# Learning complex domains and complex tasks, the promise of simulation based training

Ton de Jong

# LEARNING COMPLEX DOMAINS AND COMPLEX TASKS, THE PROMISE OF SIMULATION BASED TRAINING

**Ton de Jong (jong@edte.utwente.nl)**
Faculty of Behavioral Sciences
University of Twente
PO Box 217, 7500 AE Enschede,The Netherlands

**Abstract**
*Computer simulations enable the realization of didactical concepts such as inquiry learning, collaborative learning, and situated learning. These didactical approaches are not novel in the sense that they have just emerged, but simulation learning environments help to realize these approaches in new type of contexts. The design of such simulation learning environments is a multifaceted endeavour. First, the processes and difficulties involved in inquiry, collaboration, and knowledge application have to be identified so that measures that actually support learners in these learning processes can be created and incorporated in the application. Second personal, curricular, and organizational requirements and constraints for the multimedia supported didactical innovations should be recognized. This article presents examples from projects (SIMQUEST and Co-Lab[1]) in which simulation based learning environments in engineering and science domains have been developed and evaluated.*

## INTRODUCTION

New types of (on-line) learning environments are becoming available for use in the actual classroom rapidly. Trends that nowadays dominate the field of learning and instruction are *constructivism*, *situationism*, and *collaborative learning*. More specifically, we can say that the new view on learning entails that learners are encouraged to *construct their own knowledge* (instead of copying it from an authority be it a book or a teacher), *in realistic situations* (instead of merely decontextualised, formal situations such as the classroom), *together with others* (instead of on their own). These new trends have not emerged just by themselves; they are based on changing epistemological views. First, knowledge is not seen anymore as something that is assessed in relation to an external objectivistic "truth", but as *individually flavoured* and thus potentially different between people. Second, these individual knowledge states are exchanged between professionals that seek for mutual understanding and agreement. In this respect knowledge has a strong *social character*. Third, we have started to value knowledge that is *applicable in realistic situations*, and thus is not restricted to abstract knowledge.

[1] SIMQUEST and Co-Lab were and are partially supported by European Community under the Telematics and Information Society Technology (IST) RTD programmes, under contracts SERVIVE (ET 1020), and Co-Lab (IST-2000-25035). The author is solely responsible for the content of this article. It does not represent the opinion of the European Community or SURF, and the European Community or SURF is not responsible for any use that might be made of data appearing therein. For project details see the project websites: www.simquest.nl, and www.co-lab.nl. My thanks go to all the persons who have or are working on one of the projects and whose ideas are represented in this paper.

**SIMQUEST**

SIMQUEST was created to serve teachers and learners involved in discovery learning. SIMQUEST is an authoring system dedicated to simulations for discovery learning. It has the following two goals:

- To provide *learners* with supportive environments for discovery learning, in the form of cognitive tools directed at scaffolding the processes of discovery leaning;
- To provide *authors* with a flexible tool for creating simulation-based discovery learning environments, containing both technical and conceptual support for the authoring process.

The central focus of this presentation is the learning aspect, for the authoring aspect see van Joolingen and de Jong (2003) and de Jong et al., (in press). The primary learning goal for learners who work with a SIMQUEST learning environment is to construct knowledge of the domain under inquiry. This does not necessarily imply that the learner must know the model underlying the simulation in all detail. The goal is to understand the principles of the domain that account for the observed behaviour and/or the effects of actions performed within the domain (we have called this “intuitive knowledge”, see Swaak & de Jong, 2001). To reach this goal, students have to overcome the many problems they have with discovery learning (see for an overview de Jong & van Joolingen, 1998). In SIMQUEST applications, simulations are embedded in instructional support which aims at supporting learners in the discovery process. Currently, SIMQUEST provides four types of instructional support for learners:

- *Model progression.* A learning environment created with SIMQUEST may contain a number of different simulation models, ordered along dimensions such as difficulty, ‘order’ (qualitative vs. quantitative), or perspective on the domain;
- *Assignments.* Assignments provide the learner with short-term goals, like finding a specified relation, predicting the behaviour of the simulation or achieving a specified simulation state. In co-operation with model progression, assignments decompose the overall learning goal of a simulation into a number of subgoals. Learners can answer assignments and then receive feedback on their answer;
- *Explanations.* In the SIMQUEST authoring system, the author can define textual, graphical, and multimedia explanations. These explanations can be used to provide learners with extra information on variables, relations, or events in the simulation;
- *Monitoring*. The monitoring tool helps learners monitor, compare, and replay the experiments they have been doing, and that, in relation to answers to investigation assignments, can provide feedback on the relation between the experiments and answers chosen.

