To Main Proceedings Document

Methodological Issues of Using Business Simulators in Teaching and Research

Andreas Größler
Industrieseminar der Universität Mannheim
D - 68131 Mannheim, Germany

Phone: (+49 621) 181-15 83, Fax: (+49 621) 181-15 79
E-mail: agroe@gmx.de

Abstract

Business simulators can be used for psychological experimentation and for teaching purposes. It is briefly discussed why these uses seem promising. The teaching effectiveness can be tested in evaluation studies comparing two slightly varied simulators. In both cases, psychological experiments and evaluation, methodological issues can occur which are due to the nature of experimenting, but are also caused by specific characteristics of simulators. Twelve issues can be identified. It is shown how a formal development process for business simulators can mitigate some of the potential problems. Therefore, a prototypical life-cycle model of the development of business simulators is described.

Business simulators and interactive learning environments are promising tools for teaching and psychological research.[1] In teaching, business simulators are used to mediate systemic knowledge: knowledge about the relationship between structure and behavior. In psychological research, complex simulation environments are used to assess subjects' behavior in complex situations and their capability to control such situations.

The teaching effectiveness of business simulators has not been proved so far. To a certain degree, this lack of empirical evidence is caused by a wrong approach towards evaluation: the effectiveness and efficiency of simulation tools is either trivial or cannot be proved in general. In addition to that, however, many experimental approaches are affected by methodological shortcomings. Basically the same issues have to be taken into account, if business simulators are used to conduct psychological experiments. In both cases, subjects or learners are experiencing a virtual, complex situation. Thus, the only difference between these two forms of using simulators (either as a training or research tool) is that in teaching long-term changes in the cognitive structure of the subjects are intended, which is not the case with psychological experiments.

In this paper, twelve (plus one) issues of business simulators are extracted from the literature and presented in a structured form. Examples are provided in order to illustrate potential problems when conclusions concerning teaching effectiveness or psychological characteristics are to be drawn. Methods to improve either business simulators or experimental methodology are described that should mitigate the effects of the issues presented.

The Use of Business Simulators for Training and Research

Business simulators are mainly used for two purposes: in teaching, they are expected to help students understanding principles of dynamic systems; in research, they are used to investigate human decision making in complex situations and to understand the human mind.

Why business simulators could be seen as effective tools to make people learn about dynamic cause-effect-relations can be concluded with the help of two lines of argumentation. The first argument compares business simulators with (the disadvantages) of conventional teaching methods. The other argument discusses current strands in theoretical instructional research and their relation to the instruments actually in use for teaching.

Stein Greenblat (1988, p. 16) identifies five disadvantages of conventional teaching (she takes a lecture with discussion as an example). These disadvantages are contrasted by characteristics of simulation games, which could help solve the problems identified before (Table 1).

Disadvantages of lectures (with discussion)	*Solution by business simulators*
Learners are mostly passive	Learners have to be active (learning by experience)
Material must be presented in a strict, sequential order that is determined by teacher	Only task determines order of material that can, therefore, mostly deliberately be chosen by the learner
Discussions are characterized by social hierarchies or what is socially desirable	Discussions are characterized by experiences made with simulator
Systemic, holistic points of view are difficult to mediate	Students are forced to achieve a systemic view in order to manage the simulators successfully
Verbal descriptions are interpreted differently	Terms are defined by their use in the simulation

Table 1: Comparison of conventional and teaching with business simulators

In a similar way, Richmond (1993, p. 26) contrasted a teacher-oriented style of teaching/learning with student-oriented teaching/learning, which emphasizes the role of an active learner. In Richmond's view, business simulators are tools to support this paradigm of student-orientation.

Following a more theoretic approach towards the supposed effectiveness of business simulators, Stein Greenblat (1981, p. 140) lists six propositions of teaching theory that seem to illustrate the adequacy of business simulators for teaching complex issues:

1. The human cognitive apparatus is not seen as a container any more that can be filled with knowledge, but knowledge is constructed (constructivism; Duffy and Jonassen, 1992).
2. More important than "static" knowledge is the ability and the motivation to learn.
3. Active exploration and self-controlled search for learning resources are considered crucial to avoid inert knowledge.
4. Learning has no value itself but must be goal-oriented.

