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# Constructivist Use of Business Simulators in Education

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**Abstract**

The goal of this paper is to define and propose a model of possible use of business simulators to support education in constructivism sense and with a respect to revised Bloom's taxonomy of learning objectives. This model is particularly focused on re-construction of prior partial knowledge using the falsification approach.

**Keywords:** Simulator, model, education, constructivism, falsification

## Introduction

During final oral examinations we were often surprised by heuristics or shortcuts in the knowledge presented by our university students. There seemed to be common patterns in misconceptions and similar missing links which were mainly on the deeper level of understanding.

The problem has been especially related to the applicability of partial knowledge. Although many theories and models are alone understood quite well by the students, the whole is missing. It seems that according to Spiro, et al. (1991) one of the reasons is that this is a viable strategy for the students. But because we teach business students, it is obvious that the proper understanding of all main principles working together in the right context is crucial for their success in the real world. And thus we as teachers cannot be satisfied with such an outcome.

Sometimes suddenly a moment of "aha" appeared right in front of us during the oral examination and the students realized their own knowledge gaps through falsification of their own heuristics, got the insight and felt the relevance – but we believe that unfortunately mainly only according to the question examined.

Nevertheless, this situation was in several cases accompanied with positive emotions and perceived satisfaction on both sides. Like in a good thriller where the meaning of all that has been shown before is shifted in a short while and the "hidden truth" is realized suddenly.

We suppose it is quite common for anyone not just in education to have such an experience. It is in the very heart of learning to discover new knowledge on the basis of reconstructing the old one and change of meaning.

But we don't want to happen it occasionally. Rather, we would like to manage this process and deliver insights like that also in our curriculum. And not just in the curriculum but also in the practice, because we believe analogous situation may be also found in many organizations coping with knowledge management issues.

The goal of this paper is thus to define and propose a model of possible use of simulators supporting this managed change of meaning on the level of individual knowledge using

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falsification and re-construction of prior partial knowledge.

The main method used here to gather relevant concepts and data is based on one hand on a literature review and on the other hand on observations of the heuristics which we and our students were usually using to solve questions related to real world problems during examinations and business simulator usage.

This means that our thoughts are mainly a qualitative inquiry and we need to test the model later using more rigorous approaches.

## Business Simulators in Education

Although the usage of computer simulators to support learning has a tradition long nearly 50 years (Faria, 2001; Tonks, 2005), it seems that the basic terms are used in a confusing manner. We may find several synonyms for nearly the same – like management flight simulators, microworlds, interactive learning environments (ILEs) etc.

In this paper we would like to use for clarification our own earlier definition (Heskova and Vojtko, 2007). The main points of the definition are that business simulators have three different layers – (1) model providing needed simulations, (2) user interface allowing input and output, both quantitave and qualitative, and (3) learning environment introducing problem, supporting process of knowledge construction and feedback for it.

Our definition is in the general sense similar to earlier definitions of Davidsen (2000), distinguishing just two components – model and user interface – and Maier and Größler (2000), who assume "that computer simulations have three key aspects, the underlying model, the human-computer interface and various functionalities."

These authors also provide a very comprehensive taxonomy of computer simulators built for educational purposes. They classify business simulators under the category of gaming simulation which is in our opinion inappropriate, especially from the constructivist point of view.

Nevertheless, this taxonomy shows another interesting point in division between modelling (transparent box) vs. gaming approaches to the use of simulators (black box or semi-transparent box).

Modelling approach then provides a possibility of changes in underlying model structure by users themselves. This approach is usually based on system dynamics and systems thinking, multiagent approach or discrete modelling

The modelling approach is from our experience the most valuable one for a new knowledge discovery because the model structure can be changed in any particular moment of learning to reflect other assumptions and point of view of the user. But on the other hand there is a serious shortcoming in the need of users' abilities to change the structure of the model accordingly, not just parameters. This limits the applicability from this point of view.

The second, gaming approach is very common in business education. The underlying model is set and just its parameters can be changed. This limits also the possibilities of learning because there is finite number of assumptions and preset embedded knowledge. On the other hand this may be very simple for the user to just use the prepared model – and various user interfaces may be provided reflecting different contexts.

