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# M7.2.3
## Third NNR user group workshop on Qualitative Reasoning and Modelling

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| **Dissemination Level** | | |
| **PU** | Public | X |
| **PP** | Restricted to other programme participants (including the Commission | |
| **RE** | Restricted to a group specified by the consortium (including the Commission | |
| **CO** | Confidential, only for members of the consortium (including the Commission Services) | |

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**Abstract**
This document describes the goals, contents, and results of the third WP4/WP6 workshop on qualitative reasoning and modelling, held in Birini, Latvia, 25-29 September 2006.

**Document history**

| Version | Status | Date | Author |
|---|---|---|---|
| 01 | Draft – Initial structure and ideas for each section | 04/10/2006 | Liem |
| 02 | Added agenda & section about collaborative modelling using the Repository/OWL/Model merging. Augmented introduction. Added references. | 26/10/2006<br>27/10/2006 | Liem |
| 03 | Section 5 about Sketch | 28/11/2006 | Bouwer |
| 04 | Improved section 5, including figures | 29/11/2006 | Bouwer |
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| 06 | Added section 6 and overall refinement | 21/08/2007 | Bredeweg |
| Final | Minor corrections | 22/08/2007 | Bredeweg & Liem |
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## Contents

# 1. Introduction

This workshop was the third in a series of training workshops for WP4 and WP6 of the Naturnet-Redime project. The goal of this workshop was to support the WP6 participants in their continuing work on their Qualitative Reasoning (QR) case study models [1,2,3,4,5]. This workshop was co-located with the Naturnet-Redime project meeting in Latvia (September, 2006). About half the time was spent presenting, demonstrating and working with the new collaborative features in the model building and simulation workbench Garp3. UvA (Anders Bouwer) gave a presentation about the new Sketch environment [6], which supports the structured approach to building QR models [11] (Chapter 5). UvA (Jochem Liem) gave a presentation on sharing and reusing qualitative models with the new OWL import/export functionality, the qualitative model repository and the model merging functionality (Chapter 4) [6]. The other half of the time, the project partners presented their case studies and models, and the participants discussed how the models could be improved. DDNI (Eugenia Cioaca) gave a presentation about the Danube Delta River Model, CLGE (Elena Nakova) presented the model about the River Mesta, and UnB (Paulo Salles) presented a number of models about the river Riacho Fundo in Brazil. Concurrently, an experiment was performed with local students from the University of Latvia and from the Vidzeme Regional University in Riga to measure the usability and learning effect of running and inspecting qualitative models using the Garp3 QR workbench developed in WP4 (Chapter 6).

# 2. Participation

Representatives from each WP4/WP6 partner were present and actively involved in all aspects of the workshop.

| | |
|---|---|
| UvA: | Bert Bredeweg, Anders Bouwer, Jochem Liem, and Elinor Bakker |
| UvA/UnB: | Paulo Salles |
| UoJ: | Tim Nuttle |
| CLGE: | Elena Nakova |
| DDNI: | Eugenia Cioaca |
| UoH: | Richard Noble |
| BOKU: | Andreas Zitek |

The experiment held at the University of Latvia and at the Vidzeme Regional University is discussed in Section 6.

# 3. Workshop Agenda

The activities carried out during the September 2006 meeting in Latvia are listed below. Notice that a large part of Monday 25th was allocated for the Naturnet-Redime project meeting, and that a large part of Tuesday 26th was reserved for dissemination with local stakeholders. The remaining time was used for WP4/WP6 activities and the experiment with students.

Monday 25th of September 2006

| **Time** | **Birini Castle** |
|---|---|
| 8.30 – 10.45 | WP4/6 Presentations about Sketch (Anders Bouwer) and Sharing and Reuse of Qualitative Models (Jochem Liem) |
| *10.45 – 17.30* | *Naturnet-Redime project meeting* |

Tuesday 26th of September 2006

| **Time** | **Birini Castle** |
|---|---|
| 8.30 – 10.00 | WP4/6 Presentations about case study models: Danube Delta (Eugenia Cioaca), River Mesta (Elena Nakova), Riacho Fundo (Paulo Salles) |
| *10.00 – 17.30* | *Project Presentations for local stakeholders.* |

Wednesday 27th of September 2006

| **Time** | **Birini Castle** | **Riga** |
|---|---|---|
| 9.30 – 13.00 | WP4/6 Discussion about case study models: Danube Delta (Eugenia Cioaca), River Mesta (Elena Nakova) | Experiment with local students (treatment group) (Elinor Bakker & Anders Bouwer) |
| 14.00 – 17.30 | Discussion about case study: Riacho Fundo (Paulo Salles)<br><br>Practical session working on Garp3's collaborative features. Focus: OWL, Model export/import, Model repository, and Model Copy/Paste (Jochem Liem and Bert Bredeweg) | Experiment with local students (control group) (Anders Bouwer & Elinor Bakker) |

Thursday 28th of September 2006

| **Time** | **Birini Castle** |
|---|---|
| 9.00 – 11.00 | WP4/6 Presentations and discussion about the River Trent and Great Ouse (Richard Noble) and River Kamp (Andreas Zitek) |
| 11.15 – 13.00 | WP4/6 Administrative issues / Publications |
| 14.00 – 17.00 | Practical session working on Garp3's collaborative features. Focus: Sketch environment for expression and sharing intermediate model results following the Framework for building qualitative models (Anders Bouwer and Bert Bredeweg). |

Friday 29th of September 2006

| Time | Birini Castle |
|---|---|
| 9.30 – 10.30 | Setting up designs for model evaluation (Paulo Salles) |
| 10.30 – 12.00 | Project management issues (Tim Nuttle) |

# 4. Qualitative Model Sharing, Searching, and Reuse

The model sharing, searching, and reuse session started with a demonstration given by UvA (Jochem Liem) showing some of the new collaborative functionality added to Garp3:

- OWL import and export functionality [7,8,9],
- the qualitative model repository,
- multiple model support, and
- model merging (copy/paste) functionality [6].

The participants were given the task to collaboratively create a communicating vessels model. The participants were divided into groups and given separate assignments to model a particular part of the system (see Table 1). The work had to be shared via the repository (using the OWL export). Afterwards, each group had to take the work of the other groups from the repository (using OWL import), and create a complete working model.

Group 1 (UnB and DDNI) built the scenario. Group 2 (UoJ and CLGE) modelled a contained liquid. The third group (UoH and BOKU) modelled the liquid flow. During the assignment the UvA WP4 members were there to support the modelling activity. Since all participants have become experienced Garp3 users during the project, creating the model parts was effortless. The only difference compared to the aimed results in Table 1 was the layout.

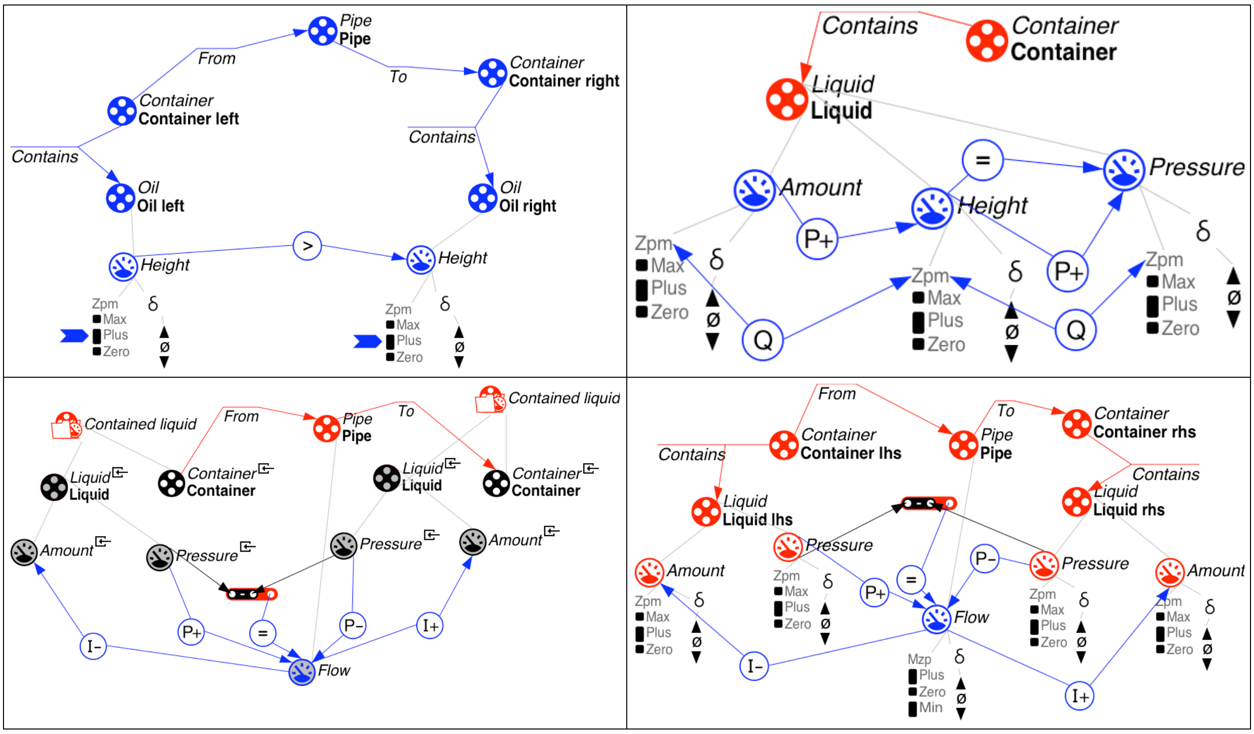


Table 1: The communicating vessels model decomposed into different aggregates: The scenario (top-left), a contained liquid (top-right), liquid flow version1 (bottom-left), and liquid flow version2 (bottom-right).