5. Learning occurs when students are actively engaged with objects.
6. Finding and analyzing relevant information in an abundance of data is necessary to understand complex systems.

In this sense, business simulators can even be superior than reality because they provide possibilities for experiential learning with direct and immediate feedback about the consequences of decisions (Lane, 1995, p. 610). According to Goodyear et al. (1991, p. 274) these seemingly positive effects of business simulators can be summarized in a way that

> „simulation-based learning is usually expected to motivate, to invite active and deep processing of subject matter, to allow for systematic exploration, for fruitful failure, and for unlimited practice, all of which should contribute to better learning outcomes, reduced learning time, or both.“

However suggestive these arguments are, they are no proof for the teaching effectiveness of business simulators. There is only little evidence in the literature that simulators are as effective as they are supposed to be (Lane, 1995, p. 613). Most papers about this topic only report on anecdotal data and not on empirical evidence. Those papers, which try to collect empirical evidence, often show methodological shortcomings. However, in order to justify their further and extended use, 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, p. 145). There is a need for common research concepts, definitions, methods and procedures. And it needs a reduction of methodological problems in the evaluation studies.

But, as said before, business simulators are not only used for teaching purposes. In a 1993 paper, Brehmer and Dörner describe business simulators as tools to conduct psychological research. In this case, simulators are used to investigate the decision making process of subjects in complex situations. This investigation is done in order to draw conclusions about the human mind, reasoning processes, and the ability of subjects to handle apparently chaotic situations. (For a review of experiments with simulators see, e. g., Funke, J., 1991, p. 188.)

The most prominent reason for using simulators in psychological research is "ecological validity" (Buchner, 1995, p. 28). Unlike in classical experiments, can subjects—with the help of simulators—be confronted with a real-world problem in a context which is as complex as reality. Because simulators are, however, only a "virtual reality", experiments can still be conducted within a laboratory (i. e. controlled) setting. Furthermore, simulators allow experimentation without being confronted with real world consequences. They make experimentation possible and useful, when in the real world situation such experimentation would be too costly or—for ethical reasons—not feasible; or where the decisions and their consequences are too broadly separated in time. Other reasons for the use of simulators are the possibility to replicate the initial situation, and the opportunity to investigate extreme conditions without risk (Pidd, 1992, p. 7; Milling, 1996, p. 1841).

Although the use of simulators for research purposes seems promising when higher mental processes are to be examined, there has also been a discussion about the usefulness and adequacy of simulators out of methodological reasons. The rest of this paper focuses on these concerns and applies them also to evaluation studies with business simulators.

12 (+ 1) Issues of Business Simulators

When conducting evaluation research, not only characteristics of the learning tool business simulator have to be taken into account. What also has to be considered are characteristics of their users and situational determinants (Funke, 1995a, pp. 250–251). Figure 1 depicts the three influencing factors on evaluation studies: instrument, user, and learning situation. The instrument (= business simulator) is composed of three components as well, namely underlying formal model, human-computer interaction (user interface) and functionality provided within the game (Maier and Größler, in print).

The figure also symbolizes what evaluation research can achieve: the search for characteristics of business simulators, which are effective for specific groups of users in specific situations, must take over the place of a search for the absolute effectiveness 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."

Thus, comparative evaluation studies about the effectiveness of two slightly varied business simulators are the only reasonable evaluation studies for business simulators (Größler, Notzon and Shehzad, 1999).