Both approaches are viable but under different conditions. Both may provide very helpful experience reflecting the real world complexity. And both are capable to provide logical consequences of various actions under different circumstances.

Also, according to Anderson and Lawton (2009, p. 195) "to be effective, simulations require a substantial time commitment from participants. Consequently, the literature suggests that business simulations are an inefficient pedagogy for teaching terminology, factual knowledge, basic concepts, or principles [...]. The basics of a course can be covered more quickly in lectures. It may be an open debate as to whether students will be able to retain or implement some of these basics if lecture is the sole method of delivery, but few will dispute that lectures are much faster."

**Constructivism – A Missing Theoretical**

**Link between Education And Simulation?**

Lainema (2009, p. 50) suggests that "a comprehensive theory about learning and knowing through simulation and gaming is missing." The majority of interest has been devoted to the experiental aspects of simulators' supporting role in learning (e.g. by Kolb, 1984; Kayes, 2002) and grounding in the theory of education is not employed well in this sense.

Fortunately, the roots of constructivism and often used experiental learning approaches are according to Lainema (2009) very similar and have a lot in common. Thus it is possible to use this paradigm as a starting point of our inquiry.

What are the most important principles of constructivism? We will now summarise them according to the highly refererred to authors Duffy and Cunningham (1996):

- All learning is a process of construction of knowledge.
- There are many possible ways of knowledge construction and thus also multiple perspectives and meanings.
- Knowledge is always context dependent and learning should occur in appropriate contexts.
- Learning is mediated by tools, signs and symbols.
- Learning occurs in social setting, is based on discussion and communication with others.
- Learning also means an engagement in the community of practice.
- We are able to reflect our own learning and understand the way we know or know not.

We may add that this all is in concordance with many thoughts of Jan Amos Comenius, famous Czech teacher and educator from 17th century. Just to mention one of his sayings within this context: "pupil is not a jar to be filled but a torch to be lit." In other words, it is not sufficient just to deliver pure knowledge through education. Also feelings and attitudes are important.

The main relevance of constructivism regarding the business simulators' usage in education is in much higher involvement of free will on the side of students, i.e. learner-centered learning – in providing them relevant problems, safe environment for experiments and surprises from discoveries, interaction with others in social setting or possibility of their own planning of learning etc. This all should lead to more realistic and holistic learning experience in comparison with traditional objectivistic approaches.

But on the other hand a problem of motivation of students arises, because there is also a shift in the role of teachers. They are not the only right authority delivering knowledge but rather facilitators of individual knowledge construction.

**Knowledge, Heuristics And Learning**

If we look to the Merriam-Webster OnLine dictionary (2009), the word knowledge is defined as: "(1): the fact or condition of knowing something with familiarity gained through experience or association (2): acquaintance with or understanding of a science, art, or technique."

It is obvious that by using knowledge it is possible to answer three basic questions – what, how and why. The question what is related to the awareness of concepts and their meaning in particular situation (declarative knowledge). The question how deals with procedures and methods of change of the situation (procedural knowledge). And finally, the question why is focused on the underlying structure of the situation and broader context (structural knowledge). All these questions may be answered differently by different people as we have shown before in relation to the constructivism.

Also, as because we are not just conscious but also unconscious in many ways, Polanyi's explicit vs. tacit knowledge distinction needs to be considered (Nonaka and Takeuchi, 1995). The tacit knowledge relates to the uncosciuous and cannot be articulated unless made explicit, i.e. realized.

Another approach is of Baumard (1999), who is adding implicit knowledge. This knowledge could be made explicit but no one wants to express it.

We have mentioned heuristics earlier. As we might see the process of their use by the students has much to do with the tacit knowledge.

For the needs of this paper we would like to define heuristic according to the Principia Cybernetica Web (2009) this way: "An aid to discovery, any device or procedure used to reduce problem-solving effort, a rule of thumb." The problem is – are we able to tackle the heuristics properly in the education?

It has important consequences for business education because in so complex world purely analytical decisions are not in many situations feasible and the students should cope with this accordingly. On the other hand, heuristics should not be misleading and confounding like we occasionally experience.

But of course, knowledge cannot be considered static. We use it every day in a changing world. We create it every day through our own actions, discoveries, communication with others and encountering our knowledge boundaries.