The participants first saved their files to normal Garp3 *.hgp*, and afterwards exported the models as *.OWL* files. These files were uploaded to the Qualitative Model Repository on the QRM Portal (www.garp3.org → *models* → *repository*, see Figure 1). The model repository index was updated, and allowed participants to download each other's models. By selecting the 'Container' entity in the repository, the repository shows only the models that have a Container entity in them (shown in Figure 2). Once each group downloaded the model parts of the other groups, they could proceed to integrate them.

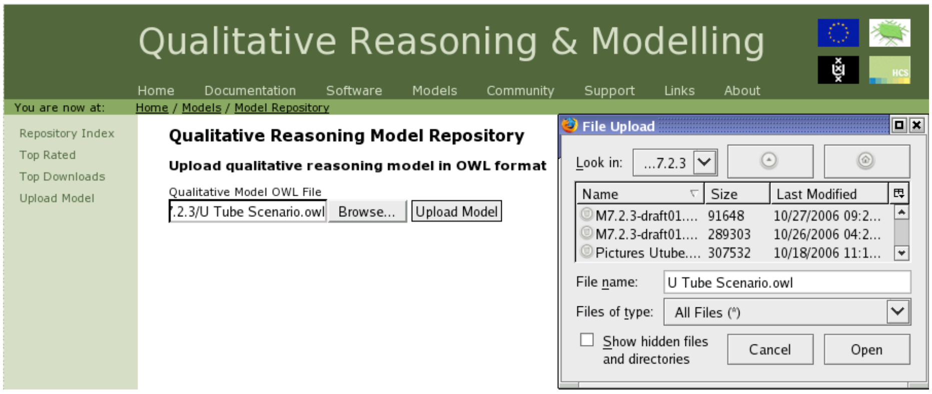


Figure 1: The communicating vessels scenario being uploaded to the qualitative model repository.

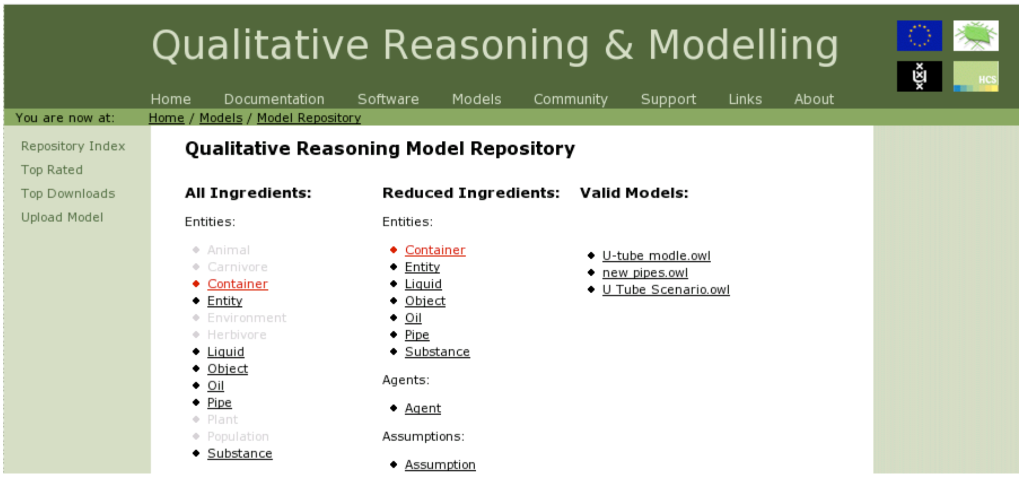


Figure 2: The qualitative model repository index showing only the models that have a container in them.

The groups opened each of the *.OWL* files in Garp3 (see Figure 3). Most groups chose the model with only the scenario as the one they would complete. All participants integrated the three models in two steps. First opening the model fragment canvasses of the three models, and then copy/pasting the contained liquid and flow model fragments to the empty model fragment canvas of the scenario model (see Figure 3). The copy/paste (model merging) functionality automatically takes care that all the definitions used in the model fragments (or scenarios) are merged with the definitions into which these aggregates are pasted. The participants then proceeded to testing the model.

Once the participants simulated their completed models, they noticed that the simulation results were not as expected. Instead of the four states the model typically generates, only one state was present in the simulation (see Figure 4). Further inspection shows that the height of the oil in the container on the left is greater than the height of the oil on the right, and therefore there should be a flow. Inspecting the values shows that the magnitudes of the heights of the oil can be determined to be 'plus', but the derivatives cannot be determined. Showing a list of active model fragments for state one reveals that none of the model fragments have fired.

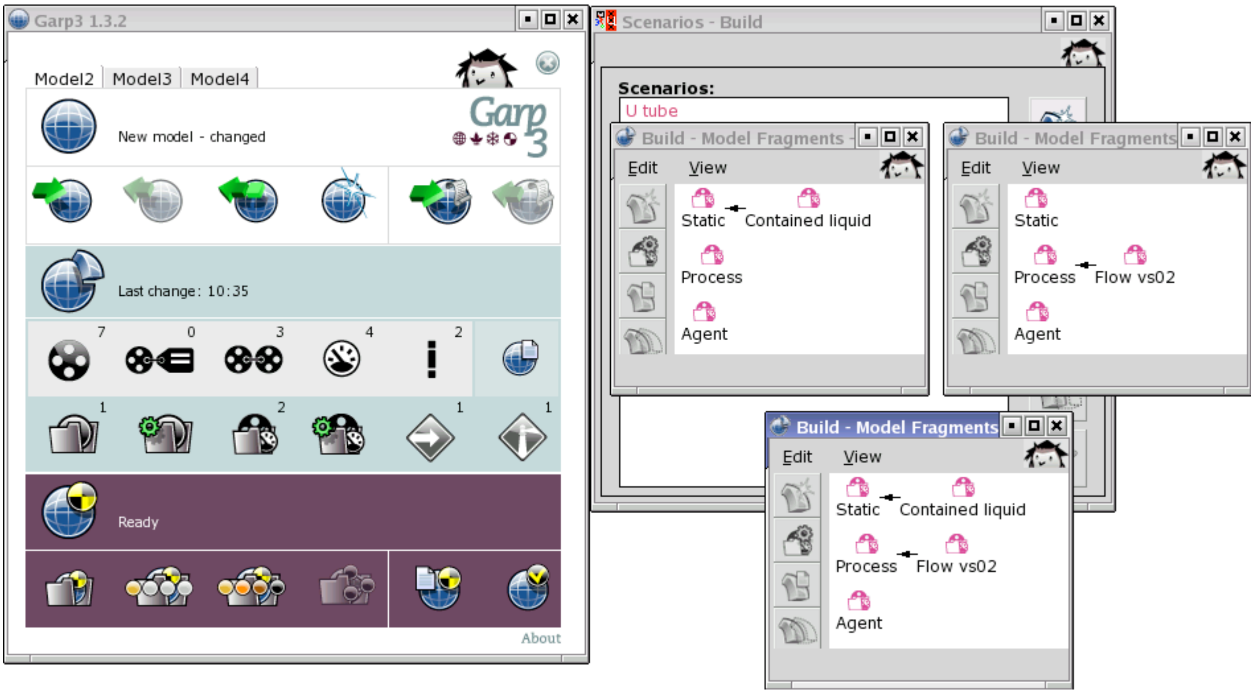


Figure 3: Assembling each of the model parts into one full model. Left: The main program window with the three opened models after copy/pasting the model fragments of the models with only a model fragment into the model with the scenario. Right background: The scenarios list of the model with only the scenario. Right foreground (clockwise): The model fragments canvasses of the model with the contained liquid, the model with the flow model fragment, and the model with only the scenario after copy/pasting each of the other model fragments in.

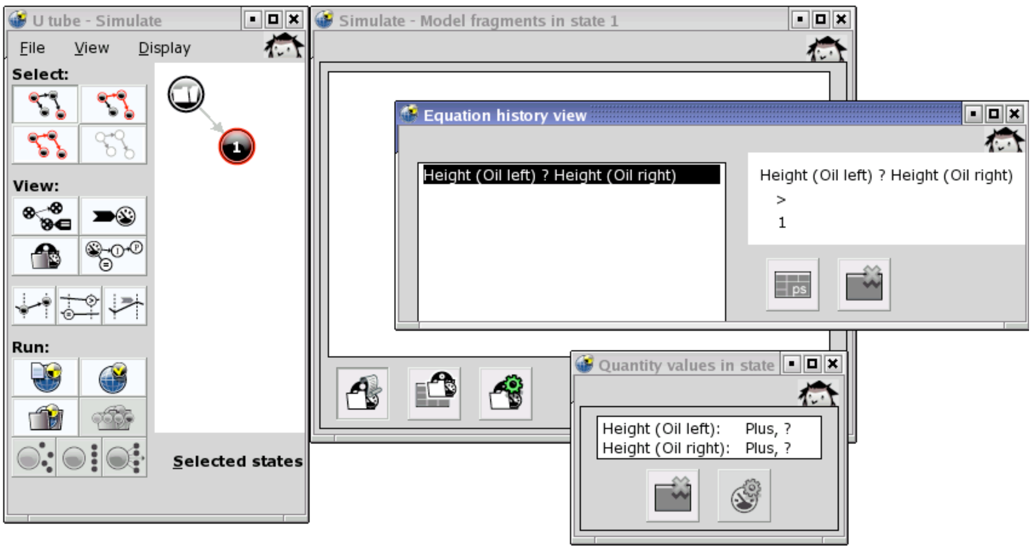


Figure 4: Running the assembled model yields only one state (left). No model fragments have fired (background right). The height of the oil on the left is greater than the height of the oil on the left (right top). The derivative of the height of the oil in both containers cannot be determined, but the magnitudes are both ‘plus’ (right bottom).