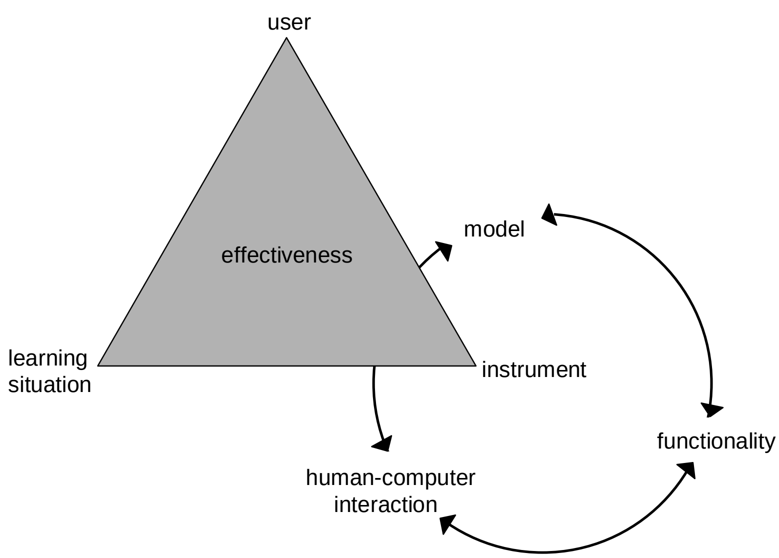

Figure 1: Components of evaluation research about the effectiveness of business simulators

In the psychological literature, a list of unsettled methodological issues of using business simulators as instruments for psychological purposes are identified. It is described that—in order to achieve valid data—some topics concerning simulators and their use have to be clarified. These issues, however, can be also interpreted as representing problems of evaluation research about the teaching effectiveness of business simulators. Thus, most of the issues mentioned in the following are relevant for evaluation research as well.

Twelve problem fields of simulators in scientific studies can be identified (Funke, 1995b, pp. 207–210; Süß, 1999, pp. 221–222; Keys and Wolfe, 1990, p. 324). In the following list, these twelve issues are categorized into the three components of evaluation research identified above (although this categorization cannot be done exclusively). Furthermore, some brief ideas are presented, how problematic influences on the validity of experiments and evaluation studies can be lessened.

1. Characteristics of instrument used

    1.1. **Validity of model**. While business simulators are based on formal models, the real-world domain itself usually is not completely open to formal description. Therefore, the validity of the simulation often depends on the ability, knowledge, and experience of the modeler. For external validity, this is in particular true when qualitative relations are to be modeled (for instance, the relationship between image of a firm and its market share). Nevertheless, in some experimental contexts, external validity is not necessary (and not desired, for example, in order to suppress influences of existing knowledge about a domain). In contrast to external validity, we call a simulator internally valid if its behavior follows sound and logical rules. Internal validity of the simulator, therefore, is a prerequisite for any use as a research tool. While this is an issue that cannot be solved ultimately, it can, nevertheless, be mitigated by a careful validation process of the business simulator (Barlas, 1996, p. 200; see also below) and by thorough education of modelers and designers.

    1.2. **Level of abstraction**. The right level of abstraction and detail of a simulation cannot formally be determined. Which level of detail, which information is necessary to understand a scenario, which is superfluous? This point is connected with not fully understood effects of information about the context of the scenario. Instructional design might provide answers or more detailed decision heuristics in the future concerning this basic question.

    1.3. **Handling of time**. The "compression of time" in business simulators could affect users. For example, the process of planning and controlling a scenario might also be compressed in comparison to real world decision making processes. (On the question of different types of "time" in business simulators, see Größler, 1999). The validity of a score based on control performance, therefore, can be doubted. However, "compression and expansion of time" are major advantages of business simulators (Kim, 1989, p. 327) which cause, on the other hand, problems with experimentation. Business simulators with adjustable time frames can be used to investigate this problem (Größler, 1999).

    1.4. **Too complex**. Some simulators are so complex (regarding number and interconnectedness of variables, dynamic behavior, handling of user interface; Packer and Glass-Husain, 1997, p. 80) that subjects are not able to control them. They just use trial-and-error strategies while gaming. Performance scores are not valid in this case. Lane (1995, pp. 605–607) discusses the trade-off between fidelity (or ecological validity) and gaming character of simulators. See Hays and Singer (1989, p. 50) for a definition of fidelity. The problem might diminish with advances in instructional design theory.

    1.5. **Cul-de-sac situations**. Some simulators tend to get stuck in situations without the possibility to improve it, although subjects recognize their errors. See also Brehmer (1992, p. 224). In contrast to that, some errors cannot be observed because the corresponding effects occur much later or in another area of the simulated system (Goodyear et al., 1991, p. 278). This issue can be solved applying a rigorous and thorough testing of the business simulator using standard procedures from software development (see, for instance, Sommerville, 1992).

