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Abstract

This deliverable brings forward the first round of evaluation of the DynaLearn software as carried out with students of the Biological Faculty of Sofia University.

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Contents

1. Introduction

This deliverable reports two evaluation activities performed at the Institute of Biodiversity and Ecosystem Research in Bulgaria. These evaluations used the DynaLearn software version 0.6.4 in the pilot study and version 0.6.16 in the second evaluation activity.

The overall goal of the evaluation activities are specified in the Description of Work:

The objects of evaluation were determined on the requirements and definitions included in the DOW for WP7. "Based on the work in progress on the *Curriculum and content models (WP6),* each case study will develop lessons and an evaluation plan focusing on several different topics in the curriculum (including at least some of the models they have developed themselves). *Each case study will focus on different aspects of the curriculum and features of the prototype of the DynaLearn software. Using the prepared lessons and evaluation plan, each beneficiary will evaluate the DynaLearn prototype and the curriculum in real educational setting"* (cf. Bredeweg, 2008, DoW).

Our main goal for evaluation was to assess the contribution of learning by qualitative modelling with DynaLearn on students' understanding of ecological systems.

In specific terms, we aim to assess the effect of DynaLearn's key features and of modelling on students':

- **a.** Conceptual Understanding (CU) - *their learning of content knowledge related to the behaviour of complex ecosystems*.
- ***b.*** Scientific reasoning, Qualitative reasoning, and System Thinking (SQS) – *their acquisition of scientific reasoning skills and ability to cope with complexity, through QR approach and language.*
- ***c.*** Motivation and attitudes (M/A) – *their disposition towards learning and learning by modelling.*

The above, as a function of learning with an environment encompassing:

1. Conceptual Modelling (CM) – in terms of DynaLearn's specific modelling language, modelling process and 6 modelling levels – the Learning Spaces.
2. Conversational agents (VC) – this act in various functions and roles while interacting with the learner, especially for structuring learning activities and communicating feedback.
3. Semantic Technologies (ST) – individualization of learning via DynaLearn tools for ontology mapping, diagnostic procedures, and the semantic repository.

The DoW defines 7 questions to be addressed, formulated in general terms. These questions, and the cells in the inquiry space into which they are related, are (cf. Mioduser et al., 2010):

1. Does the diagrammatic approach (as organised in the DynaLearn setting) actually allow learners to address more complex problems? [1a, 1b]
2. Does the meta-vocabulary from which a conceptual interpretation is built, provide learners a domain independent analytic instruments that enables them to construct more fine grained and trough analyses of how students work? [3a, 3b]
3. Do the embodied conversational agents establish the 'involvement momentum' required for learners to actually benefit from the added value provided by the software for handling conceptual knowledge? Which agents work best? And why or why not? [2a, 2b, 2c]
4. Do the instruments to individualise learning (ontology mapping, diagnostic procedures, and semantic repository) adequately steer learners in acquiring the target subject matter? [3a]
5. Does the personal autonomy cause learners to be more motivated? [general L]
6. Do learners actually learn better when using the full set of DynaLearn results? [general L]
7. And are students more motivated to take on science curricula? [1c, 2c, 3c]

The two evaluation studies described in this deliverable focus on questions Q1, Q2 and Q7. In the first evaluation study, students create a concept map on LS1 and a model on LS6 based on the content of a scientific paper. The final models are analysed and compared with the problems that the students had during the course. The results should help answer the questions whether the meta-vocabulary of DynaLearn allows students to better analyse the topic, and whether the diagrammatic approach allows students to understand more complex systems.

In the second evaluation study, students create models on LS1 through LS4. They are tested on their knowledge using an exam. The results on the topics in which they use the DynaLearn software are compared with the topics in which they do not use the DynaLearn software. This should contribute to answering the question whether students can more deeply understand systems and therefore more complex systems (Q1) and whether the meta-vocabulary allows the students to better understand complex systems (Q2).

In both evaluation studies, motivation questionnaires were given to evaluate whether students are more motivated to learn more science (using the DynaLearn tool) (Q7).

2. Evaluation activity 1 – Pilot study

2.1. Introduction

DynaLearn software (Bredeweg et al., 2010) and its functionality were presented to bachelor students in the Faculty of Biology, of Sofia University. During their lecture course "Actual problems of climate and water resources" (cf. Uzunov, 2005; Uzunov & Kovachev. 2009) the students both explored models created by the IBER team and developed their own models in two Learning Spaces (LS1 and LS6). The students discussed difficulties encountered during modeling with the IBER team.