It took some time before the participants discovered what was the cause of none of the model fragments firing. The issue was that the scenario talks about containers filled with oil, and the model fragments refer to liquid. As each of the participants only defined the model ingredients necessary for their specific model fragment or scenario, the knowledge that oil is a liquid was not represented (see Figure 5a). Solving this issue (shown in Figure 5b) allows the scenario to match on the model fragments and fixed the simulation (shown in Figure 6).

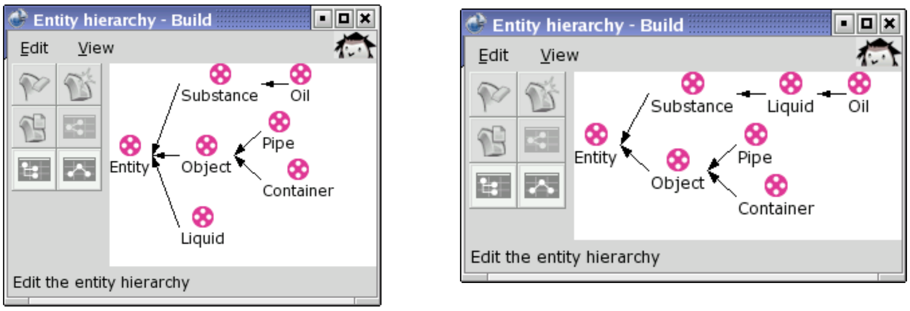


Figure 5a and 5b: In the entity hierarchy on the left (5a), oil is not a liquid. Fixing this yields the entity hierarchy on the right (5b).

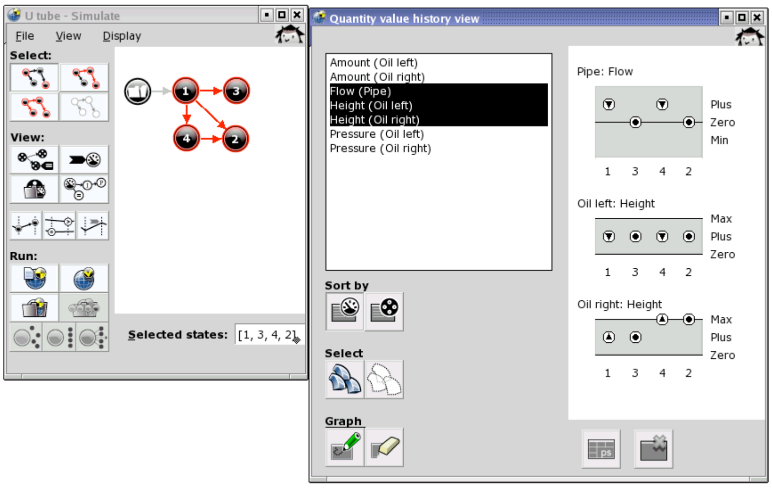


Figure 6: The correct simulation after debugging the model.

## 4.1. Concluding remarks

The participants were very positive about the OWL support, model repository and model merging functionality. Particularly because it supports model builders to more efficiently build models by sharing, searching for and reusing modelling work. This evaluation also stressed the fact again that model building is a difficult activity, because models are hard to debug. Even within the favourable conditions of this evaluation, it is not trivial to create a working model. When reusing a wide variety of models, more model-problems will occur by model merging, which have to be fixed. Therefore, future work should also focus on supporting model-debugging activities.

# 5. Supporting the Structured Approach to Modelling

UvA (Anders Bouwer) started this session with a presentation about the new Sketch environment in the collaborative workbench [6]. This Sketch environment consists of seven editors that allow users to represent their ideas about a domain in increasing levels of detail: the Concept map editor, the Structure editor, the Process definitions editor, the Agents and external influences definitions editor, the Causal model editor, the Scenarios editor, and the State-transition graph editor. Working through this set of editors structures the model building process, as each editor corresponds to a step in the framework for structured modelling [11], and the resulting sketches can be shared as intermediate modelling results. This helps to establish a common understanding of the domain between modellers, before building a final simulation model.

After the presentation, six domain experts from WP6 tested the new Sketch environment functionality by using it to represent knowledge about their river ecology case studies, which they had already specified in the diagrams in their case study descriptions [1,2,3,4,5] (at the time using third-party software, such as the CmapTools, retrieved from http://cmap.ihmc.us in September 2006). UvA WP4 participants were available for support and could be asked questions. Because it was considered important to explore issues related to the graphical user interface in detail, the focus in this test session was on the graphical editors: the Concept map editor, the Structure model editor, the Causal model editor, and the Behaviour graph editor.

## 5.1. The Concept Map Editor

To test the Concept map editor (Figure 7), the participants were asked to create a concept map representing the concept map from their case study description as correctly as possible, including the concepts in their domain of expertise, as well as the relationships between them. Since the general interface mechanisms of the Concept map editor are very similar to the editors in the Build part of Garp3, participants could immediately start creating a concept map, and they felt it was very convenient to have this facility within the Garp3 tool. Participants liked the ability to add comments to concepts and relations. Two bugs were discovered, and there were several features, that some of the participants used in their original diagrams, which are currently not present in the Concept map editor in Garp3:

- When changing the comments about a relation, the tool tips on the screen are not updated correctly (bug)
- When updating from one specific version of Garp3 to another, errors occur (bug).
- One participant used different sizes of nodes or text font for different concepts (e.g., to focus on particular concepts in a map).
- One participant used colours to categorize different types of concepts.
- Several participants created multiple related concept maps.

The bugs have already been solved. The issue of creating multiple concept maps is considered important, and will be implemented as soon as possible. In addition, there were some other comments and extra feature requests:

- Use the same concept in multiple places in the same diagram.
- Use a single link to multiple concepts.
- It would be nice to have different tool tips for every single relation instance.
- Add more hooks to the graphical concept nodes for relations to connect to.
- Metadata window disappears when you push ‘save’, which is slightly unexpected.
- When adding a new relation or concept, delete the existing text with one click (instead of deleting after full selection).

The first two feature requests do not fit well with the design of the current interface, however. Using the same concept multiple times violates the principle of concept maps of representing all information about a particular concept around one spot so that it can be found easily. Using one link that branches out to multiple concepts violates the Garp3 design practice of a direct mapping between knowledge item and its graphical representation, and might make it more difficult to select a particular link (to inspect it in detail, or to delete it). The rest of the issues will be considered for possible future work.

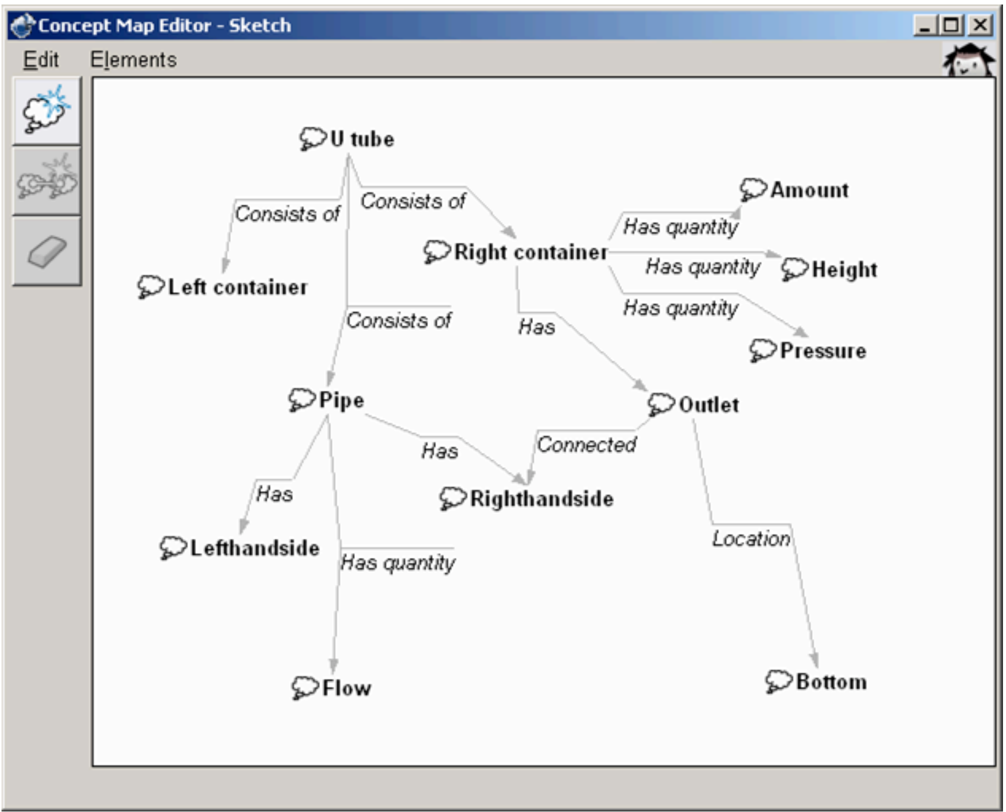


Figure 7: The Concept map editor.

## 5.2. The Structure editor

To test the Structure editor (Figure 8), the participants were asked to create a diagram of the structure of the system of their case study, involving entities, agents, assumptions, and structural relationships, such as ‘contains’, ‘connected-to’, etc. The Structure editor is very similar to the Concept map editor, so the participants could generate their diagrams quite fast. They commented that it is nice to be able to change whether something is undefined, agent, entity, etc. In their feedback, the following issues could be discerned:

- Be able to have multiple maps.
- The keyboard shortcut CTRL+C should be used for ‘Copy’, not for ‘add Concept’.
- It would be nice to be able to import (part of) the concept map into the structure editor and be able to assign clouds to entities, assumptions, agents, etc.
- Would it be able to scale (zoom) the view so you can fit more on the screen?
- Would it be better to have separate windows for entities vs. agents, etc.? When would you want to mix them together? Do assumptions belong in this editor?
- Use multiple links from relations to assign assumptions to relations specifying, e.g., uncertainty about a relation.