2. Characteristics of user/subjects

   2.1. **Different cognitive processes involved**. In different phases of using a simulator different cognitive processes could prevail (Funke, U., 1991, p. 115; Reigeluth and Schwartz, 1989, p. 2). To take this into account, different measures for these different phases might be needed. But firstly, a common psychological theory of these cognitive processes has to be articulated. Then, different scores for these different processes can be implemented within business simulators.

   2.2. **No real risk**. Although subjects usually are very much involved in the game, real risks cannot be simulated. Therefore, subjects could tend to take more risks than in reality. This is a fundamental issue because it is at the same time an important advantage of simulations (Milling, 1995, p. 106).

   2.3. **Ambiguity of (process) scores**. It is argued that static scores (outcome measures) hardly contain information about the process of flying the simulator (for instance, Bakken, 1989, p. 309). Process measures (like, e. g., the strategy that a subject followed), which are used to eliminate this disadvantage, are, however, open to multiple interpretations and are usually not unambiguous. Thus, if process scores are used their interpretation must be laid down in advance, not post hoc, and they must be quantifiable.

   2.4. **Confounded user characteristics**. There might be a lot of relevant user characteristics which can hardly be controlled completely (e. g., pre usage knowledge about domain, motivation, expertise in working with computer, general intelligence etc.). Based on psychological theories those characteristics that might be confounded have to be controlled and examined during experimentation. This is, however, a basic issue for all evaluation studies and psychological experiments.

   2.5. **No optimal solution**. It is a characteristic of complex problems that no optimal solution can be computed. In the same way, usually no optimal solution in business simulators does exist, which could be used to assess the performance of subjects using the simulator (no absolute benchmark). However, performance can be compared to other users, for example, to experts in the domain (relative benchmark). It has to be seen as a sign of ecological validity that the optimal solution is not known.

3. Characteristics of learning (or experimental) situation

   3.1. **Duration of game run**. Playing a scenario often takes a considerably long time (in some cases a few hours) but yields only one independent measure of the game score. Thus, reliability of data is often limited. Furthermore, users can get tired or bored. The single measurement provided by one game run, on the other hand, is usually accompanied by many observations which leads to the problem of data reduction (Brehmer, 1992, p. 221). This is a basic issue because complex situations just need time to be understood and managed by users.

   3.2. **Integration with other teaching**. It is often stated that business simulators should be used in connection with other training measures (for instance, after teaching basic, declarative knowledge about the domain). The final aim is to embed the simulation into a complete suite of teaching methods ("interactive learning environment"). How simulators can practically be combined with other instructional media and what characteristics these other media should have is, however, only rarely discussed. Which effects are due to the simulation, and which are due to the other measures, remains unclear. See also Kerres (1998, p. 111, 115) for the importance of research about the embedding of teaching media into a didactic context. Instructional design might have more answers in the future.

Besides these methodological issues, it must be considered that the actual **costs** and the opportunity costs of developing and experimenting with business simulators are high. Although there are no cost data for developing business simulators, costs for the development of “conventional” computer-based training (CBT) programs are estimated to be about 10,000–30,000 Euro per hour training (Kerres, 1998, p. 122). In addition to that, working with business simulators often takes a considerably long time, in order to understand the complex content they convey. Thus, opportunity costs are high as well.

The issues described in this section have the potential to affect any research with business simulators. Thus, their consideration might be crucial for the usefulness and meaningfulness of any scientific study incorporating business simulators.

Not all of these issues are to the same amount relevant for both, teaching and psychological research. For example, issue 2.2 (“no real risk”) can cause a problem when decision making under stress should be investigated with the use of a business simulator because subjects just do not experience the same kind of stress as in reality. But for evaluation purposes issue 2.2 is mostly irrelevant. Most of the other issues, however, have influences on both kind of experimental research. Thus, in practice, teachers and researchers should best consider all points in order to prevent negative effects on their training or study, respectively.

Overcoming Limits of (Current) Business Simulators

When considering the list of issues presented above, it is obvious that the quality of the business simulator is one important factor for the quality of the experiment or the evaluation. Although there are problems which are basically caused by experimental methodology and which are the same for experiments not including business simulators, there are nevertheless some points that are simulator specific. These issues can be mitigated by a simulator that is designed for experimentation (for an prototypical example see Größler, Notzon and Shehzad, 1999). Note, however, that some authors have doubts whether simulators can be designed for both purposes simultaneously, namely allowing to conduct psychological experiments and to mediate knowledge (Andersen et al., 1990).

A formal and well-documented development process can be helpful in creating business simulators which exclude problems that are caused by some of the twelve issues. Figure 2 depicts an ideal life-cycle model of business simulators.

The initiation phase starts with the idea to develop a business simulator. Fundamental goals are laid down that should be achieved with the help of the simulator (e. g., to make users learn about a domain). Also, decisions about the intended audience and a coarse definition of the domain can be found in this phase. Another important activity is to investigate whether the desired effects cannot be achieved with higher effectiveness or lower costs by other means (i. e. other training interventions; see Duke, 1981, p. 49).

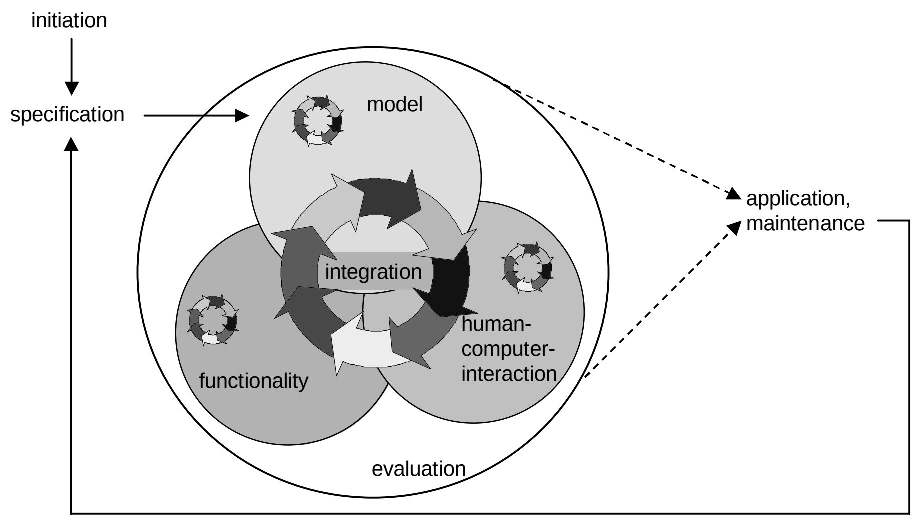

Figure 2: Life-cycle model of the development of business simulators

The specification phase makes these considerations more concrete. Regarding the audience one has to find out about existing knowledge and motivation. The level of abstraction desired is laid down. Principal decisions about usual gaming duration, integration with other teaching, and fidelity have to be made. These decisions form the specification, which is compared to the resources that can be used to develop the simulator. Estimations about costs and duration of the development project are calculated (see Sommerville, 1992, for estimations of software projects).

The iteration through the three main components of business simulators usually starts with the (formal) model. The reason for this is that a model is required as basis for human-computer-interaction and functionality. A formal model is a product per se, while a user interface or functions do not make sense without a model on which they are based. The development of the model equals the analysis phase in classical software life-cycles: a real-world domain is transferred into a formal model (Schader and Rundshagen, 1996, p. 34).

The development of all three components has to be coordinated and the parts must be integrated into a single software package. Although basic requirements have already been made in specification, details of the implementation cannot be laid down until the work in the components has started. For example, it is impossible to clarify the exact number and names of model variables which are necessary in developing a human-computer interaction component. However, these facts are not known until modeling has started. Integration also means the implementation of a program framework that can be accessed by the operating system. Usually, this frame program calls a simulation engine to provide simulation and other functionality.

At a certain point in time, the iterative cycle through the components comes to an end (in the best case, when developers and clients are satisfied with the work). Then, the business simulator is ready to use. This application phase is always also a maintenance phase: bugs have to be eliminated, imprecise information must be corrected and adjustments to real-world changes have to be made (e. g., if accounting standards change). Severe problems or the wish for further development lead to another proceeding through the complete cycle starting with a new specification phase.