Figure 1 gives an example of a part of a learning environment created with SIMQUEST (see van der Meij & de Jong, 2003). In this learning environment (called “Moment”) learners explore the behaviour of moment in two situations: moment on a bolt caused by a force on an open-end spanner (displayed in Figure 1), and moment on a hoisting crane caused by a load. This figure does not include instructional support.

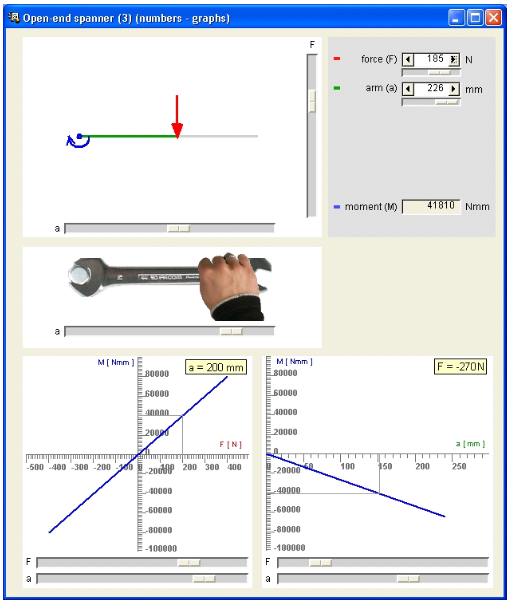


Figure 1. *Example of a SimQuest simulation*

Instructional support (e.g., assignments) and the simulation are fully integrated in SimQuest. The simulation can be set in a certain state by the assignment and can be controlled from the assignment by the learner. Also, values from the assignment are used for generating adequate feedback.

## CO-LAB

In today's working environment, employees have to collect, make sense of and use more and more information to keep up with developments in their field. To make the most of this information they need to acquire new knowledge and skills and develop better ways to collaborate with fellow workers based at different locations. The Co-Lab project is designed to develop a learning environment that will give users remote access to a virtual workspace for collaborative inquiry-based learning using experimentation and modelling. Initially, Co-Lab develops demonstration software for the fields of water management and climate control in greenhouses.

The objective of the Co-Lab project is to design, develop, and evaluate a new system for collaborative, inquiry-based learning. Basically, Co-Lab follows an inquiry based approach with a number of (not necessarily sequential) phases: orientation, hypothesis, experiment, data interpretation, conclusion, and evaluation (see Njoo & de Jong, 1993; de Jong et al., 2002). Compared to simulation-based learning environments Co-Lab has a number of specific characteristics:

- In Co-Lab a series of instructional support measures is built in, as it is in the SimQuest learning environments;
- In Co-Lab expressing the conclusions of the discovery process is done is a specific way, namely by "modelling". Learners in the end create a runnable model of the domain. To create this model, learners are provided with modelling tools in the phases orientation, hypothesis, and conclusion;
- In Co-Lab, for discovery, learners do not only have a simulation environment available (as is the case in SimQuest) but also local and remote laboratories and databases. This means that learners can work with "real" data;

- In Co-Lab the learning process is a collaborative endeavour. Over and in all phases of the inquiry cycle three learners work together to reach the ultimate goal (a runnable model). Inquiry learning forms an excellent basis for collaboration since at a number of points in the learning process specific decisions need to be taken (e.g., which hypothesis to test, which variable values to change etc.). To facilitate this collaboration they have access to collaborative workspaces (based on whiteboards) and dedicated communication facilities.

The design of Co-Lab is based on a “building metaphor”. Learners enter a building for a specific topic and may move between floors (different levels of the same topic) and at each floor move between a laboratory (to do experiments), a theory room (for the modelling aspect), and a meeting room (where overall planning and discussion takes place). Initially, in Co-Lab we will develop demonstration software for the fields of water management and climate control in greenhouses. For water management we have access to large external databases of water flow in actual rivers, for climate control in greenhouses an external laboratory will be built. Figure 2 shows an overview of a mock-up of one level in a Co-Lab building.