The first three issues will be addressed as soon as possible. The fourth point (zoom) is indeed considered desirable, but not easy to implement. The fifth point challenges the basic design of the editor, but the designers feel that it is useful to combine entities, agents, and assumptions in a single editor to create a complete view of the system structure. It should be noted, however, that the notion of 'assumptions' here refers to structural assumptions (not operating and not simplifying assumptions). The last point would require a change to the basic representation underlying Garp3, and is considered an issue too complex to address in the Sketch editors, since they are meant to generate intuitive representations.

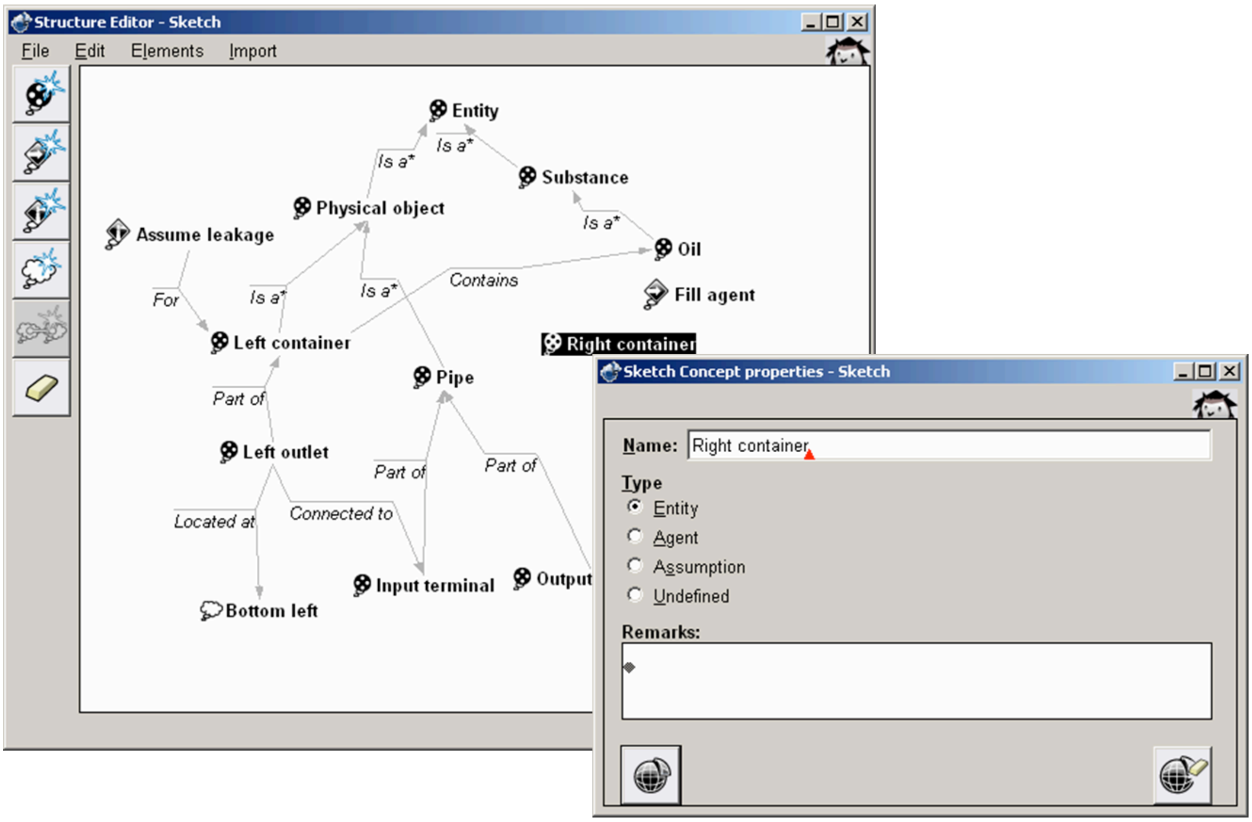


Figure 8: The Structure editor.

## 5.3. The Causal model editor

To test the Causal model editor (Figure 9), the participants were asked to create a model of the causal dependencies involved in the system of their case study, consisting of the relevant quantities and the 'I+', 'I-', 'P+' and 'P-' relationships between them. The feedback from the participants contained the following issues:

- The name of the entity (or agent) is not represented together with the quantity, as it is in the Build and Simulate environment. This makes it necessary to create unique names for quantities, whereas in the Build and Simulate environment, the quantity names may be identical if they occur in different entities (or agents).
- Think about including assumptions in the causal model (e.g., this influence only happens under certain conditions).

These issues will be considered for possible future work.

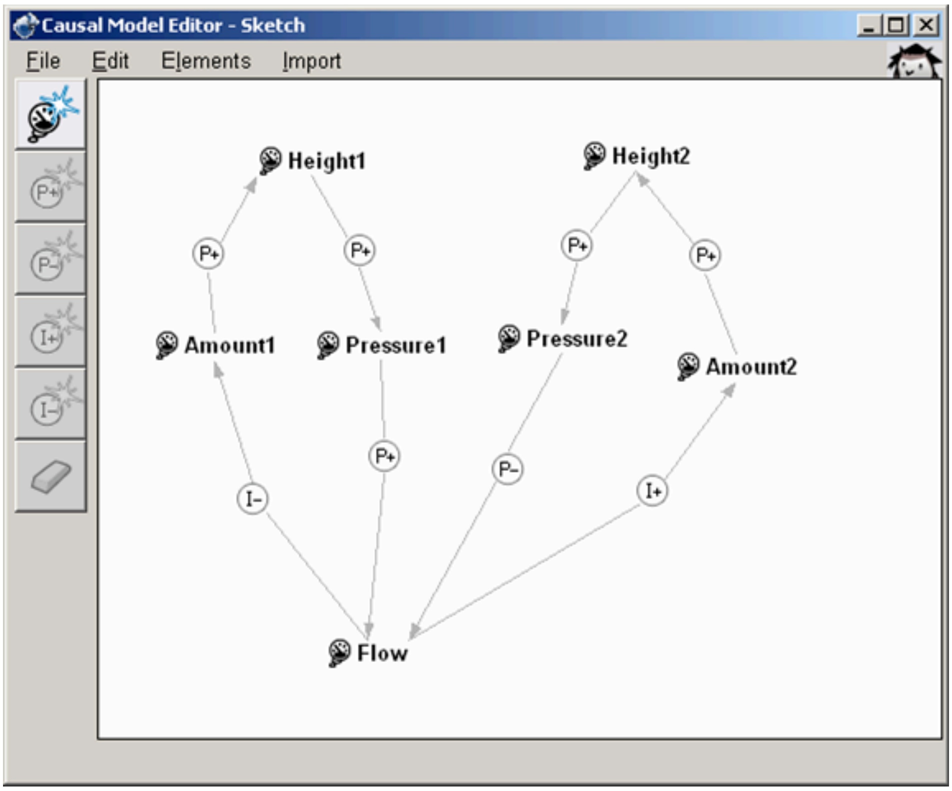


Figure 9: The Causal model editor.

## 5.4. The State-transition graph editor

To test the State-transition graph editor (Figure 10), the participants were asked to make a graph consisting of several states representing different behavioural states of the system of their case study, and the possible transitions between states. Each state can contain value or in/equality statements involving the quantities that are imported from the causal model editor. Feedback from the participants referred to the following bugs and feature requests:

- Sometimes a statement is not inserted after saving (bug).
- Changes to quantity names in the state graph also affect the causal model (bug). This triggered an interesting discussion about what should be possible to import and export.
- When you change the state ID to a non-numerical value, things go wrong (bug).
- Multiple instances of same quantity name possible in the state properties window (bug).
- The default editing of labels seems non-optimal. Editing text will change all values throughout the state graph if you're not careful to create a new statement first. Too difficult to make small changes to statements to indicate small changes from one state to another (especially annoying when copying states and then editing them). This is inconsistent, e.g., with the current situation that when you change the inequality sign in a statement, it doesn't change all similar statements everywhere.
- The 'Save' button, which has to be pressed to save an in/equality statement, is not located near the statements. Perhaps an arrow tool could be used to add entries to list of statements?
- It is confusing that the default text for the right-hand-side text field is 'NewValue', although it may show a value *or* a quantity. Can the default text be adapted to 'New value or quantity'?

- Values that are not used in any statement are deleted automatically, but perhaps this is too strict.
- Sketch freezes when sub-window is open. *This is in fact standard behaviour, and also present in other screens of Garp3.*
- It is not so easy to differentiate different entities with the same quantity (see also the first issue related to the Causal model editor).

The bugs are currently being addressed. The remaining issues will be considered for possible future work.