A very important perspective on knowledge change is given by Bloom's taxonomy (Bloom, et al., 1959). This taxonomy classifies the output of learning, i.e. acquiring of new knowledge on individual level, into three main domains: cognitive (knowing), affective (feeling) and psychomotor (doing). This framework broadens the perspective because emotions and actions are taken into account.

In this sense, there are several levels of learning objectives in the cognitive category (Bloom, et al., 1959) – (1): basic knowledge, (2): comprehension, (3): application, (4): analysis, (5): synthesis, (6): evaluation – which should be supported by different tools and methods and also assessed differently.

A lot of research in the area of business simulation involvement in cognitive learning has been undertaken from the perspective of original Bloom's taxonomy (e.g. Keys and Wolfe, 1990; Faria, 2001; Gosen and Washbush, 2004). Unfortunately, it seems that especially at higher levels of cognitive learning the evidence of significant contribution of simulations' usage is weak and nearly the same as 20 years ago (Anderson and Lawton, 2009).

We think that because the original Bloom's taxonomy has been revised by Anderson, et al. (2000), it should be helpful to shift also the research of simulations' usage for learning in this direction. The main reason is that the new revised taxonomy may be more disambiguous and better grounded in the area of cognitive psychology. Which also means that further research focused on assessment of the simulators' contribution to the higher levels of cognitive learning may be easier and less confusing due to this clarification.

The beforementioned Anderson, et al. (2000) taxonomy classifies the learning objectives in a little bit different way than the original one: (1) remembering, (2) understanding, (3) applying, (4) analyzing, (5) evaluating, and (6) creating (synthesis).

It also combines these learning objectives with factual, conceptual, procedural and metacognitive knowledge dimensions which help to divide content and methods accordingly.
A map of previous concepts is provided on the next figure 1.

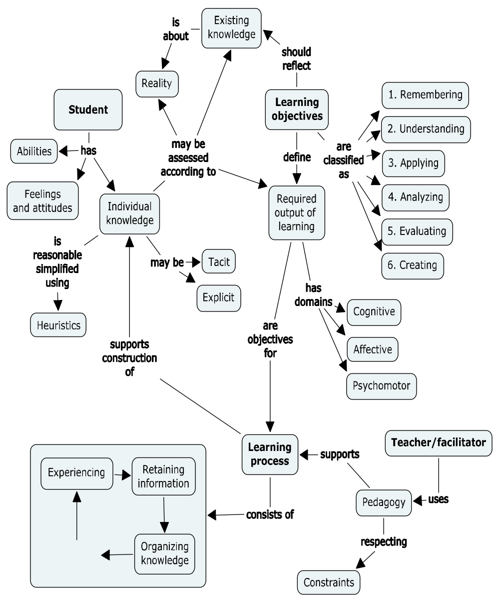


*Fig 1 A map of concepts related to constructivist learning*

## A Proposed Model of Constructivist Use of Business Simulators in Education

From our perspective we would like to relate our contribution to earlier attempts focused on efficient use of computer simulators in education (e.g. Hsu, 1989; Davidsen, 2000; Alessi, 2000; Sterman, 2000; Anderson and Lawton, 2009).

Amongst others, we have chosen two of approaches focused on learner not the teacher. Hsu (1989) provides for the use of education simulators this 4-step learning process:

- retaining information,
- organizing knowledge,
- experiencing, and
- firming.

Another way is suggested for example by Sterman (2000). His approach is based on system dynamics methodology, thus it is focused on an ability to explicitly model system behaviour (transparent-box approach) by users, and could be described in these steps:

- definition of problem and purpose of solution,
- dynamic hypotheses,
- model formulation,
- testing of the model,
- proposing and testing of policies.

Our model respects previous definition of business simulator (Heskova and Vojtko, 2007), the general 4-step learning process by Hsu (1989) but relates it with the taxonomy of education simulators provided by Maier and Größler (2000) and the taxonomy of learning objectives by Anderson, et al. (2000).

We think it is useful now to notice how the higher levels of the taxonomy of learning objectives could be employed in the scope of business simulators' usage. These are – applying, analyzing, evaluating and creating. First of all, we need to distinguish between various situations in which we could use business simulators for the support of learning. Each of them has consequences for the overall learning process.