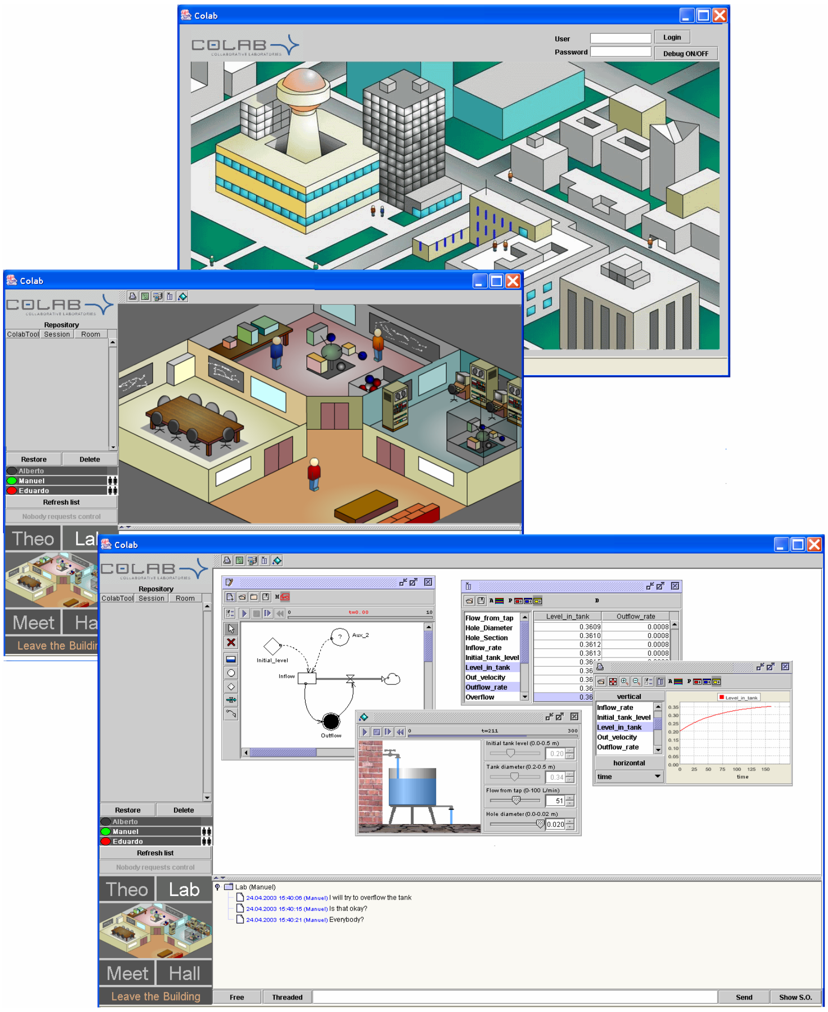


Figure 2. *Overall impression of the Co-Lab environment. Upper part: Co-Lab city with different buildings; middle section: one floor in a building; bottom part: specific tools.*

In parallel with the technical development of the Co-Lab environment, a comprehensive support system (similar to the one created for SIMQUEST) will be developed to help learners in their experimentation, collaboration, and modelling activities. In addition, Co-Lab will be designed to be integrated with the curriculum.

## CONCLUSIONS

This paper started with an overview of trends in learning and instruction: constructivism, collaborative learning, and situated learning. These trends can be recognized in the examples that were presented: SIMQUEST and Co-Lab.

In SIMQUEST the first focus was on constructivism in the form of discovery learning. The core of SIMQUEST learning environments is always a simulation in which learners change values of input variables and observe values of output variables to discover the underlying model. By creating a structure around the simulation as we do in SIMQUEST, part of this constructivism is taken away. The design challenge is to give students just enough support to enable them to engage in discovery with giving away as little as possible (both from a content and from a discovery process perspective). Most of the SIMQUEST learning environments that we created have a realistic context, as for example could be seen in the learning environment displayed in Figure 1. Other examples of realistic simulations we have created are “growth of tomatoes in greenhouses” and a “sewage plant”. Both these simulation learning environments are very encompassing environments with submodules on more fundamental science issues. This principle of a family of simulations under one specific theme has also been used in the Co-Lab learning environment. At the start SIMQUEST learning environments were designed for individual learning. Recently we have added facilities for collaborative learning. Now, the prior knowledge of learners can be indicated with their views on propositions in the domain (true, not true, to be tested, etc.) and after having completed their views on a list of propositions, the lists of two students can be combined and students are offered chat facilities to discuss their individual views. When they collaboratively decide to test a specific proposition the SIMQUEST collaboration tools can present the students with an appropriate assignment (see Gijlers & de Jong, in preparation).

In Co-Lab the situatedness of the learning environment is amplified by making data sources such as real (remote and local) laboratories available to students. The collaborative aspect that is inherent in Co-Lab also introduces a realistic aspect. Collaboration is included to foster learning but it is also an important aspect of real scientific discovery (see for example Dunbar, 2001). Taking this into account, our learning goals have also shifted from specific domain related learning goals to include other professional goals such as “collaboration”, “communication”, and “working methods”. In Co-Lab the constructivistic aspect is found in the discovery learning that is the primary mode of learning in Co-Lab but, in addition to what happens in SIMQUEST, also in the modelling that students are supposed to do and which gives them the opportunity to express their thoughts in a formal way.