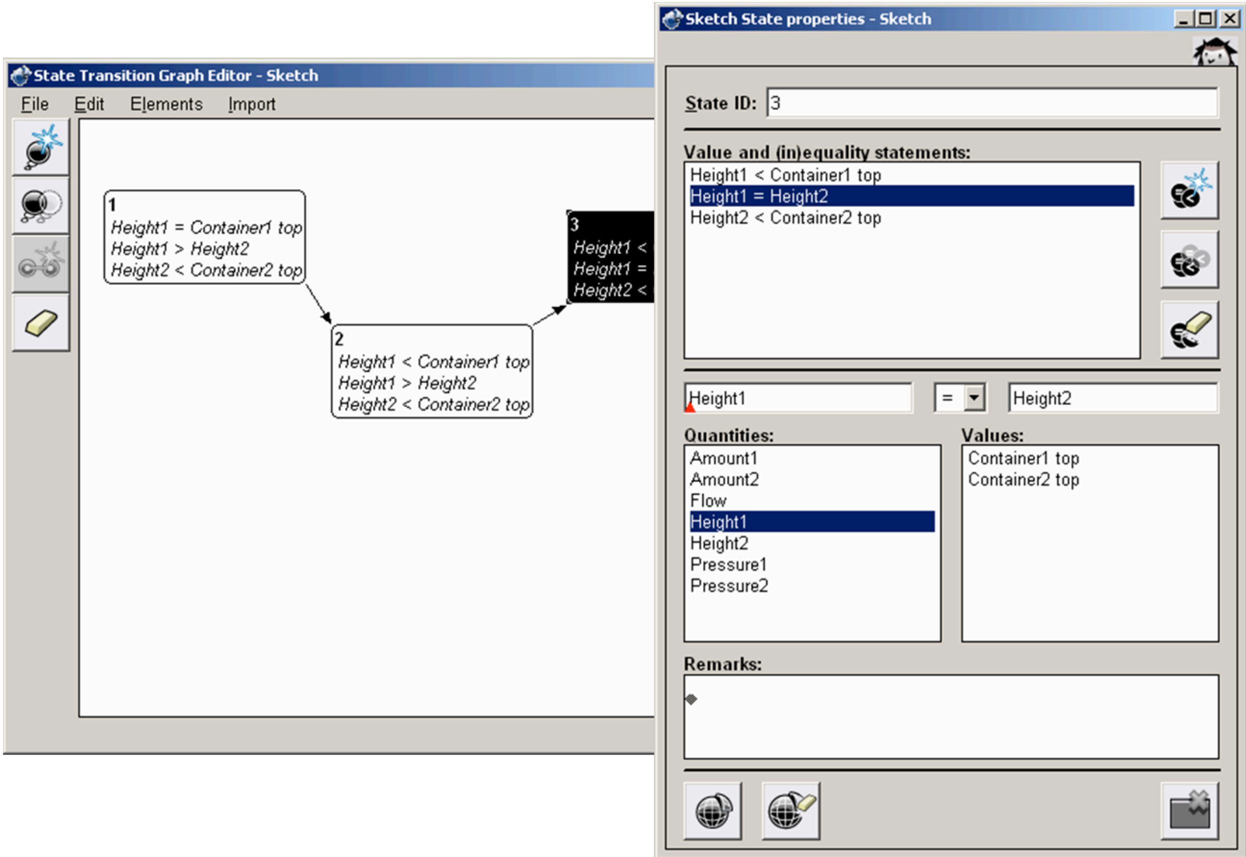


Figure 10: The State-transition graph editor.

## 5.5. General remarks and additional feature requests

In general, the participants welcomed the addition of the Sketch functionality and provided some useful comments and ideas for further improvements. These include the following feature requests:

- Include some short help text about what each sketch environment is for.
- The possibility to generate textual output from the Sketches (or even the whole model).
- The possibility to enter characters which are currently forbidden in the names of concepts, entities, agents, assumptions and quantities, such as hyphens, apostrophes, etc., as well as capital letters, which are currently transformed to lowercase (except for the first character, which is always capitalized).
- The addition of an undo option/key (it should be noted, however, that many Garp3 dialogs already have a ‘cancel’ or ‘undo changes’ button).
- Make the direction of the arrow more predictable when creating relationships.
- The possibility to select or delete multiple (or all) items at once.

- Have a keyboard shortcut for 'Select all'.

Regarding the first issue, work is already in progress to make help texts available from every screen in Garp3. The remaining issues will be considered for possible future work.

## 5.6. Current and future work on the Sketch environment

Besides addressing the points already mentioned in sections 5.1-5.5, current work concentrates on functionality for importing information from one sketch to another, which will further facilitate creating sketches that form a consistent and coherent set of representations about the domain. Future work may also focus further integration of transforming the sketch representations into running simulation models. This is expected to further enhance structuring of the model building process, and will support users in refining their initial conceptual ideas into detailed representations of expert knowledge.

# 6. Experiment: Learning about SD using QR

This section presents a study on using Garp3 for education. Garp3 is a workbench that supports users in acquiring conceptual knowledge, particularly concerning cause-effect reasoning. Using a model previously developed by experts on issues relevant to sustainable development, learners interacted with the software working through a set of assignments. Even during the short duration of the experiment most learners in the treatment condition significantly improved their knowledge compared to learners in the control group.

## 6.1. Introduction

Qualitative Reasoning (QR) is a research area within Artificial Intelligence (AI) that focuses on means to articulate and communicate *conceptual* knowledge such as system structure, causality, the start and end of processes, the assumptions and conditions under which facts are true, qualitative distinct behaviours, etc. Cognitive science research has shown that when learners develop a causal model of a system's behaviour, they are better able to apply their knowledge to new situations [20]. QR models are a way to develop such causal models, because they explicitly capture the fundamental knowledge and elements of a system, while suppressing irrelevant detail.

In the last few years, tools have being developed that take a diagrammatic approach to having learners interact with automated qualitative reasoning engines [12,16]. Diagrammatic representations help reduce working memory load (cognitive offloading), allowing students to work through more complex problems. Such representations also help them in presenting their ideas to others for discussion and collaboration. This relates to the idea of using concept maps [18]. The main difference is that our approach uses a rich and detailed semantics, based on QR formalisms.

The Garp3 software is developed to be a workbench for learners to advance their conceptual ideas on cause-effect analysis of systems' behaviour [14]. By using this QR workbench users can investigate the logical consequences of their common sense ideas and use expert knowledge to improve their own understanding of phenomena.

But how useful is the Garp3 software actually for these purposes? To provide an answer for this question, the Garp3 workbench was presented to two groups of Latvian students from the University of Latvia and from the Vidzeme Regional University. These students were Bachelors (final year) and Masters (first year) and had no prior knowledge of QR technology. These students were therefore well suited to investigate the usability of the software with real novice stakeholders, which was the main goal of the event.

The software has many features that can be used to create potentially interesting and useful educational experiences. Participants may build their own model from scratch, individually or collaboratively interact with existing models, make sketches of yet vague ideas, discuss a causal model within a group, etc. For the interaction with the Latvian students we opted for a traditional experimental setting that investigates whether the software can be used effectively to learn something in the first place. After all, due to its many options the Garp3 software may appear complex and one may wonder whether this fundamentally hampers its usability for education.

## 6.2. Millennium development goals

As domain knowledge we re-used a Garp3 model developed by experts focusing on the Millennium Development Goals (MDG) (see e.g. http://www.un.org/millenniumgoals/). The model used in the evaluation study presented here relates to the seventh Millennium Development Goal (MDG7), to 'ensure environmental sustainability'. The MDG were defined in The Millennium Declaration, signed in 2000 at the United Nations (UN), and consist of 8 goals and 18 targets on poverty, hunger, education, gender equality, health, environment and cooperation, to be achieved mostly by 2015. There are 48 indicators to monitor progress of countries towards achieving the goals. National governments are expected to periodically report on the situation of the MDG. Among these goals, the MDG7 is probably the most difficult to understand and to achieve on time. In fact, most national reports published so far mentioned difficulties with MDG7 [17]. Reasons for that include conceptual problems in defining sustainability, problems to select (or create) suitable indicators to monitor MDG7, and the availability of good quality data.

Recent work in this context has focused on building qualitative models and simulations of issues concerning the MDG7 in order to create insight and awareness on behalf of the state-holders. The 'deforestation model' is one of those models [19,21]. It includes three of the indicators selected for monitoring this goal:

- proportion of land area covered by vegetation (indicator 25),
- land area protected to maintain biological diversity (indicator 26), and
- the proportion of people without sustainable access to safe drinking water (indicator 30).

## 6.3. QR model of MDG7

The MDG7 QR model used for the study reported here captures key ideas relevant to deforestation. Figure 11 shows the scenario for this model. It consists of the entities 'vegetation', 'land', 'water' and 'human', and a set of configurations detailing the relationships between them (e.g. vegetation 'grows on' land). The scenario specifies 'wood cutters' as an agent 'active in' the vegetation. Initially one quantity is defined, namely 'land with vegetation' (assigned to vegetation), with value 'large' and an unknown derivative (direction of change). The simulator will add other quantities when it finds model fragments that apply to this scenario which introduce new quantities.

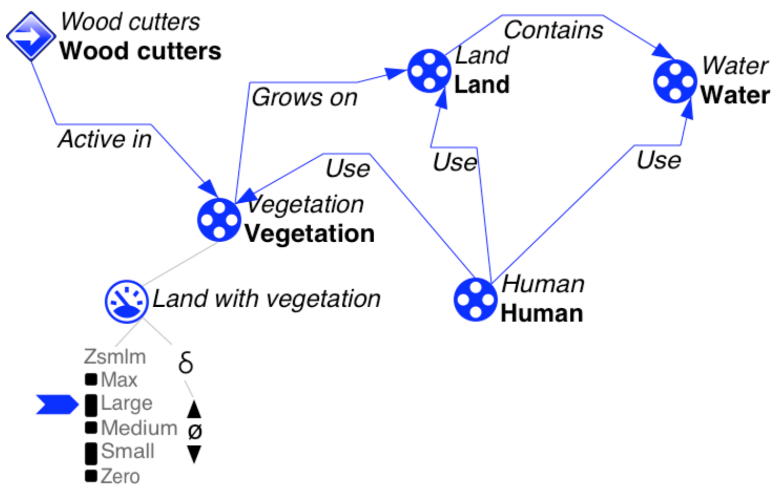


Figure 11: Scenario of the deforestation model

Simulating the scenario from Figure 11 results in a relatively simple state-graph as shown in Figure 12. The initial scenario leads to a single interpretation (state 1), given the knowledge available in the model fragments. This state changes into state 2, which changes into state 3, which changes into state 4. State 4 is a steady state from which no further transitions are happening.


Figure 12: State-graph when simulating the deforestation model

The causal model underlying each of the states is similar and is shown in Figure 13. It shows the entities and the quantities assigned to each of them (e.g. 'wood cutters: deforestation rate'). It also shows the direct influences (I+/I-) and the proportionalities (P+/P-) between the quantities.