The general research question was:

- Does the use of the DynaLearn features increase the students' understanding of complexity of an ecological/environmental system?

2.2. Method

2.2.1. Participants

One group of 5 bachelor students without modelling experience participated in the pilot study in Bulgaria (See Appendix B3). Each of them took a scientific paper describing an ecological study as the basis of their models.

2.2.2. Variables

For this round of evaluation, we used the following variables: 1a, 1b, 1c (See Table 1).

Table 1. Dependent and independent variables used in the pilot study.

	1 **CM**	**2** **VC**	**3** **ST**
a) CU	√		
b) SR/M	√		
c) M/A	√		

2.2.3. Implementation instruments

The first evaluation activity took place during the 2nd academic semester (February – May) of the 2010 at the Biological Faculty of Sofia University. A group of 5 students attended 6 lessons each lasting 2 hour in which they worked with the DynaLearn software. They worked with two Learning Spaces available in the DynaLearn software – LS1 and LS6. At the beginning of the course the students received a scientific article about two important topics in the course (Water cycle and Nutrient cycle). During the course, the students had to learn the qualitative modelling language and learn to model with this language. These tasks consisted of building a concept map, representing entities and configuration between them, define quantities and the causal relationships between them, define quantities spaces that would result in a meaningful simulation and to correctly structure the model using model fragments.

At the end of the course, the students were requested to complete a motivation questionnaire comprising different categories of items.

Session 1: Introduction into Qualitative reasoning (QR) (Bredeweg & Forbus, 2003).

Objectives: Introduce students to “Qualitative Reasoning” and “Learning by Modelling”;

- Introduction in Qualitative Reasoning;
- Presentation of basic ideas of concept mapping;
- Presented background of specific scientific texts describing concept maps;
- Presentation of models to support learning how to use DynaLearn software to introduce basic conceptual ideas in these software;

Session 2: Concept mapping (Water cycle).

Objectives: Complexity and clarity of concept map.

The tasks of students were:

- Provide a basic knowledge model of Water cycle using the concept map;
- Create a concept map of the Water cycle;
- Describe the key words and content in concept maps in written answer;
- Describe the reasons and predict the consequences of a given problem;
- Identify a set of concepts and relations between them;
- Compare and discuss the maps produced by the students;
- Create a simple causal chain exploring the concepts developed in the concept;

Session 3: LS6 modelling of Water cycle.

Objectives: Complexity and clarity of a model.

- Identify the structure of the system using the DynaLearn software – entities, configurations, quantities, quantities space;
- Provide training examples on how to use the software;

Session 4: Causal differentiation.

Objectives: Differentiating between causal direct influences (I) and proportionalities (P).

- Explaining and identifying the main processes in the text and differentiate causal influences;
- Ask the students to make short explanation of these processes;
- Make a short presentation to teach how to use I's and P's;

Session 5: State graph and simulations.

- Explanation of state graph;
- Identify the possible sequences of state;
- Explanation of the results obtained in different scenarios;

Session 6: Final presentation and motivation questionnaire

- Presentation of the final models;
- Motivation questionnaire;

2.2.4. Design and Data collection instruments

The design of the pilot study included one small group of 5 bachelor students without modelling experience.

The data collection instruments were:

- Concept map and explanation (beginning of the course)
- Final model and explanation (end of the course) (See Appendix A2)
- Motivation questionnaire (end of the course) (See Appendix A1)

These instruments are used to measure conceptual understanding, understanding of the complexity of ecosystems and also motivation and attitudes.

At the beginning of the course, the students had to describe and give explanations of the main entities and the configuration between them. We provided scientific articles to our students that discuss the main course topics (Water cycle). Their task was to define and describe the main entities and configurations between them. Furthermore, they have to write the short explanation of these entities and configurations.

At the end of the course, each student had to present his or her final model (implemented in LS6 in DynaLearn software) (See Appendix A2).

Furthermore, at the end of the course the students were requested to complete a motivation questionnaire comprising different categories of items. The overall motivation questionnaire of the first set of evaluation and answers of the students are show in Appendix A1.