Their preference in a given curriculum depends on learning objectives (synthesis of prior knowledge, falsification of incorrect knowledge), learners' abilities (e.g. are they able to change the model structure on their own?) and resource constraints (i.e. time and staff availability etc.).

Table 1*:* Categorization of learning situations

<table>
<tr><td></td><td colspan="2">Number of simulators</td></tr>
<tr><td rowspan="4">Number of users</td><td rowspan="2">1. Individual use, single simulator, black box/ semi-transparent box</td><td>2a. Individual use, multiple simulators, black box/semi-transparent box</td></tr>
<tr><td>2b. Individual use, multiple simulators, transparent box</td></tr>
<tr><td rowspan="2">3. Team use, single simulator, black box/ semi-transparent box</td><td>4a. Team use, multiple simulators, black box/semi-transparent box</td></tr>
<tr><td>4b. Team use, multiple simulators, transparent box</td></tr>
</table>

*Individual Learning Situations*

The simplest learning situation is where every student works with just one business simulator, i.e. three layers – model, user interface and learning environment. We need to mention that it may mean several runs or more case studies/scenarios involved in the learning process etc. But each student tries to solve given problem individually and the structure of model itself is not changed although changes of model parameters, e.g. different scenarios, are possible.

In this case, the business simulator may be used both to destruct prior usufficient knowledge using falsification approach (hypotheses testing) or to construct new knowledge using experimenting and analysis of the underlying model structure.

If we look at this learning situation from the point of view of black box/transparent box approach, we would like to argue that black box approach is suitable mainly for firming prior knowledge (including synthesis) or falsification – the feedback provided shows inconsistencies in user's knowledge. But unless at least the semi-transparent box approach or a specific support on the side of learning environment is used, it is not clear if new knowledge is constructed accordingly – it may be rather tacit. Nevertheless, it may be easily always falsified again.

Another important point is related to the explicit/tacit knowledge distinction. The student's perception of behaviour patterns during recurring runs should help to construct both – but our goal is to ensure that the student is aware of the important concepts and relations between them. Thus we think it is important to support setting and testing individual hypotheses in the learning process. And the hypotheses should of course reflect individual heuristics to deliver surprising outcomes.

Relations of this learning situation to the all of the higher levels of learning objectives from the taxonomy of Anderson, et al. (2000) are shown in the Figure 2.

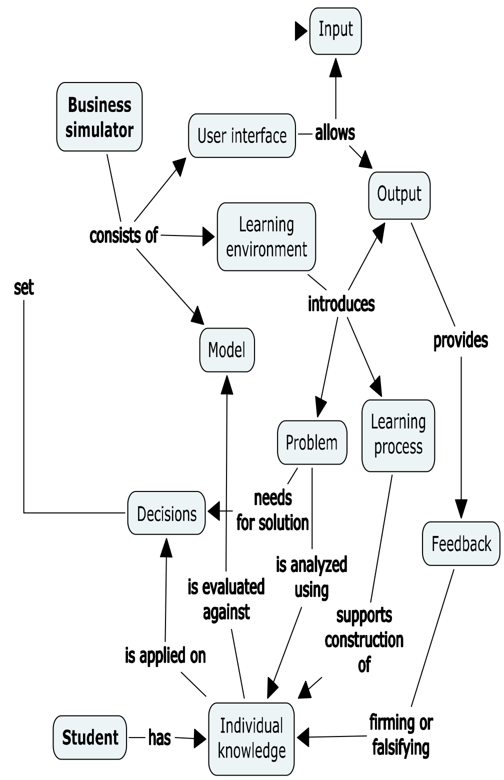


*Fig 2 A concept map of individual use, black box/semi-transparent box approach to business simulator usage*

The second learning situation involves again one user but multiple simulators. It means in our definition that different user interfaces or different underlying models are used, which is especially related to transparent box approach (2b) or different roles played by the users (2a) – e.g. subjects in supply chain or managerial roles in an organization.