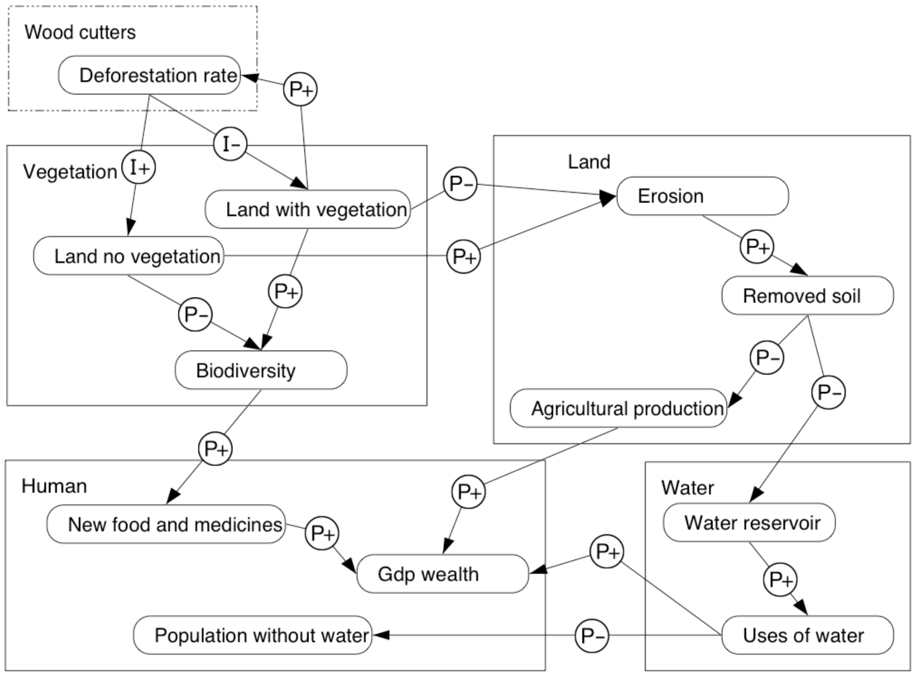


Figure 13: Causal model generated by Garp3 for the deforestation model

'Deforestation rate' is treated as an exogenous quantity in this model. Consequently, the 'deforestation rate' is at the start of the cause-effect chain. In summary, when deforestation is active it reduces the 'land with vegetation', which in turn causes the 'biodiversity' to decrease and consequently reduces the chances of finding 'new food and medicines'. 'Land with vegetation' (when decreasing) also causes 'erosion' to increase which leads to less 'agricultural production' and less water contained in 'water reservoirs'. Ultimately, all these factors come together in the 'Gross Domestic Product (GDP wealth)', which reflects the human wealth and decreases (when deforestation is active).

Figure 14 depicts the value history. It shows the value and the derivative in each state for each quantity. For instance, in state 2 'biodiversity' has magnitude 'medium' and is 'decreasing'. In this simulation an active deforestation causes the GDP wealth to decrease and become zero. The intermediate quantities change in a similar or in opposite manner depending on their relationships in the causal network.

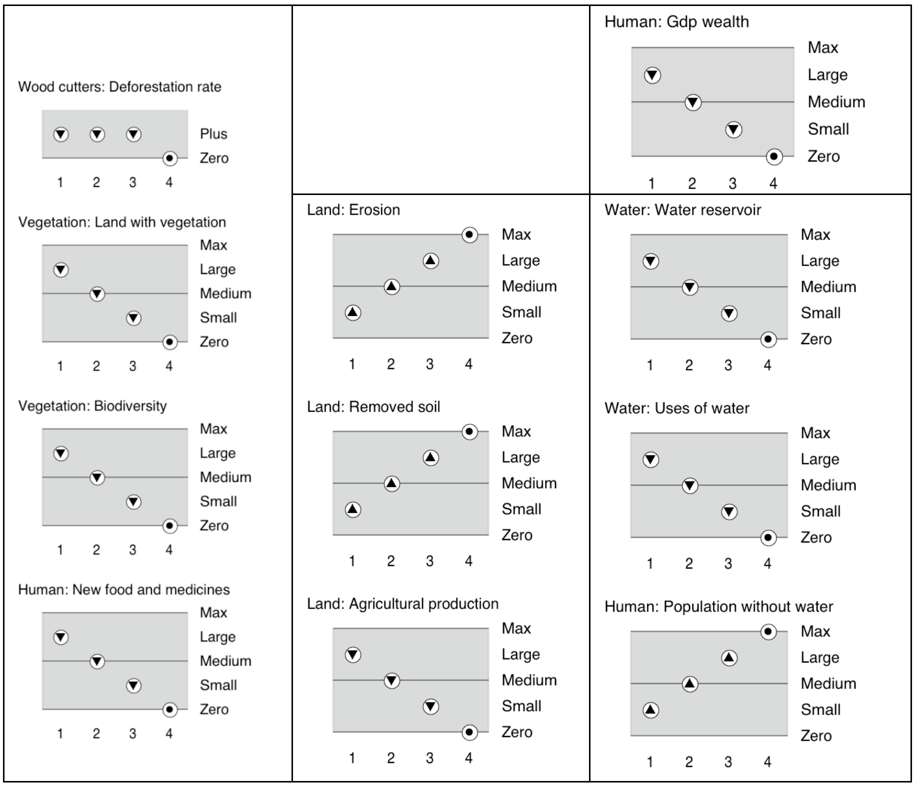


Figure 14: Value history of the quantities in the deforestation model

## 6.4. Materials (see also Appendix)

### 6.4.1. Pre-test and post-test, and additional questionnaire

To access the domain knowledge of the learners in the experiment two unique questionnaires were developed (pre-test and post-test), each consisting of 36 items, equally divided over five categories of question types:

- Classify: True of False
    - If A then B (e.g. IF erosion increases, THEN uses of water increase).
    - A because B (e.g. Agricultural production increased BECAUSE erosion increased).
- Fill out: Increases or Decreases
    - IF A increases/decreases then B …? (e.g. IF erosion increases, THEN wealth (GDP) …?)
    - A increases/decreases because B …? (e.g. Wealth (GDP) decreases, BECAUSE biodiversity …?)
- Causal chain. Starting with a statement such as ‘A increases/decreases’, fill out increase or decrease for 6 affected quantities.

An additional questionnaire was used to access the learners’ attitude towards the experiment. These questions had to be answer using a 7-point scale ranging from negative (very difficult) to positive (very easy). It involved questions such as:

- Did you enjoy today’s session?
- Did you find it difficult or easy to use the software interface?

### 6.4.2. Treatment model set and questions

The model and its simulation results are not extremely difficult, but still expected to be relatively new and complex enough for the target learners. In fact, it was felt that during the treatment the subject matter should be administered as a model sequence of progressive complexity, particularly concerning the causal model details. Therefore the model was reorganised into a sequence of six models (notice that each of these models produces a state-graph as shown in Figure 12):

1. Wood cutters: deforestation rate; Vegetation: land with vegetation, land with no vegetation, and biodiversity.
2. Wood cutters: deforestation rate; Vegetation: land with vegetation, land with no vegetation, and biodiversity; Human: new food and medicines.
3. Wood cutters: deforestation rate; Vegetation: land with vegetation, land with no vegetation, and biodiversity; Land: erosion, removed soil, and agricultural production.
4. Wood cutters: deforestation rate; Vegetation: land with vegetation, land with no vegetation, and biodiversity; Land: erosion, removed soil, and agricultural production; Water: water reservoir, and uses of water.
5. Wood cutters: deforestation rate; Vegetation: land with vegetation, land with no vegetation, and biodiversity; Land: erosion, removed soil, and agricultural production; Water: water reservoir, and uses of water; Human: population without water.
6. Full model as shown in Figure 13.

For each model, four treatment questions were developed in order to engage the learners in interacting with the model. For example, the treatment questions for the first model were:

- Q1: Which quantity is influenced negatively by deforestation? (Answer: Land with vegetation).
- Q2: If land with vegetation decreases, what will happen to biodiversity? (Answer: decreases).
- Q3: What is the value of biodiversity in state 1 and 4? (Answer: large and zero).
- Q4: Which quantity is increasing? (Answer: land with no vegetation)

### 6.4.3. Procedure

The experimental setup is shown in Table 2. During the introduction the students were familiarised with the sequence of activities they would be carrying out, without explaining the exact goals of the experiment. It was also stated that the experiment was not testing individual capabilities. To assess the pre-knowledge of the learners the pre-test (36 items) was administered first.

Table 2: Experimental setup

| | *15 min* | *15 min* | *60 min* | *15 min* | *15 min* |
|---|---|---|---|---|---|
| *Treatment* | Introduction | Pre-test | Working with Garp3 | Post-test | Closing |
| *Control* | Introduction | Pre-test | Lecture on ICT | Post-test | Closing |

After the pre-test the students in the treatment condition worked through the models (as described above) and the students in the control group attended a lecture on the use of computers for education. Notice that in the treatment group the participants had to start the software by themselves, including loading the required model, running the full simulation, and opening the causal model and value history. The treatment questions were handed out on paper, while the answers were shown centrally (and read aloud) by the experiment leaders after the majority of students finished answering the questions for a sub-model. No additional explanation was given (see Figure 15 for an impression).

Both the treatment and the lecture lasted approximately one hour, after which the post-test was administered to both groups. The post-test was in principle similar to the pre-test, but consisted of a different set of questions on the same subject matter. In the treatment the learners also filled out the additional questionnaire. The experiment was closed by briefly explaining the overall goal and organisation of the event. In the control group this of course required some additional effort in order to ensure that participants would also appreciate the experience (e.g. interested students were given additional information about the Garp3 software).