2.3. Results

During the pilot study the students created concept maps using the DynaLearn software and successfully implemented a domain model in Learning Space 6 of DynaLearn. An example of a model created by a student is shown in Appendix A2.

Conceptual modelling was new to all of the students. At the beginning of the course the students tried to incorporate all aspects relevant to the domain of study described in the paper. Choosing a modelling scope that is too large is a common mistake for beginning modellers. Particularly in the beginning of the course, some of the students found it difficult to isolate the main entities, relations (configurations) and quantities in the topic they were modelling. This may have been caused by the fact that there is often no direct mapping between the concepts as they are used by authors of papers and conceptualisations as they should be used in a QR model. However, during the course, most students became more capable of distinguishing entities, configurations, and quantities as can be seen in the example model in Appendix A2. The atmosphere and water body are correctly modelled as entities. Water vapour, clouds and condensation are modelled as quantities of the atmosphere. The water body has the quantity water amount. Finally, the atmosphere is modelled as being above the water body.

Another issue the students had in the beginning of the course is distinguishing between the different forms of causality as they are used in DynaLearn (influences [I] and proportionalities [P]). However, again, the students seem to have successfully acquired these concepts which become clear when looking at the example model shown in Appendix A2. The student correctly chose the type of causal relationships between the quantities. That is, the condensation rate is proportional to the amount of water vapour in the atmosphere and the amount of rain is proportional to the amount of clouds. Furthermore, condensation has been correctly identified as a rate affecting the amount of clouds, and rain as a process affecting the amount of water in the water body.

To summarize, at the end of the course, the students seemed to have acquired the skills to correctly distinguish different concepts in a scientific paper as corresponding to a particular model ingredient type in DynaLearn. That is, which this are part of the structure of the system, and which aspects are dynamical (the quantities). Furthermore, they seemed to be able to choose the correct causal relationships between the quantities. That is, they can successfully identify the processes that are important in the system. In the opinion of the teachers, the students showed good progress towards understanding the system and gaining modelling skills.

At the end of the course the students had developed models in Learning Space 6, topics about Nutrient cycle and Water cycle. Furthermore, the students filled motivation questionnaire. The motivation questionnaires used during the pilot study was following:

1. What do you remember after this course?
2. How you evaluate Qualitative Reasoning? What is your main impression?
3. Would you like to apply qualitative reasoning in your current education? Where might this approach find appropriate applicability?
4. Do you use any specific software in your current education?
5. Is the DynaLearn software difficult to use?
6. In your opinion will you continue to use DynaLearn software in scientific graduation?
7. Would you recommend DynaLearn software as a tool for education in other biological courses?
8. Would you continue to use QR and related software and after this course?
9. Could you please give us your recommendation? They are important for us!

The results of the questionnaire are show in Appendix A.

The students seemed to particularly think they have learned how to use the DynaLearn software. None of the students mentioned learning the domain that was the topic of the course (Q1). A possible reason is that due to the small time span of the course, the largest difficulty for the students was learning the software. However, students are very enthusiastic about the software, even saying that it is easy to model a concepts in a model (Q2), and indicating that they think the software can be widely applied different scientific disciplines (and the education thereof).

Some students indicated that the software is difficult to use initially, but becomes easier to use in time (Q5). Other students indicated that they have no trouble using the software at all. Students indicated that will use the DynaLearn software in the rest of their education (Q5, Q8).

The main recommendations given by the students (Q9) (and shared by the teachers) are that the length of the course, the amount of contact hours (lectures and feedback) and the amount of time that could be spend working on the course are too short. Furthermore, there were not enough computers available to accommodate all students. The students felt that the educational material provided was insufficient for them to learn on their own. Finally with regards to the software, the students missed the option to use Cyrillic in the DynaLearn software. As a workaround the students wrote Bulgarian using the Latin alphabet, which is suboptimal. Furthermore, they would also like the menus and vocabulary to be in Bulgarian so that it is easier to understand.

3. Evaluation activity 2

3.1. Introduction

DynaLearn software and its functionalities were presented for bachelor, master and PhD students in the Biological Faculty of Sofia University. During their course "Actual problems of climate and water resources", the students' explored models developed by the research team and developed their own models in four Learning Spaces (Learning Spaces 1 - 4). The students discussed their modeling issues and their misunderstandings about software functionalities with the IBER team. These aspects are important for the motivation of students using the software as a learning support tool.

The general research question was: What is the students' perception of modeling activities and of the use of qualitative models in their learning process?

3.2. Method

3.2.1. Participants

The participants in the second evaluation activity in Bulgaria were one group of 10 students without modelling experience (6 bachelors, 2 masters and 2 PhD-students) (See Appendix B3). Each of the students worked with scientific paper describing an ecological study.

3.2.2. Variables

For this round of evaluation, we used modelling skill and motivational aspect (depended variables).

For independent variables we used the DynaLearn features. The students worked with 4 modelling levels (Learning Space 1 – 4) available in DynaLearn software. Table 2 shows the combination of dependent and independent variables used in this round of evaluation.

Table 2. Dependent and independent variables in second evaluation

	1 **CM**	**2** **VC**	**3** **ST**
a) CU	√		
b) SR/M	√		
c) M/A	√		

3.2.3. Implementation instruments

The instruments we used for the second evaluation activities were a pre-concept questionnaire, the students' models, a final test and a motivation questionnaire.

A group of 10 students attended a 6 lessons exercise, and worked with four Learning Spaces (LS1 – LS4). At the beginning of the course we provided the students with scientific articles about a particular course topic (Intensive agriculture). During the course the students had the following tasks: learning and using qualitative modelling language; building concept maps while representing entities and configuration between them; to be able to define quantities and quantities space; to be able to explain a simulation. During the course, the students developed models in four Learning Spaces (LS1 – LS4) with different levels of complexity. At the end of the course the students presented their models and the result of the simulations.

At the end of the course the students were requested to complete a motivation questionnaire comprising different categories of items (See Appendix B2).

The first task was to define and describe the main entities and possible relations/configurations between them. Furthermore, the students had to write short definitions of these entities and configurations and explain their choices.

Session 1: Introduction to Qualitative reasoning and DynaLearn software

Objectives:

- Introduce students to "What is the Qualitative Reasoning";
- Introduce to modelling approach;
- Presentation of basic ideas of concept maps;
- Present background of specific scientific texts describing concept maps;
- Presentation and exploitation of models to support learning how to use DynaLearn software to introduce basic conceptual ideas in the software;
- Introduce of different Learning Spaces;
- Introduce the main topic (Actual problems with water resources)

Session 2: Concept mapping (model about intensive agriculture)

Objectives: Complexity and clarity of the concept maps.

The tasks of students are:

- Provide with a basic knowledge model of Intensive agriculture using the concept map;
- Short introduction to the topic of Intensive agriculture;
- Create concept map of Intensive agriculture;
- Describe the key words, content in concept maps in written answer;

- Describe reasons and predict the consequences of a given problem;
- Introduction to concept mapping and LS1 of the DL workbench;
- Identify a set of concept and relations between them;
- Compare and discuss the maps produce by the students;

Session 3: LS 2 modelling of Intensive agriculture.

Objectives: Complexity and clarity of model.

- Practical session – work with Learning Space 2
- Create a simple causal chain exploring the concepts developed in the concept maps (Learning Space 2);
- Practical session – work with Learning Space 3. Create a LS3 model of Intensive agriculture;
- Start using Quantity Spaces (QSs). First add QS to one quantity and run a simulation and analyse the state graph. Then add QS to another quantity and teach students what a correspondence relationship is and how it should be used;
- Describe reasons and predict the consequences of a given problem;

Session 4: LS 4 modelling of Intensive agriculture

Objectives: Complexity and clarity of model of written answers

- Introduction of Learning Space 4
- Explain and identify the main processes in the text and differentiate causal influences (influences and proportionalities) in the DL model of the system;
- Ask the students to make a short explanation of these processes;
- The teacher makes a short presentation to teach how to use I's and P's;
- Create a LS4 model of Intensive agriculture;
- Homework for training: Ask students to create chains like these ones based on their own ideas. In the next lesson give 10 minutes for short presentations;

Session 5: Continuation with LS 4 modelling of Intensive agriculture

Objectives: Complexity and clarity of model of written answers

- Practical session with Learning Space 4;

Session 6: Questionnaires

- Final exam
- Motivation questionnaire

3.2.4. Design and Data collection instruments

The second evaluation activities included one group of 10 students (6 bachelor, 2 master and 2 PhD-students) without modelling experience.

The data of instruments that we collected were:

- Concept map and explanation (beginning of the course) (See Appendix B2)
- Final model and explanation (end of the course) (See Appendix B2)
- Final exam (end of the course) (See Appendix B2)
- Motivation questionnaire (end of the course) (See Appendix B1)

In this round of evaluation we used Pre- and Post- test, evaluation task and motivation/attitude questionnaire at the end of the course. The design in this evaluation was following:

Evaluation	→	Experiments	→	Evaluation
At the beginning of the course		*Evaluation tasks*		*At the end of the course*

The progression of modelling tasks comprised 4 stages, from the initial identification and definition of structural components of the system to building a complete model and running simulations.

The concept maps of the students are tools used for assessing conceptual understanding (Novak & Gowin, 1983) and ecosystems complexity understanding. The final model of the students was compare with their concept maps, built at the beginning of this course. The comparison between the concept maps and the final models were determined using the following criteria: Identifying entities and quantities & Identifying causal relationships.

At the end of the course the students filled out the motivation questionnaire. The results of this questionnaire are shown in Appendix B2. The components of this questionnaire are shown in the result section (3.3).

During the 1st lesson, the students had to describe and give explanation of the main entities and configuration between them. Their first models (Concept maps) were compared with their final models.

3.3. Results

The conceptual modelling was new to all of the students. At the beginning of the course the students used all components related to the domain of study in the paper. For some of the students it was difficult to find the main entities and relations (configuration) between them. There was difference in complexity of the concept maps produced by the students (See Appendix B2). The number of concepts used by the students ranged between 15 and 22, and between 19 and 28 relationships.

The understanding assessment on behalf of the students was done on the basis their concept map at the beginning of the course and their explanation during the pre-test, and their explanation at the post-test.

At the end of the course the students used only key words, the essential of these articles. The number of the concepts and configuration showed huge decrease (10 concepts and 5 configurations). The students describe the aim of activity in a more generic way.

50 % of the students involved in this study, preferred to work with Learning Space 3 (See Figure 1). However, most of the students (70%) think that Learning Space 4 is the most informative and gives biggest possibilities for work. The students think LS4 gives us the biggest potentialities, but the risk to make a mistake is bigger, because it is difficult to choose I's and P's. This is the reason that they prefer work with LS3.

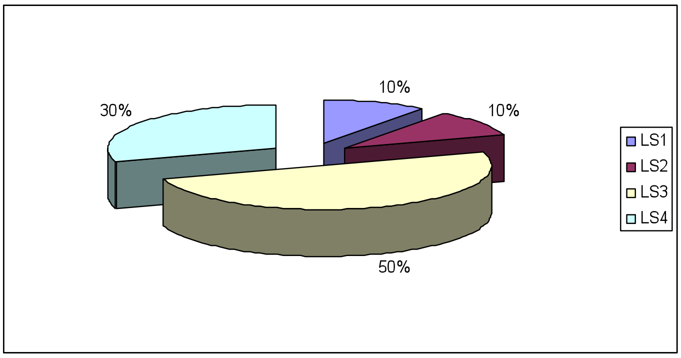

Figure 1. Answer percentage Learning Spaces preferred of the students

All of the students completely agreed with that "DynaLearn software is useful for better teaching and education of students". This means that all of the students think that DynaLearn is useful in education and helps them to learn the phenomena/processes.

At the end of the course, the students had developed models about intensive agriculture in each Learning Spaces (Learning Spaces 1 – 4) (See Appendix B2). They described aspects of the problem concerning the conflict between intensive agriculture and water resources (quantity and quality of the lakes and/or rivers).

During the final exam the students performed very well on topics explored with the DynaLearn software compared to other topics explored in other lectures (success rated from 6 *"excellent"* to 1 *"bad"*). The questions that were used were the following:

1. Describe the water cycle.
2. How does Global warming affect on the hydrological cycle?
3. Give examples of sources of pollution of water bodies.
4. What is the impact of the intensive agriculture on water quality and quantity?
5. Definition of eutrophication.

The bachelor students did not have basic knowledge on Hydrobiology yet. So, we do expect a great increase in their knowledge about Intensive agriculture, which they learned through DynaLearn software. The group of the masters and PhD students had a very good knowledge of the topic beforehand, so for us it was interesting to see whether they will have an increase in factual knowledge at the final exam. The results of this exam are shown in Figure 2.