The main advantage of this approach should be in better focus both on the side of learning and assessment. Especially for the particular individual knowledge firming/falsifying in cases where step by step learning process from easier to more difficult concepts and relations is crucial. The learning objectives then for example could include need for understanding of several system levels together (micro and macro) or system behaviour on different time scales.

We also need to emphasize the transparent box approach in this case because the students are then able to change or build their own underlying models and compare

And of course the business simulators then have to be opened for changes, which is unfortunately still rather uncommon. But it is possible and we have tried that in several cases using system dynamics methodology and multi-agent modelling. Many models based on these methodologies are available in the open form, although sometimes without the other business simulator layers.

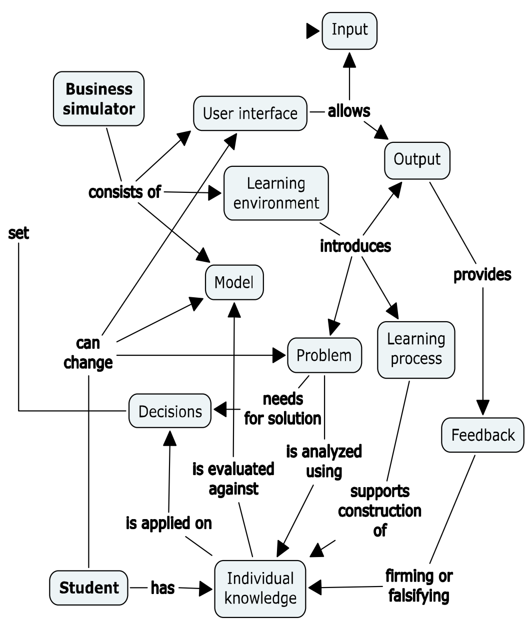


*Fig 3 A concept map of individual use, transparent box approach to business simulator usage*

For curriculum, this way of using of business simulators could for example mean that at first concepts of fixed and variable costs, revenue and profit are shown, then breakpoint analysis, marketing, controlling, human resources management etc. and finally synthesis is supported.

Each of these phases then may be assessed individually. And the assessment is possible

them. This is very promising from the constructivist point of view but also demanding on the students – they need to be able to use the right modelling language on their own.

not just on the lower levels of the taxonomy of learning objectives but also on the higher levels using the comparison of explicit conceptual or simulation models prepared by the students.

Both these learning situations mean that the complexity of learning situation is somewhat limited due to mainly rational and abstract focus (higher internal validity). The main reason is that there is no significant interaction with the other students and thus the experience and affective domain is limited too.

*Team Learning Situations*

Team learning situations provide another level of experience – interaction with the other team members which raises the overall complexity.

On one hand this is more similar to real-world circumstances (higher external validity) and human-human communication and emotions are involved, on the other hand the relation between shared team knowledge and individual knowledge is quite difficult to manage and cope with (lower internal validity) from the side of learning process and assessment.

This may be one of the reasons why the before mentioned measurement of business simulations' impact on learning has so ambiguous results and seems to be so uneasy.

Nevertheless, this team use type of learning situations has a possible specific advantage – in certain circumstances it is possible to bring together teams consisting of students with different abilities, e.g. older students with modelling or other skills or students with different specializations. Then it could be possible to apply the transparent box approach efficiently. This is uncommon in business schools yet but it seems to be promising.