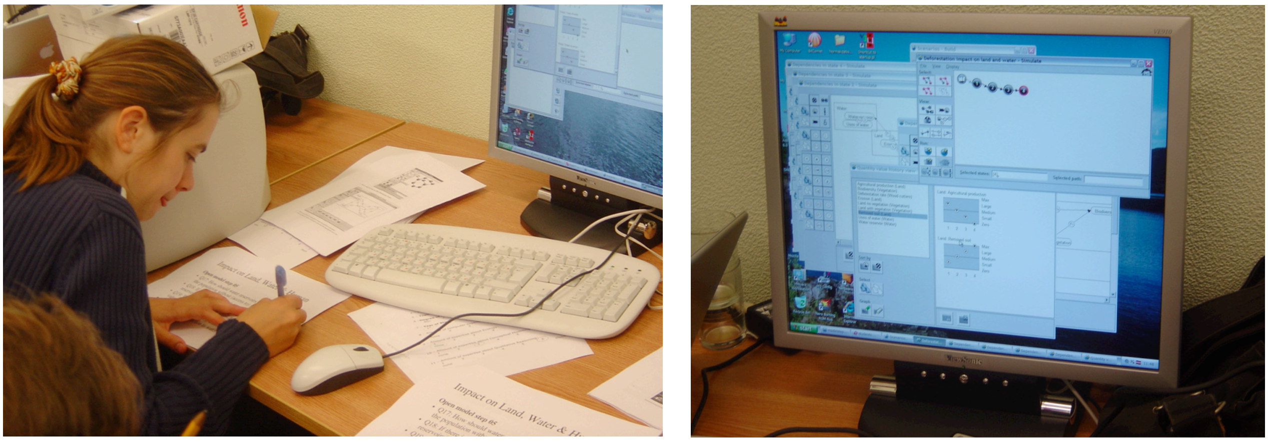

Figure 15: An impression of the treatment session.

## 6.5. Experiment results

In the experiment a group of 24 subjects was assigned to the treatment condition and a group of the 22 subjects was assigned to the control condition. Due to circumstances (lack of equipment) four subjects in the treatment condition worked together in two pairs. As the treatment was designed for individual learning and not for a collaborative approach, the scores of these four subjects were removed, and are not included in the analysis presented here.

Table 3, 4, 5 and 6 show the scores of the subjects on the pre- and post-test in both conditions. On average the subjects in the treatment group (N=20) scored 24.75 and 26.95 on the pre- and post-test, while the control group (N=22) scored 20.73 and 21.05. Thus, the treatment group improved 2.20 points, while with an improvement of 0.32 points the control group did not seem to have changed much. However, in both cases the difference between the pre- and post-test turned out non-significant. Further analysis shows that the difference on the pre-test scores between the two groups is rather high (4.02 points), and in fact significantly different at $P<0.05$ (t-test). Moreover, an average score of 26.95 out of 35 is rather high (77%, compared to 60% in the control group). This led us to hypothesize that in the treatment group the pre-knowledge was not only better then in the control group, but also reaching an upper boundary in terms of what the pre- and post-test measured, at least for the better students. Also, when students score relatively high on their understanding of the target subject matter, the opportunities for them to learn more become less. In order to investigate this hypothesis, we statistically analysed the data without the highest scores. This was done in three groups: individual scores less than 30 (N=16), 29 (N=15), and 28 (N=11). In all these cases the significant difference on the pre-test scores between the two groups disappears and the treatment group significantly scores better on the post-test compared to the pre-test (t-test: $P<0.01$, $P<0.01$, and $P<0.05$, respectively).

Table 3: Control group - Scores on pre-test

| Score | 6 | 13 | 14 | 15 | 18 | 19 | 20 | 21 | 23 | 24 | 25 | 29 | 31 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Frequency | 1 | 1 | 1 | 1 | 3 | 3 | 2 | 1 | 3 | 1 | 1 | 3 | 1 |

Table 4: Treatment group - Scores on pre-test

| Score | 17 | 18 | 19 | 20 | 21 | 23 | 24 | 27 | 28 | 29 | 30 | 31 | 32 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Frequency | 1 | 1 | 3 | 1 | 1 | 1 | 2 | 1 | 4 | 1 | 2 | 1 | 1 |

Table 5: Control group - Scores on post-test

| Score | 11 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Frequency | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 2 | 2 | 2 | 1 | 1 | 3 | 1 | 1 |

Table 6: Treatment group - Scores on post-test

| Score | 18 | 21 | 23 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 35 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Frequency | 2 | 2 | 1 | 1 | 2 | 2 | 3 | 1 | 1 | 1 | 1 | 2 | 1 |

The scores on the additional questionnaire provide insight on the attitude of the students towards the experiment, the software and its usability. “Did you find it difficult or easy to use the software interface?” scored 5.25, “Did you find the diagrams difficult or easy to understand?” scored 5.33, “Did you enjoy today’s session?” scored 5.33, and “Did you enjoy using the software?” scored 5.35, on average. Considering that 1 would be ‘not at all’ and 7 ‘very much’ this shows that students appreciated the event and considered the software easy to use.

## 6.6. Concluding remarks

This section has presented the results of a study to investigate the use of Garp3, a Qualitative Reasoning workbench, as a tool for learning about sustainable development. As subject matter a model previously developed by experts about the United Nations’ seventh Millennium Development Goal (MDG7) was used. This model includes three of the indicators selected for monitoring this goal (25, 26 and 30). The results of the experiment turned out to be very encouraging. Students in the treatment group could easily operate the software, that is open the models, run them, and inspect the simulations. Apparently the interface of the Garp3 software behaves in a way that is intuitive. The treatment was also effective in creating a significant learning effect, particularly after removing the subjects who scored very high on the pre-test.

The results presented here are in line with other studies that show the potential of using qualitative representations and automated reasoning engines for education (e.g., [12,13,16]). Moreover, being able to achieve this result within the short duration of the experiment creates promises for the impact the Garp3 software may deliver when it is used systematically on a variety of topics for education.

# 7. Conclusions

The third NaturNet-Redime workshop on qualitative modelling was successful in training researchers within the project to use the new collaborative features in the workbench Garp3 (www.garp3.org): the Sketch environment, export to and import of OWL files, the qualitative model repository, and model merging (copy/paste). The significant improvement of the participants' model building and inspection skills since the last workshop was very noticeable. Discussing the case study models gave the modellers enough input to further improve their models. Finally, the successful experiment with the Latvian students illustrates the potential of Garp3 for effective use in education.

# 8. Acknowledgements

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# 9. References

[1] Cioaca, E., Covaliov, S., David, C., Tudor, M., Torok, L. and Ibram, O. (2006) Textual description of the Danube Delta Biosphere Reserve case study. Naturnet-Redime, STREP project co-funded by the European Commission within the Sixth Framework Programme (2002-2006), Project no. 004074. Project deliverable D6.2.1.

[2] Salles, P. and Caldas, A.L. (2006) RF - Textual description of Riacho Fundo case study. Naturnet-Redime, STREP project co-funded by the European Commission within the Sixth Framework Programme (2002-2006), Project no. 004074. Project deliverable D6.4.1.

[3] Uzunov, Y. and Nakova, E. (2006) Textual description of River Mesta case study. Naturnet-Redime, STREP project co-funded by the European Commission within the Sixth Framework Programme (2002-2006), Project no. 004074. Project deliverable D6.3.1.

[4] Noble, R.A.A. and Cowx I.G. (2006) Textual description for the UK case studies on the River Trent and Great Ouse focusing on the links between the ecological and socio-economic aspects of sustainable river rehabilitation and management, Naturnet-Redime, STREP project co-funded by the European Commission within the Sixth Framework Programme (2002-2006), Project no. 004074, Project Deliverable Report D6.5.1.

[5] Zitek, A. (2006) Textual Description of the River Kamp Case Study focusing on integrated ecological, ecosystem, management, social and economic issues, Naturnet-Redime, STREP project co-funded by the European Commission within the Sixth Framework Programme (2002-2006), Project no. 004074, Project Deliverable Report D6.6.1.

[6] Liem, J., Bouwer, A. and Bredeweg, B. (2006) Collaborative QR model building and simulation *workbench*, Naturnet-Redime, STREP project co-funded by the European Commission within the Sixth Framework Programme (2002-2006), Project no. 004074, Project Deliverable Report D4.3.

[7] Liem, J. and Bredeweg, B. (2006) Document Type Definition (DTD) for QR Model Fragments - Redime. Naturnet-Redime, STREP project co-funded by the European Commission within the Sixth Framework Programme (2002-2006), Project no. 004074. Project deliverable D2.3.1.

[8] Liem, J., Bredeweg, B. and Bouwer, B. (2006) QR model-fragment library standard Redime*, Naturnet-Redime,* STREP project co-funded by the European Commission within the Sixth Framework Programme (2002-2006), Project no. 004074, Project Deliverable Report D2.3.2.

[9] Liem, J. and Bredeweg, B. (2006) OWL and qualitative reasoning models. In 29th annual German Conference on Artificial Intelligence (KI2006). *Lecture Notes on Artificial Intelligence*. Springer, 2006. (To appear).

[10] Nuttle, T., Liem, J., Bouwer, A., Bredeweg, B. and Salles, P. (2006) 2nd NNR user group workshop on Qualitative Reasoning and Modelling*,* Naturnet-Redime, STREP project co-funded by the European Commission within the Sixth Framework Programme (2002-2006), Project no. 004074, Project Deliverable Milestone M7.2.2.

[11] Bredeweg, B., Salles, P., Bouwer, A. and Liem, J. (2005) Framework for conceptual QR description of case studies. Naturnet-Redime, STREP project co-

funded by the European Commission within the Sixth Framework Programme (2002-2006), Project no. 004074. Project deliverable D6.1.