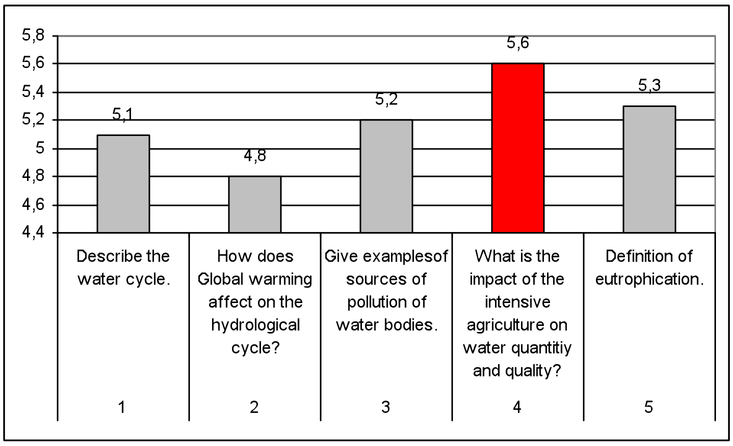

Figure 2. Result of the final exam.

The bachelor, master and PhD students showed the same result during the final exam. All of the students performed very well on the topic explored with DynaLearn compared to other topics explored in other lectures. Success rated from 1 "bad" - 6 "excellent".

At the end of the course, the student had a final exam with open questions. They gave answer to five questions. One of the questions (What is the impact of the intensive agriculture on water quality and quantity?) was implemented in DynaLearn software, so we expected that this answer would be better compared with the other. The result of the final exam is shown in Appendix B3.

At the end of the course the students filled out the motivation questionnaire (See Table 3). The results of this questionnaire are shown in Appendix B2. The opinion of the students for us was welcomed. New gates can be opened having their feedback.

Table 3 Attitudes/motivation questionnaires used during the second evaluation activities

1.	What is your **general opinion about the course and learning activity** we had together? **Very bad** 1 2 3 4 5 **Very good**
2.	What is your general **opinion about the modelling approach** you used to develop this educational activity? **Very difficult** 1 2 3 4 5 **Very easy**
3.	How did you experiencing the work with the DynaLearn software – boring or interesting? **Very boring** 1 2 3 4 5 **Very interesting**
4.	How do you evaluate your understanding of the problem of intensive agriculture after exploring the topic in DynaLearn? **Now I am very much confused** 1 2 3 4 5 **I understand much better now**
5.	How do you evaluate the importance of building models in different specific Learning Spaces of DynaLearn for your understanding? **Very little importance** 1 2 3 4 5 **Very important**
6.	Which Learning Spaces did contribute most your understanding of the concepts represented in the model? • **Concept map (LS 1)** • **Basic causal model (LS 2)** • **Basic causal model + state graph (LS 3)** • **Causal differentiation model (LS 4)**
7.	Which Learning Spaces did you like most? **Concept map (LS 1) O** **Basic causal model (LS 2)** O **Basic causal model + state graph (LS 3) O Causal differentiation model (LS4) O** Why?
8.	Modelling with the software enabled me to better understand the complexity of the topic intensive agriculture. **Incorrect** 1 2 3 4 5 **Correct**
9.	Modelling with the software opened up new ways of thinking about the system. **Incorrect** 1 2 3 4 5 **Correct**

10.	The software and its features motivated me to try to build the model. **Did not motivate.** 1 2 3 4 5 **Motivated very much**
11.	Using the software provides a very comfortable way of learning. **I fully disagree** 1 2 3 4 5 **I fully agree**.
12.	Modelling with the software could also be used in other learning topics **No** 1 2 3 4 5 **Yes.**
13.	What did you like?
14.	What did you dislike?
15.	Any ideas for improving the software?
16.	Further (general) comments?

The students had the impression that the software could be easily used for other topics, and to make your own viewpoint explicit as a basis for collaborative learning and discussion. The answers given by the students indicate that they found it an interesting and useful activity.

Most of the students indicated that the icons available in the software are easy to use. They indicate only that a "copy" button is missed.

The detailed answers of the students on the motivation questionnaire are show in Appendix B1. Here we summarize the answers of the motivation questionnaire (See Table 4).

The scores from the motivation questionnaire was high (between 3,9 and 5) from maximum 5 (See Table 4). The results of the motivation questionnaire show that students find the DynaLearn software easy to learn. They think that the software can be applied more widely in other curricula. All students indicate that they will use DynaLearn in their future education. These results suggest that students are motivated to take on more science curricula with the DynaLearn software.

The summary of the reported by students answers related to modelling experience are following:

- "………I like the fact that I can describe a process/phenomenon with diagrams/models. In this way the problem is easy to understand"
- "......Also I can describe the problem in my point of view…."
- "The way of visualization makes, the problem is easier to understand."

Table 4 Summarize of the motivation questionnaire

Question/ Student	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Average value
Q1	5	5	5	5	5	5	5	5	4	5	4,9
Q2	5	5	5	5	2	5	5	5	5	5	4,7
Q3	5	5	5	5	5	5	5	5	5	5	5,0
Q4	5	5	4	5	2	5	4	5	4	5	4,4
Q5	5	5	4	4	5	5	5	3	5	5	4,6
Q8	3	5	4	4	4	1	5	5	3	5	3,9
Q9	3	5	4	4	5	5	5	4	5	4	4,4
Q10	5	4	4	5	5	5	5	5	5	5	4,8
Q11	5	5	5	5	5	5	5	5	5	5	5,0
Q12	5	5	5	5	5	5	5	5	5	5	5,0

Legend:

Bachelor
Master
PhD

During this evaluation activity the focus was on the contribution of the modelling process to students' understanding of ecological complexity, and also on the motivation to learn through modelling. The results of this study show that the students understand the specifics of the modelling language (See Appendix B1).

4. Conclusion

This study shows the importance of using DynaLearn software for educational purposes especially in courses with a large amount of materials to be memorized by students. During the pilot study the group consisted of 5 bachelor students during the winter academic semester, and they used the DynaLearn Laerning Spaces 1 and 6. During the second evaluation activities the participants were a group consisting of 6 bachelors, 2 masters and 2 PhD students. This group used the DynaLearn Learning Spaces 1 through 4, during autumn semester (September - November).

Both evaluations studies focussed on the following three research questions described in the introduction:

Q1. Does the diagrammatic approach (as organised in the DynaLearn setting) actually allow learners to address more complex problems?

Q2. Does the meta-vocabulary from which a conceptual interpretation is built, provide learners a domain independent analytic instruments that enables them to construct more fine grained and through analyses of how students work?

Q7. And are students more motivated to take on science curricula?

In the first evaluation study, a concept map (LS1) and a LS6 model were created by the students. An analysis of the model, and the difficulties students had during development, shed light on the research questions. In general, the concept maps and the initial models that the students created showed that they were unable to distinguish different types of knowledge (entities, configuration, and quantities). Furthermore, different forms of causality were not distinguished. As the course progressed, and as is apparent in the final models, these skills were gained. This suggests that the meta-vocabulary in DynaLearn provides the student with better analytic instruments to apply to domain issues. This suggests that Q2 should be answered positively. Furthermore, since initially the students were unable to properly analyse the issues described in the scientific papers, the diagrammatic visualisation in combination with the meta-vocabulary seems to make students able to tackle more complex problems. This suggests that Q1 should also be answered positively.

The motivation questionnaire results indicate that students find the DynaLearn software easy to learn, and they think that the software can be applied more widely in other curricula. All students indicate that they will use DynaLearn in the rest of their education. Students also indicate that they want better education material so they can work more independently. These results suggest that students are motivated to take on more science curricula with the DynaLearn software (Q7).

In the second evaluation study, the students created models in LS1 through LS4 about actual problems of climate and water resources. The students were tested on their knowledge using an exam. The questions about the topic which they investigated using the DynaLearn software were compared with their results on topics which they did not investigate using the software. The students performed better on the topics they investigated using DynaLearn. This suggests that the software allows students to tackle more complex problems (Q1). Similar as in the first evaluations study, the students became more capable of distinguishing different types of model ingredient types (entities, configurations and quantities), as well as distinguishing different kinds of causality (influences of processes and proportionalities). This suggests that the students acquired a new set of analytical skills with which they can analyse topics (Q2).

The motivation questionnaire results were answered very positively. The results suggest that the students are more motivated to take on more science topics.

Future plans

For the next round of evaluation activities we plan to "integrate components from all relevant levels into a coherent pedagogical unit – an assignment, a lesson, or a complete course. These components include: the technological resources, i.e., the workbench, the pedagogical characters and the ontology-based features; the qualitative modelling language and approach; the pedagogical approach…. ".