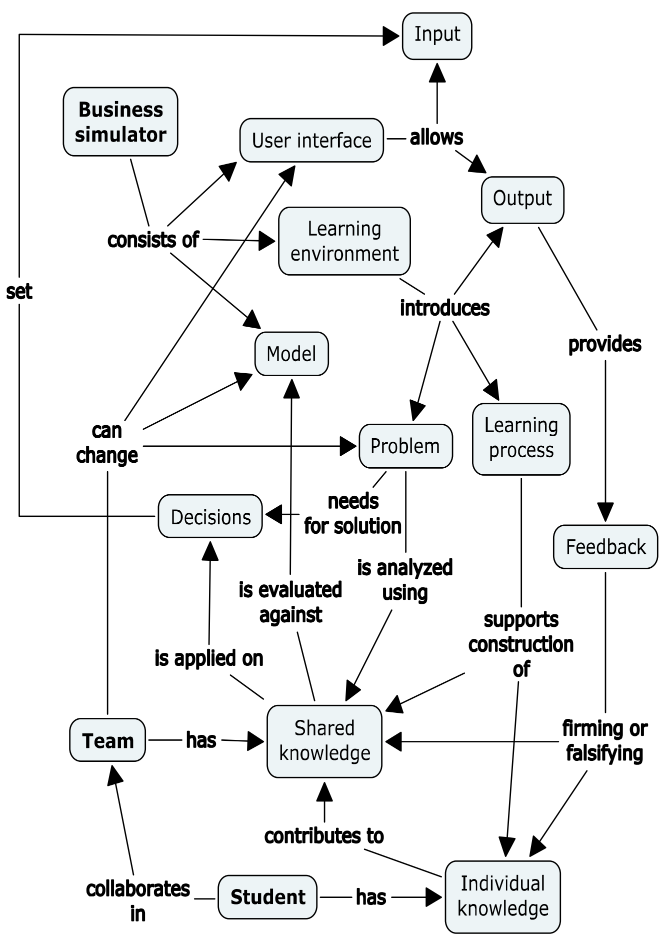


*Fig 4 A concept map of team use, transparent box approach to business simulator usage*

It is also possible to apply the black box approach but the problem of relation between individual and team shared knowledge persists.

*The Model of Constructivist Use of Business Simulators in Education*

We have argued that different learning situations according to the individual/team use, one/multiple simulators involvement and black box/transparent box approach should have different consequences for learning outcome, its assessment and further research.

This means that it is not possible to easily evaluate the learning outcome of business simulators as a whole group.

Thus our proposed model of constructivist use of business simulators in education tries to overcome the main obstacles and synthesise the findings in a coherent way. It is presented as an ideal and possibly the most beneficial one but we suppose it could be modified according to the constraints and circumstances of a given curriculum.

It is clear that to overcome many of the problems mentioned before, use of multiple simulators from easier to more difficult ones should be recommended to fully uncover their potential in learning. Also, gradual shift from black box/semi-transparent box to transparent box approach and individual to team use should be promising because it logically goes up in the taxonomy of learning objectives and adds higher levels of complexity too.

The transparent box approach is at the core of constructivist use of simulators because it supports construction of own models, meaning and discovery of new knowledge. Subsequently, hypotheses setting and testing should be an inherent part of the whole learning process. It should help to falsify own inappropriate knowledge and reconstruct it.

## Conclusions

We have shown that the whole domain of business simulators should be divided to several learning situations. We think that this categorization is needed and its nonexistence is partially the reason for difficulties in proper evaluation of learning outcomes from business simulators use as shown in literature.

We have also proposed the model of constructivist use of business simulators in education based on the beforementioned categorization. This model should provide a coherent and clarifying framework for further application in curriculum and research – mainly it is possible to consistently compare simulation learning outcomes in right categories.

The model should be of course tested. It could be done partially using the experimental design where independent variables are the categories used in the model. And we are preparing a new subject where this model will be practically applied and tested with students – hopefully allowing them to discover new knowledge on regular basis.

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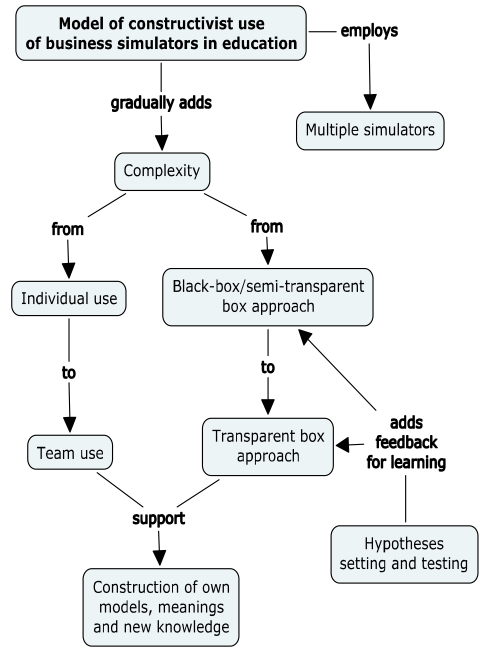


*Fig 5 The model of constructivist use of business simulators in education*

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