[12] Biswas, G., Schwartz, D., Bransford, J. and The Teachable Agents Group at Vanderbilt. (2001) Technology Support for Complex Problem Solving: From SAD Environments to AI. Smart Machines in Education. K. Forbus and P. Feltovich (eds.), AAAI Press/MIT Press, Menlo Park California, USA.

[13] Bouwer, A. (2005) Explaining Behaviour - Using Qualitative Simulation in Interactive Learning Environments, Ph.D. thesis, University of Amsterdam, Amsterdam, The Netherlands.

[14] Bredeweg, B., Bouwer, A., Jellema J., Bertels D., Linnebank F. and Liem J. (2006) Garp3 - A new Workbench for Qualitative Reasoning and Modelling. The 20th International Workshop on Qualitative Reasoning, C. Bailey-Kellogg and B. Kuipers (eds), pages 21-28, Hanover, New Hampshire, USA, 10-12 July.

[15] Bredeweg, B., Salles, P. and Neumann, M. (2006) Ecological Applications of Qualitative Reasoning. Ecological Informatics, Scope, Techniques and Applications, F. Recknagel (ed.), pages 15-47, 2nd Edition, Springer, Berlin.

[16] Forbus, K.D, Carney, K., Harris, R. and Sherin, B.L. (2001) A qualitative modeling environment for middle-school students: A progress report. The 15th International Workshop on Qualitative Reasoning, G. Biswas (ed.), pages 65-72, St. Mary’s University, San Antonio, Texas, 17-18 May.

[17] Lee, L. and Ghanimé, L. (2003) Country Reporting on MDG7: Ensuring Environmental Sustainability. UNDP - Energy and Environment Group Bureau for Development Policy, November.

[18] Novak, J.D. and Gowin, D.B. (1984) Learning how to learn. Cambridge University Press, New York, New York.

[19] Salles, P. (2005) Qualitative representations of indicators of environmental sustainability of the Millennium Development Goals. The 19th International Workshop on Qualitative Reasoning, M. Hofbaur, B. Rinner, F. Wotawa (eds), pages 78-88, Graz, Austria, 18-20 May.

[20] Schumacher, R. M. and Gentner, D. (1988). Transfer of training as analogical mapping. IEEE Transactions of Systems, Man, and Cybernetics, 18:592-600.

[21] UnB (Universidade de Brasília); PUC Minas; PNUD (2004) Sustentabilidade ambiental: Objetivo 7: garantir a sustentabilidade ambiental. Coleção de estudos temáticos sobre os Objetivos de Desenvolvimento do Milênio. Belo Horizonte: PUC Minas / IDHS.

# Appendix

## Pre-test: DEFORESTATION – Test I

### I – Answer True ( T ) or False ( F ).

1 - ( ) **IF** deforestation happens,
**THEN** land without vegetation cover increases.

2 – ( ) **IF** erosion increases,
**THEN** uses of water increase.

3 - ( ) **IF** biodiversity decreases,
**THEN** production of new food and medicines decreases.

4 - ( ) **IF** land with no vegetation cover decreases,
**THEN** agricultural production decreases.

5 – ( ) **IF** deforestation stops,
**THEN** biodiversity decreases.

6 - ( ) **IF** production of new food and medicines decreases,
**THEN** wealth (GDP) increases.

7 - ( ) **IF** agricultural production decreases,
**THEN** wealth (GDP) decreases.

### II – Answer True ( T ) or False ( F ).

8 - ( ) The water reservoir decreased
**BECAUSE** erosion increased.

9 – ( ) Production of new food and medicines increased
**BECAUSE** biodiversity decreased.

10 - ( ) Agricultural production increased
**BECAUSE** erosion increased.

11 – ( ) Population without water increased
**BECAUSE** water reservoir decreased.

12 – ( ) Land with vegetation cover increased
**BECAUSE** deforestation stoped.

13 – ( ) Wealth (GDP) increased
**BECAUSE** uses of water decreased.

**III – Fill in the blank spaces with INCREASES or DECREASES.**

14 - **IF** deforestation happens,
**THEN** land with vegetation cover __________________.

15 - IF erosion increases,
**THEN** wealth (GDP) _________________.

16 - **IF** biodiversity increases,
**THEN** production of new food and medicines ________________

17 - **IF** land with no vegetation cover decreases,
**THEN** biodiversity ____________________

18 - **IF** land with vegetation cover increases,
**THEN** production of new food and medicines _________________

19 - **IF** erosion increases,
**THEN** agricultural production ______________________

20 - **IF** land with no vegetation cover increases,
**THEN** erosion ____________________.

21 - **IF** deforestation stops,
**THEN** biodiversity _______________

**IV – Fill in the blank spaces with INCREASES or DECREASES.**

22 - Water reservoir increases
**BECAUSE** the amount of removed soil _________________

23 - Production of new food and medicines decreases
**BECAUSE** biodiversity ________________

24 - Wealth (GDP) increases
**BECAUSE** land with no vegetation cover___________.

25 - Wealth (GDP) decreases
**BECAUSE** biodiversity _________________.

26 – Uses of water increases
**BECAUSE** water reservoir _________________

27 – Uses of water increases
**BECAUSE** land with vegetation cover ________________________

28 - Erosion decreases
**BECAUSE** land with no vegetation cover____________________

29 - Agricultural production increases
**BECAUSE** erosion______________________

**V- Fill in the blank spaces with INCREASES or DECREASES.**

30 - **IF** land with vegetation cover increases, **THEN:**

the amount of removed soil ______________________

water reservoir _________________________________

wealth (GDP) _________________________________

deforestation __________________________________

uses of water __________________________________

agricultural production ___________________________

## Post-test: DEFORESTATION – Test II

### I – Answer True ( T ) or False ( F ).

1 - ( ) **IF** deforestation happens,
**THEN** Production of new food and medicines increases.

2 - ( ) **IF** land with vegetation cover increases,
**THEN** biodiversity decreases.

3 – ( ) **IF** water reservoir decreases,
**THEN** uses of water decrease.

4 – ( ) **IF** erosion increases,
**THEN** population without water increases.

5- ( ) **IF** deforestation stops,
**THEN** wealth (GDP) increases.

6 - ( ) **IF** biodiversity increases,
**THEN** wealth (GDP) decreases.

7 - ( ) **IF** erosion increases,
**THEN** wealth (GDP) increases.

### II – Answer True ( T ) or False ( F ).

8 – ( ) Water reservoir increased
**BECAUSE** the amount of removed soil increased.

9 – ( ) Land with no vegetation cover increased
**BECAUSE** deforestation happens.

10 **-** ( ) Erosion increased
**BECAUSE** land with no vegetation cover decreased.

11 - ( ) The amount of removed soil decreased
**BECAUSE** erosion increased.

12 – ( ) Production of new food and medicines decreased
**BECAUSE** deforestation stoped.

13- ( ) Uses of water decreased
**BECAUSE** water reservoir increased.

14- ( ) Land with vegetation cover increased
**BECAUSE** deforestation stoped.

**III – Fill in the blank spaces with INCREASES or DECREASES.**

15- **IF** land with vegetation cover increases,
**THEN** biodiversity _______________

16- **IF** deforestation happens,
**THEN** production of new food and medicines _______________

17- **IF** erosion decreases,
**THEN** the amount of removed soil____________________

18- **IF** the amount of removed soil increases,
**THEN** agricultural production__________________

19 - **IF** land with no vegetation cover increases,
**THEN** agricultural production _____________________

20 - **IF** erosion decreases,
**THEN** agricultural production _____________________________

21 - **IF** the amount of removed soil decreases,
**THEN** water reservoir ________________________

22 – **IF** water reservoir decreases,
**THEN** uses of water ___________________________

**IV – Fill in the blank spaces with INCREASES or DECREASES.**

23 - Agricultural production decreases
**BECAUSE** the amount of removed soil ___________________

24 – Uses of water decreases
**BECAUSE** land with no vegetation cover _________________________

25 – The amount of removed soil increases
**BECAUSE** erosion ________________________

26 – Deforestation decreases
**BECAUSE** land with vegetation cover ________________________

27 - The water reservoir decreases
**BECAUSE** erosion ________________________

28 - Production of new food and medicines increases
**BECAUSE** biodiversity ________________________

29 - Uses of water decreases
**BECAUSE** the amount of removed soil ________________________

**V - Fill in the blank spaces with INCREASES or DECREASES.**

30 - **IF** land with no vegetation cover increases, **THEN:**

population without water ___________________________

biodiversity ______________________________________

wealth (GDP) ____________________________________

removed soil _____________________________________

water reservoir ___________________________________

production of new food and medicines________________

# Additional questionnaire (students' attitude towards experiment)

## PARTICIPANT DATA

**Please fill in or circle the relevant data**

1 – **Participant name:**

2 – **Participant number:**

3 – **Male / Female**

4 – **Age:**

5 – **Topic of Study:**

6 –**Degree of Study:**
BSc / MSc / …

7 – **Year of Study:**
1st / 2nd / 3rd / 4th / …th

8 – Amount of computer experience:

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| none | | | | | | much |

9 – Amount of expertise about Ecology:

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| none | | | | | | much |

10 – Amount of expertise about Conceptual Modelling:

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| none | | | | | | much |

11 – Amount of expertise about Qualitative Reasoning:

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| none | | | | | | much |

**PARTICIPANT FEEDBACK**

1 – How much do you feel you have learned during the session?

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| nothing | | | | | | much |

2 – Did you find it difficult or easy to answer the test questions?

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| very difficult | | | | | | very easy |

3 – Did you find it difficult or easy to use the software interface?

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| very difficult | | | | | | very easy |

4 – Did you find the diagrams difficult or easy to understand?

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| very difficult | | | | | | very easy |

5 – Did you enjoy today's session?

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| not at all | | | | | | very much |

6 – Did you enjoy using the software?

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| not at all | | | | | | very much |

7 – If you want, you can leave remarks about today's session: