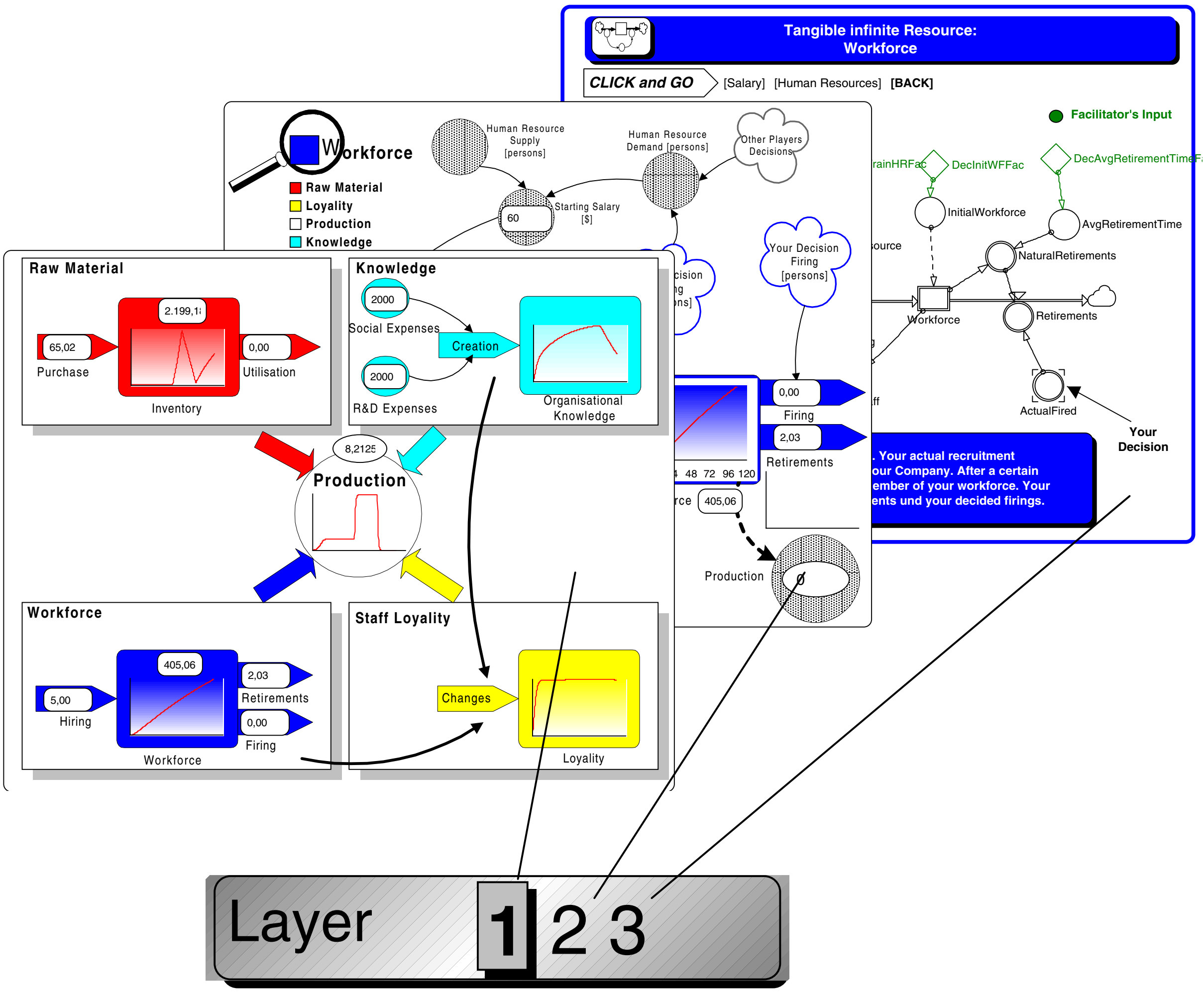

Figure 6: Three levels of detail in business simulator

The business simulator presented here is a networking game, that is, it can be used in a local area network. Up to four players (minimum one) can play and compete for common resources. It is possible to simulate one to three players by the computer. Players have the opportunity to try their decisions in a “strategic mode”. Thus, they can conduct if-then-analyses without advancing the actual simulation game.

The business simulator is embedded in a learning environment which contains additional material, for example,

- a cover story as a motivational factor,
- instructions how to handle the simulation,
- questions to guide reflection before and after using the simulator,
- information about the domain modeled,
- and links to additional sources of information (for example in the WWW).

Examples of Experimental Settings Using the Resources ILE

In addition to the up to four players, a facilitator can influence and observe the game. For this purpose, a special interface was created. Technically, the facilitator plays the role of a fifth player. Figure 7 depicts the main facilitator screen.

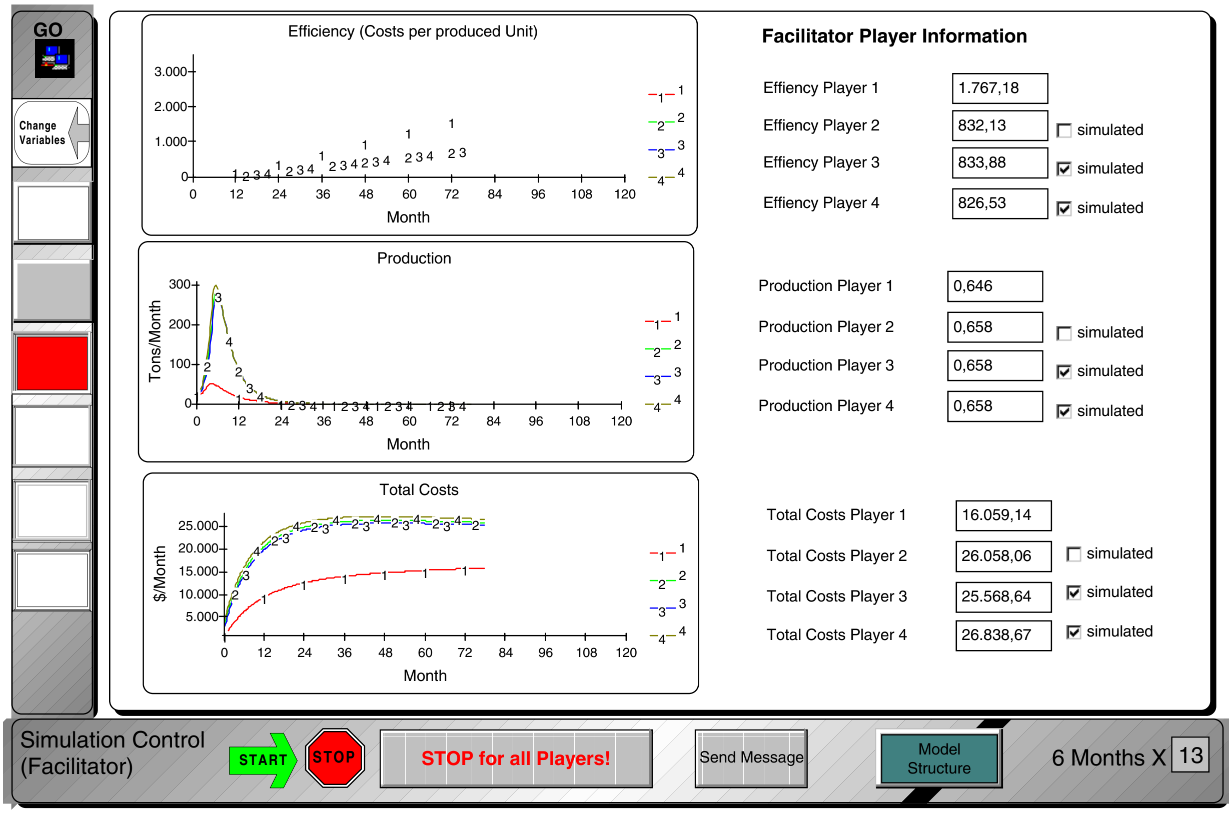

Figure 7: Main screen for facilitator

In the main screen, the facilitator can start and stop the simulation for all players. Messages can be sent to each player and the most important performance variables be monitored. However, the game facilitator/experimenter has more possibilities to influence the simulation and observe the proceeding of the game. Buttons on the left hand side allow to observe detailed behavior of the four players.