Parallel to implementation and documentation activities, tests for validity and correctness of the business simulator are conducted. The validity of the complete business simulator is mainly influenced by the validity of the formal model used (see Barlas, 1996, for the validity of system dynamics models). For internal validity this is the case because the behavior of the simulator is exclusively determined by the model. Sound and logical behavior is therefore caused by the model.

Human-computer interaction and functionality are combined with a formal model for the reason to increase effectiveness and relevance towards a learning goal. In contrast to internal validity, external validity is therefore also influenced by these components. Nevertheless, the formal model still plays an important role in investigating external validity as well. The formal model determines, for instance, which part of reality is contained in the simulation, what degree of detail should be achieved etc. Furthermore is the model the only component of simulators which validity can be examined separately.

In particular, system dynamics claims to allow modeling of qualitative variables and interconnections between variables. This, however, determines that also examining the validity of a system dynamics model has to be based on qualitative arguments (Forrester, 1961, p. 128). There is no absolute test of model validity. Nevertheless, tried and tested quantitative approaches can be applied, too. The validation of a system dynamics model should aim at three aspects: structure, behavior, and policy implications (Forrester and Senge, 1980).

The validation of business simulators, which contain a formal model, a human-computer interaction component and functionality, is still an open research area. Even when the quest for validity is restricted to the underlying system dynamics model (which is a reasonable starting point) still many unanswered questions remain. For the validity of models used in a business simulator different rules might apply than to those of standalone models. This problem is expressed by the common statement of system dynamicists that "we don't model systems, we model problems." Underlying models of business simulators are not meant to represent a problem but a (often generic) situation or system. The "problem" of models within business simulators is to mediate the knowledge desired to the user of the simulation. They should be part of an effective means to make people learn about a system.

In this paper claims about the effectiveness and relevance of business simulators for learning and experimenting were described. However, issues exist which hinder the full exploitation of simulators within teaching and research. Twelve methodological issues were identified. The impact of the issues and ways to mitigate negative effects were briefly discussed. Costs are another important factor when applying business simulators. At the end, a life-cycle model for the development of business simulators was presented that could be a chance to relieve some of the problems explained before. Special attention was paid to the process of validating a business simulator.

References

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

Bakken, B.E. (1989). Learning in Dynamic Simulation Games; Using Performance as a Measure. In Milling, P.M., Zahn, E.O.K. (eds.), *Computer-Based Management of*

Complex Systems: Collected Papers from the 1989 International System Dynamics Conference, Springer, Berlin et al., pp. 309–316.

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

Barlas, Y. (1996). Formal Aspects of Model Validity and Validation in System Dynamics. *System Dynamics Review* 12(3), 183–210.

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

Brehmer, B. (1992). Dynamic Decision Making: Human Control of Complex Systems. *Acta Psychologica* 81, 211–241.

Brehmer, B., Dörner, D. (1993). Experiments with Computer-Simulated Microworlds: Escaping Both the Narrow Straits of the Laboratory and the Deep Blue Sea of the Field Study. *Computers in Human Behavior* 9, 171–184.

Buchner, A. (1995). Basic Topics and Approaches to the Study of Complex Problem Solving. In Frensch, P.A., Funke, J. (eds.), *Complex Problem Solving – The European Perspective*, Lawrence Erlbaum, Hillsdale/Hove, pp. 27–63.

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

Duffy, T.M., Jonassen, D.H. (1992). Constructivism: New Implications for Instructional Technology. In Duffy, T.M., Jonassen, D.H. (eds.), *Constructivism and the Technology of Instruction. A Conversation*, Lawrence Erlbaum, Hillsdale/Hove/London, pp. 1–16.

Duke, R.D. (1981). The Game Design Process. In Stein Greenblat, C., Duke, R.D. (eds.), *Principles and Practices of Gaming-Simulation*, Sage, Beverly Hills/London, pp. 47–53.

Forrester, J.W. (1961). *Industrial Dynamics*. MIT Press, Cambridge, MA.

Forrester, J.W., Senge, P.M. (1980). Tests for Building Confidence in System Dynamics Models. *TIMS Studies in the Management Sciences* 14, 209–228.

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

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

Funke, J. (1995b). 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., Mühlbradt, T. (eds.), *Planspiele im Personal- und Organisationsmanagement*, Angewandte Psychologie, Göttingen, pp. 205–216.

Funke, U. (1991). Die Validität einer computergestützten Systemsimulation zur Diagnose von Problemlösekompetenz [On the Validity of a Computer-Based Simulation as a Diagnosis of Problem Solving Competence]. In Schuler, H., Funke, U. (eds.), *Eignungsdiagnostik in Forschung und Praxis*, Angewandte Psychologie, Stuttgart, pp. 114–122.

Goodyear, P., Njoo, M., Hijne, H., van Berkum, J.J.A. (1991). Learning Processes, Learner Attributes and Simulations. *Education & Computing* 6, 263–304

Größler, A. (1999). The Influence of Decision Time on Performance in Use of a Business Simulator. In Cavana, R.Y. et al. (eds.), *Systems Thinking for the Next Millenium – Proceedings of the 1999 Conference of the International System Dynamics Society*, Wellington, New Zealand [CD-ROM Proceedings, Abstract p. 75].

Größler, A., Notzon, I., Shehzad, A. (1999). Constructing an Interactive Learning Environment (ILE) to Conduct Evaluation Experiments. In Cavana, R.Y. et al. (eds.), *Systems Thinking for the Next Millenium – Proceedings of the 1999 Conference of the International System Dynamics Society*, Wellington, New Zealand [CD-ROM Proceedings, Abstract p. 145].

Hays, R.T., Singer, M.J. (1989). *Simulation Fidelity in Training System Design*, Springer, New York.

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

Keys, B., Wolfe, J. (1996). The Role of Management Games and Simulations in Education and Research. *Yearly Review, Journal of Management* 16(2), 307–336.

Kim, D.H. (1989). Learning Laboratories: Designing a Reflective Learning Environment. In Milling, P.M., Zahn, E.O.K. (eds.), *Computer-Based Management of Complex Systems: Collected Papers from the 1989 International System Dynamics Conference*, Springer, Berlin et al., pp. 327–334.

Lane, D.C. (1995). On a Resurgence of Management Simulations and Games. *Journal of the Operational Research Society* 46, 604–625.

Maier, F., Größler, A. (In print). What are we talking about?—A taxonomy of computer simulations to support learning. Accepted for publication in *System Dynamics Review*.

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.

Milling, P. (1996). Simulationen in der Produktion [Simulation in Production]. In Kern, W., Schröder, H.-H., Weber, J. (eds.), *Handbuch der Produktionswirtschaft*, 2nd edition, Schäffer-Poeschel, Stuttgart, pp. 1840–1852.

Packer, D.W., Glass-Husain, W. (1997). Designing Interactive Multi-User Learning Laboratories. In Barlas, Y., Diker, V.G., Polat, S. (eds.), *15th International System Dynamics Conference: Systems Approach to Learning and Education into the 21st Century*, Istanbul, pp. 79–86.

Pidd, M. (1993). *Computer Simulation in Management Science*, 3rd edition, John Wiley & Sons, Chichester et al.

Reigeluth, C.M., Schwartz, E. (1989). An Instructional Theory for the Design of Computer-Based Simulations. *Journal of Computer-Based Instruction* 16(1), 1–10.

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

Richmond, B. (1993). Systems Thinking. Critical Thinking Skills for the 1990s and Beyond. *System Dynamics Review* 9(2), 113–133.

Schader, M., Rundshagen, M. (1996). *Objektorientierte Analyse* [Object Oriented Analysis], 2nd edition, Springer, Berlin et al.

Sommerville, I. (1992). *Software Engineering*, 4th edition, Addison-Wesley, Wokingham et al.

Stein Greenblat, C. (1981). Teaching with Simulation Games: A Review of Claims and Evidence. In Stein Greenblat, C., Duke, R.D. (eds.), *Principles and Practices of Gaming-Simulation*, Sage, Beverly Hills/London, pp. 139–153.

Stein Greenblat, C. (1988). *Designing Games and Simulations*, Sage, Newburry Park et al.

Süß, H.-M. (1999). Intelligenz und komplexes Problemlösen [Intelligence and Complex Problem Solving]. *Psychologische Rundschau* 50(4), 220–228.

Notes

1. Throughout the rest of the paper only the term “business simulator” is used. For a definition of terms see Maier and Größler (in print).