Developing learning environments that follow innovative pedagogical concepts is one thing, having them introduced in actual instruction and training is yet another accomplishment. For SIMQUEST we have now found cooperation with professional publishers and have produced simulation environments that form a unit with other course material (most particular a book). This helps teachers in the way that they now can choose for one integrated course and do not need to use the SIMQUEST authoring facilities to adapt a simulation to their own situation. Although, intended originally for use by teachers directly, we now have found that teachers do not have the time, skills, and interest to design or even adapt a computer based learning environment. Having the software fit with the curriculum is also a major concern in the Co-Lab project. One issue that is particularly important here is that working in the Co-Lab environment almost inevitably means that a) this concerns a multi-hours involvement of learners and b) there is an integration of different science domains (physics, chemistry, biology etc.). The demonstrators to be developed in Co-Lab (in the areas of water management and climate control in greenhouses) are situated and appealing topics, but both require an integration of domains and an extensive time investment. Currently, this does not always line up with the curriculum structure.

Related to these issues is the very important place of the teacher or trainer (or training department). For SIMQUEST we have found that teachers have little experience in discovery learning, and especially the teachers we have been working with (who came from middle vocational training) had fear to give their students the freedom and responsibilities that these open learning environments require. What we found was that teachers sometimes restricted the freedom of discovery learning again and changed the learning environment in a very structured, set-by-step, learning experience (see De Jong et al., 1998). We try to overcome this by including suggestions and information in an advice tool for authors in the SIMQUEST authoring environment (see Pieters, Limbach, & de Jong, in press). Also, a specific training course for teachers has been developed.

A third point that hampers the introduction of innovative learning environments is the need for new ways of assessment. Introducing new ways of learning necessarily means that new goals are reached and thus new assessment methods should be used. For SIMQUEST we have developed a new type of test, the intuitive knowledge test (Swaak & de Jong, 1996). For collaborative learning environments assessment methods that takes the learning process into account need to be developed.

Many innovative approaches to learning and instruction developed in projects fail to make it to the actual schools or companies. To have a lasting place in the actual curriculum, a strong relation between the software and the rest of the curriculum (in content, timing, and approach) and/or the conditions in the working environment is a necessary condition. In addition teachers should have the adequate skills and the necessary commitment. Finally, there should be a readiness (and the formal authority) to use new ways of assessment.

## REFERENCES


DUNBAR, K. (2001). What scientific thinking reveals about the nature of cognition. In Crowley, K., Schunn, C. D., & Okada, T. (Eds.) *Designing for science: Implications from everyday, classroom, and professional settings*. Mahwah, NJ: Lawrence Erlbaum Associates.

GIJLERS, H. & DE JONG, T. (in preparation). Confronting knowledge in a collaborative discovery setting.

DE JONG, T., & VAN JOOLINGEN, W.R. (1998). Scientific discovery learning with computer simulations of conceptual domains. *Review of Educational Research*, *68*, 179-202.

DE JONG, T., VAN JOOLINGEN, W.R., LAZONDER, A., OOTES, S., SAVELSBERGH, E., & WILHELM, P. (2002). *Co-Lab Specifications. Part 1 – Theoretical background*. Co-Lab deliverable D3. Enschede (The Netherlands): University of Twente.

DE JONG, T., VAN JOOLINGEN, W.R., SWAAK, J., VEERMANS, K., LIMBACH, R., KING, S., & GUREGHIAN, D. (1998). Self-directed learning in simulation-based discovery environments. *Journal of Computer Assisted Learning*, *14,* 235-246.

DE JONG, T., VAN JOOLINGEN, W.R., VEERMANS, K., & VAN DER MEIJ, J. (in press). Designing discovery learning environments; in search for re-usable components. In M. Spector & D. Wiley (Eds.), *Innovations in instructional technology: Essays in honor of M. David Merrill*. New Jersey: Lawrence Erlbaum.

VAN JOOLINGEN, W.R., & DE JONG, T. (2003). SimQuest: Authoring educational simulations. In T. Murray, S. Blessing & S. Ainsworth (Eds.) *Authoring tools for advanced technology educational software: Toward cost-effective production of adaptive, interactive, and intelligent educational software* (pp 1-31). Dordrecht: Kluwer Academic Publishers.

VAN DER MEIJ, J., & DE JONG, T. (2003). *Learning with Multiple Representations. Supporting students' translation between representations in a simulation-based learning environment*. Paper presented at the EARLI conference. Italy: Padova, August 2003.

NJOO, M., & DE JONG, T. (1993). Exploratory learning with a computer simulation for control theory: Learning processes and instructional support. *Journal of Research in Science Teaching*, *30*, 821-844.

PIETERS, J., LIMBACH, R., & DE JONG, T. (in press). Designing learning environments: Process analysis and implications for designing an information system. *International Journal of Learning Technology*.

SWAAK, J., & DE JONG, T. de (1996). Measuring intuitive knowledge in science: the development of the what-if test. *Studies in Educational Evaluation*, 22, 341-362.

SWAAK, J., & DE JONG, T. (2001). Discovery simulations and the assessment of intuitive knowledge. *Journal of Computer Assisted Learning*, *17*, 284-295.