An experimenter can also lay down the value of many variables of the underlying system dynamics model. Delay times are the most prominent ones. For example, training time for new employees can be set. See Figure 8 for all input fields to influence model variables.

Further influence on the functionality of the business simulator—in this prototypical version—can be achieved by manipulating the network-game initialization files of Powersim® (`*.psn` and `*.pss` files) or through direct manipulation of Powersim® simulation controls. Through this mechanism the availability of a "strategic mode", the number of processing periods per decision step, initial values of level variables, and the automatic progression of the simulation can be effected. In a next, more elaborate version of the ILE these functions are planned to be built-in the facilitator's interface, too.

Let us describe one application of such advanced possibilities for experimentation. The three layers of detail in this business simulator (as discussed above) are not only meant to allow easier user navigation. They also permit to conduct experiments about different levels of transparency. Therefore, the experimenter can conduct gaming session with or without Layer 2 or Layer 3, so that users have only coarse information, detailed information or comprehensive information available. This provides the possibility for research on transparent-box business simulators (Machuca et al. 1998; Größler 1998).

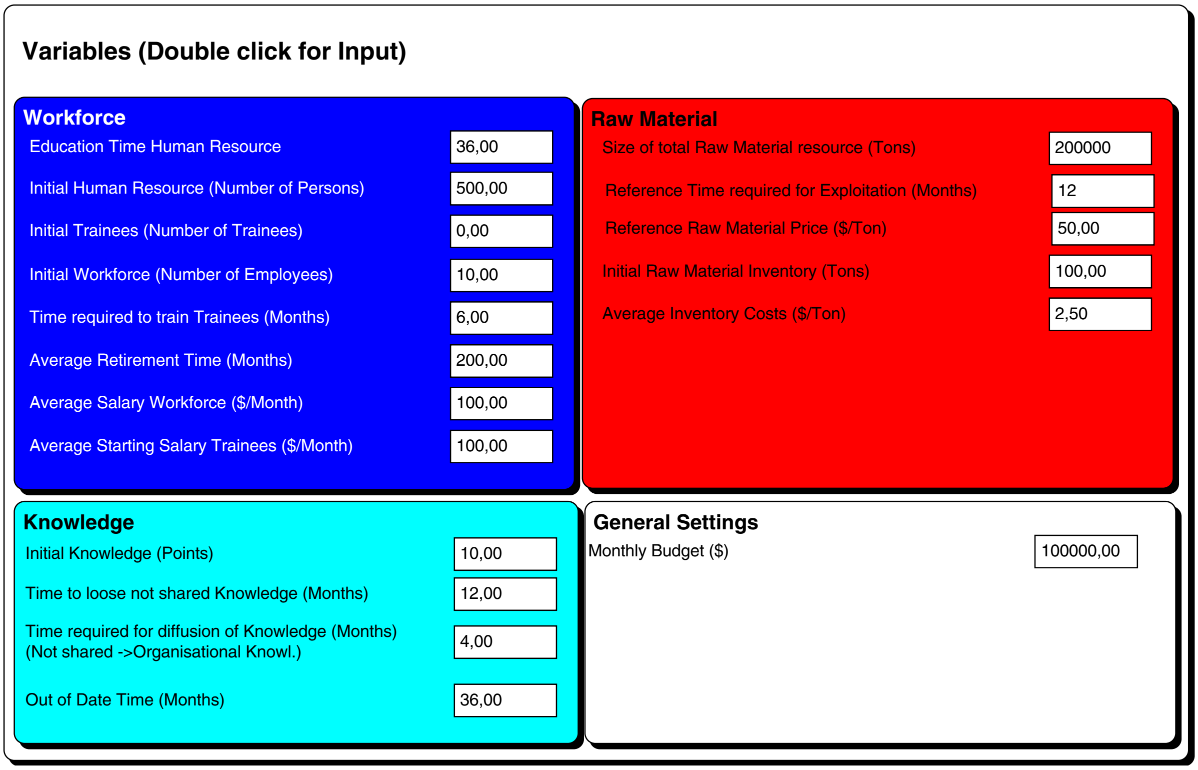

Figure 8: Screen to configure model variables

With the help of these features, it becomes easier for a facilitator to conduct evaluation experiments following the classical pre test/post test control group design. With a suitable knowledge test to assess changes in knowledge of the users, this experimental design looks as depicted in Figure 9.

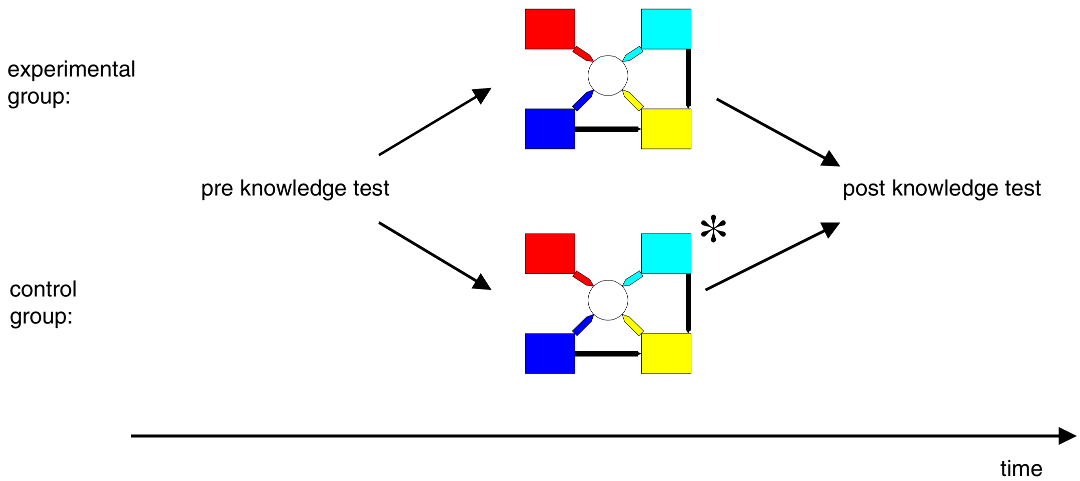

Figure 9: Pre test/post test experimental design with control group using ILE

Pre and post knowledge test are equal for all groups. They are used to evaluate changes in the cognitive structure of the subjects. Performance is evaluated with the ILE (for example, efficiency of production), which also serves as treatment. Therefore, in the control group the ILE runs with a known, fixed variable setting (for instance, default values). The experimental group uses an ILE that is modified in one variable. This variation can be easily done with the help of the facilitator's interface.[10] Differences between experimental and control group in performance or knowledge are presumably due to the variation of this variable—if they are statistically significant.

However, only an initial share of the points listed above for an experimentation-ready ILE could be achieved with this prototype. From its concept, the ILE provides opportunities for experimentation. As just mentioned, many features of the model and the user interface can be changed, but not in an as easy way as we wished. Still necessary in some cases are, for example, changing of initialization or configuration files. We have not touched the important point of different, validated performance indicators. There are mainly two reasons for these issues:

1. A limitation in resources for development of the ILE (three persons, five weeks).
2. Technical problems and inflexibility of the used simulation and development tool. In this area, the re-programming of the interface components and simulation controls in an all-purpose programming language would definitely offer big potential. The development of the system dynamics model could still be done with Powersim®.

Thus, only explorative studies have been conducted with the help of the ILE presented so far. Nevertheless, the impact of it lies in two points: Firstly, it is a paradigm for future ILE, which should be created with evaluation purposes in mind. Secondly, an improved and enhanced version of the ILE can definitely be used in experiments about the effectiveness of business simulators as laid down in the beginning of this paper.

The first part of this paper showed that questions of absolute or relative effectiveness of interactive learning environments can hardly be answered. Like with other teaching methods, the efficacy of simulation games depends on situation, tool, and learner. Statements about a simulator's effectiveness are only reasonable in such a specific context. However, in order to improve business simulators, these tools can be assessed using an experimental approach. Thus, two simulations are compared which differ in exactly one feature. Usually, business simulators are not built to support experimentation. Therefore, a prototypical ILE was presented that allows an easy variation of important model variables.

References

Andersen, D. F., Chung, I. J., Richardson, G. P. and Stewart, T. R. (1990). Issues in Designing Interactive Games Based on System Dynamics Models. In Andersen, D. F., Richardson, G. P. and Sterman, J. D. (eds.), *Proceedings of the 1990 International System Dynamics Conference*, Chestnut Hill, pp. 31–45.

Bakken, B. E., Gould, J. and Kim, D. (1994). Experimentation in Learning Organizations: A Management Flight Simulator Approach. In Morecroft, J. D. W. and Sterman, J. D. (eds.), *Modeling for Learning Organizations*, Portland, pp. 243–266.

Bosco, J. (1986). An Analysis of Evaluations of Interactive Video. *Educational Technology*, May 1986, 7–17.

Broadbent, D. E., FitzGerald, P. and Broadbent, M. H. P. (1986). Implicit and Explicit Knowledge in the Control of Complex Systems. *British Journal of Psychology* 77, 33–50.

Clark, R. E. (1983). Reconsidering Research on Learning from Media. *Review of Educational Research* 53(4), 445–459.

Cook, T. D. and Campbell, D. T. (1979). *Quasi-Experimentation. Design and Analysis Issues for Field Settings*, Boston et al.

Dierickx, I. and Cool, K. (1989). Asset Stock Accumulation and Sustainability of Competitive Advantage. *Management Science* 35(12), 1504–1510.

Doyle, J. K. (1997). The Cognitive Psychology of Systems Thinking: An Agenda for Collaborative Research. In Barlas, Y., Diker, V. G. and Polat, S. (eds.), *15th International System Dynamics Conference: Systems Approach to Learning and Education into the 21st Century*, Istanbul, pp. 7–10.

Funke, J. (1991). Solving Complex Problems: Exploration and Control of Complex Systems. In Sternberg, R. J. and Frensch, P. A. (eds.), *Complex Problem Solving – Principles and Mechanisms*, Hillsdale/Hove, pp. 185–222.

Funke, J. (1993). Microworlds Based on Linear Equation Systems: A New Approach to Complex Problem Solving and Experimental Results. In Strube, G. and Wender, K. F. (eds.), *The Cognitive Psychology of Knowledge*, Amsterdam, pp. 313–330.

Funke, J. (1995a). Erforschung komplexen Problemlösens durch computerunterstützte Planspiele: Kritische Anmerkungen zur Forschungsmethodologie [Research on Complex Problem Solving with Computer-Based Planning Games: Critical Comments on the Research Methodology]. In Geilhardt, T. and Mühlbradt, T. (eds.), *Planspiele im Personal- und Organisationsmanagement*, Göttingen, pp. 205–216.

Funke, J. (1995b). Experimental Research on Complex Problem Solving. In Frensch, P. A. and Funke, J. (eds.), *Complex Problem Solving – The European Perspective*, Hillsdale/Hove, pp. 243–268.

Graham, A. K. and Senge, P. M. (1990). Computer-based Case Studies and Learning Laboratory Projects. *System Dynamics Review* 6(1), 100–105.

Größler, A. (1998). Structural Transparency as an Element of Business Simulators. In System Dynamics Society (ed.), *Proceedings of the Sixteenth International Conference of the System Dynamics Society*, Québec City, p. 39.

Haider, H. (1993). Was ist implizit am impliziten Wissen und Lernen? [What is Implicit with Implicit Knowledge and Learning?]. *Sprache und Kognition* 12(1), 44–52.

Hayes, W. L. (1994). *Statistics*, 5th edition, Fort Worth et al.

Kerres, M. 1998. *Multimediale und telemediale Lernumgebungen* [Multimedia and Telemedia Learning Environments]. München/Wien.

Klein, R. D. and Fleck, Jr., R. A. (1990). International Business Simulation/Gaming: An Assessment and Review. *Simulation & Gaming* 21(2), 147–165.

Köbberling, A. (1971). *Effektiveres Lehren durch Programmierten Unterricht?* Weinheim/Basel/Berlin.

Machuca, J. A. D., del Castillo, J. C. R., Carrillo, M. A. D. and Zamora, M. M. G. (1998). Our Ten Years of Work on Transparent Box Business Simulation. In System Dynamics Society (eds.), *Proceedings of the Sixteenth International Conference of the System Dynamics Society*, Québec City, p. 5.

Maier, F. H. and Größler, A. (1998). A Taxonomy for Computer Simulations to Support Learning about Socio-Economic Systems. In System Dynamics Society (ed.), *Proceedings of the Sixteenth International Conference of the System Dynamics Society*, Québec City, pp. 57–58.

Marchionini, G. (1989). Making the Transition from Print to Electronic Encyclopedias: Adaptation of Mental Models. *International Journal of Man-Machine Studies* 30(6), 591–618.

Milling, P. (1995). Organisationales Lernen und seine Unterstützung durch Managementsimulatoren [Organizational Learning and its Support through Management Simulations]. *Zeitschrift für Betriebswirtschaft, Ergänzungsheft 3/95: Lernende Unternehmen*, 93–112.

Morecroft, J. D. W. (1997). The Rise and Fall of People Express: A Dynamic Resource-Based View. In Barlas, Y., Diker, V. G. and Polat, S. (eds.), *Proceedings of the 15th International System Dynamics Conference*, Istanbul, pp. 579–586.

Norris, D. R. and Snyder, C. A. (1982). External Validation of Simulation Games. *Simulation & Games* 13(1), 73–85.

Prahalad, C. K. and Bettis, R. A. (1986). The Dominant Logic: A new Linkage between Diversity and Performance. *Strategic Management Journal* 7, 485–501.

Richardson, G. P. (1996). Problems for the Future of System Dynamics. *System Dynamics Review* 12(2), 141–157.

Roethlisberger, F. J. and Dickson, W. J. (1939). *Management and the Worker*, Cambridge.

Schulmeister, R. (1996). *Grundlagen hypermedialer Lernsysteme: Theorie, Didaktik, Design* [Foundations of Hypermedia Training Systems: Theory, Didactics, Design], Bonn et al.

Spender, J.-C. (1998). The Dynamics of Individual and Organizational Knowledge. In Eden, C. and Spender, J.-C. (eds.), *Managerial and Organizational Cognition*, London/Thousand Oaks/New Delhi, pp. 13–39.

Stolurow, L. M. (1962). Implications of Current Research and Future Trends. *Journal of Educational Research* 55(9), 519–527.

Süß, H.-M. (In print). Intelligenz und komplexes Problemlösen [Intelligence and Complex Problem Solving]. To be published in *Psychologische Rundschau, Themenheft "Komplexes Problemlösen"*.

Thurman, R. A. (1993). Instructional Simulation from a Cognitive Psychology Viewpoint. *Educational Technology, Research and Development* 41(4), 75–89.

Wernerfelt, B. (1984). A Resource-Based View of the Firm. *Strategic Management Journal* 5, 171–180.

Wolfe, J. (1985). The Teaching Effectiveness of Games in Collegiate Business Courses. *Simulation & Games* 16(3), 251–288.

Notes

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1. Both terms, "business simulators" and "interactive learning environments" are synonymously used in this paper. For a more detailed definition see, for instance, Maier and Größler 1998.
2. As the term "business simulators" already implies, the domain of these tools are business and economics. Most of the statements in this paper, however, can be applied to simulators from other domains as well.

3. Klein and Fleck (1990, p. 156) argue that classical pre and post tests measure what they call the "recall effect", not a learning effect. However, this seems to be dependent on the validity of the tests used.
4. A validated test to measure learning success is assumed.
5. According to Clark (1983, p. 453) educational media are just "vehicles for instruction". What matters is content. Thus, any teaching measure can lead to any learning objective in principle. However, "certain elements" seem to facilitate learning. For example, gaming simulations seem to be well suited to teach dynamically changing matters (Reigeluth and Schwartz 1989, p. 2).
6. Köbberling (1971, pp. 5–7) discusses the possibility to achieve reliable statements about the relative effectiveness of training methods in specific situations. This ought to be done through a substantial number of replicated "evaluative experiments."
7. Hays and Singer (1989, p. 140) briefly describe different concepts for cost analysis of training measures.
8. Neglecting at this point different cost of developing the discussed measures of education. In particular for computer-based methods, the development cost are relatively high: Kerres (1998, p. 122) gives an estimation of 10,000 to 30,000 Euro per one hour of Computer-based Training. However, cost estimation for the development of business simulators have not been given in the literature yet.
9. Course on "Interactive Learning Environments" as part of the master program in system dynamics at the University of Bergen, Norway. Lecturer was Pål Davidsen whose support is gratefully acknowledged.
10. Of course, every experimentation should be initiated by theoretical thoughts and be guided by well-formulated hypotheses.