Furthermore, given that the hardware requirements will be met by the available computers, during the next round of evaluations we will aim to evaluate more aspects of the DynaLearn software, such as the Semantic Technology and the Virtual Characters.

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Appendix A – Results of first evaluation activities in Bulgaria

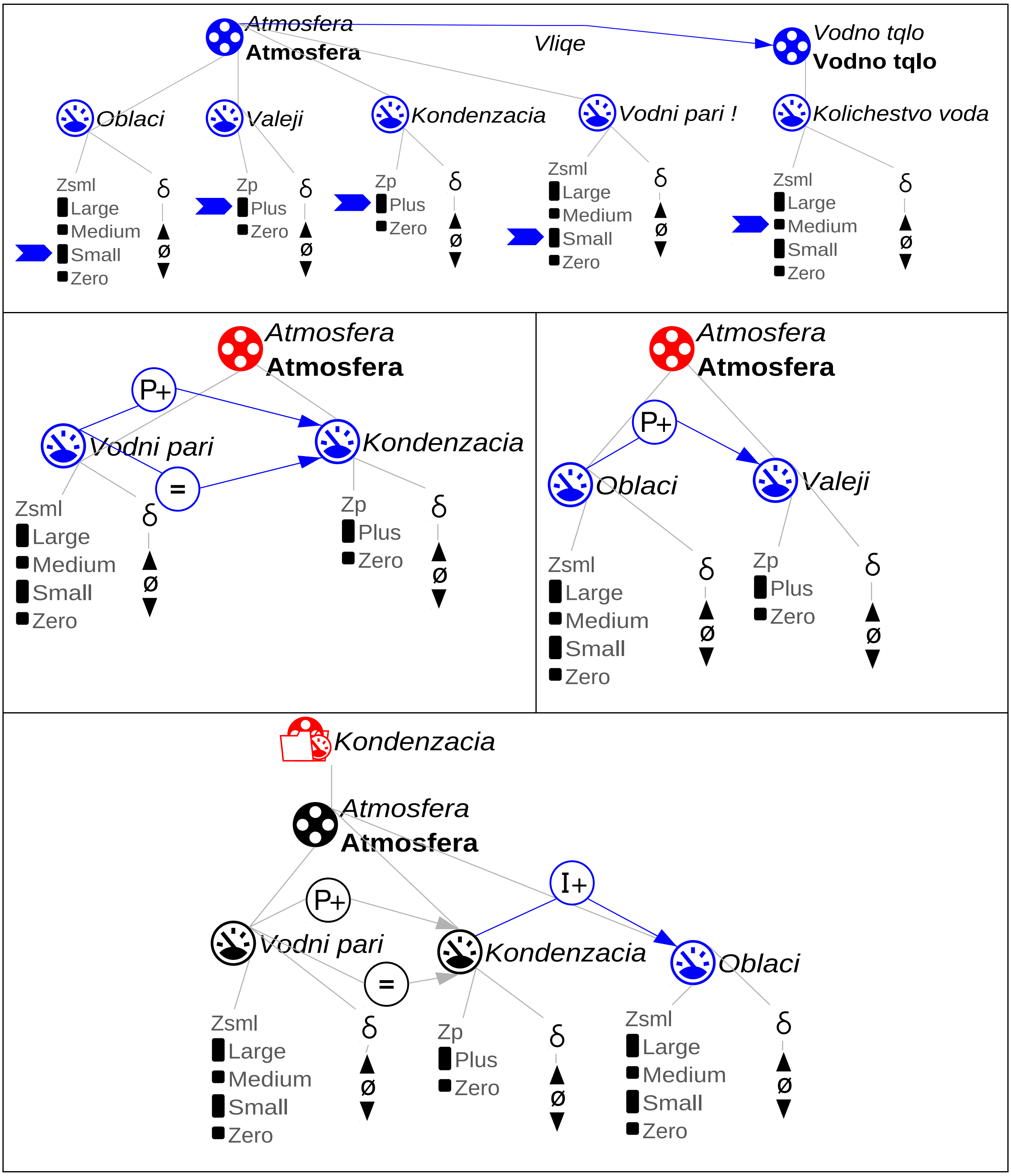
Appendix A1 – Motivation questionnaire + Answers

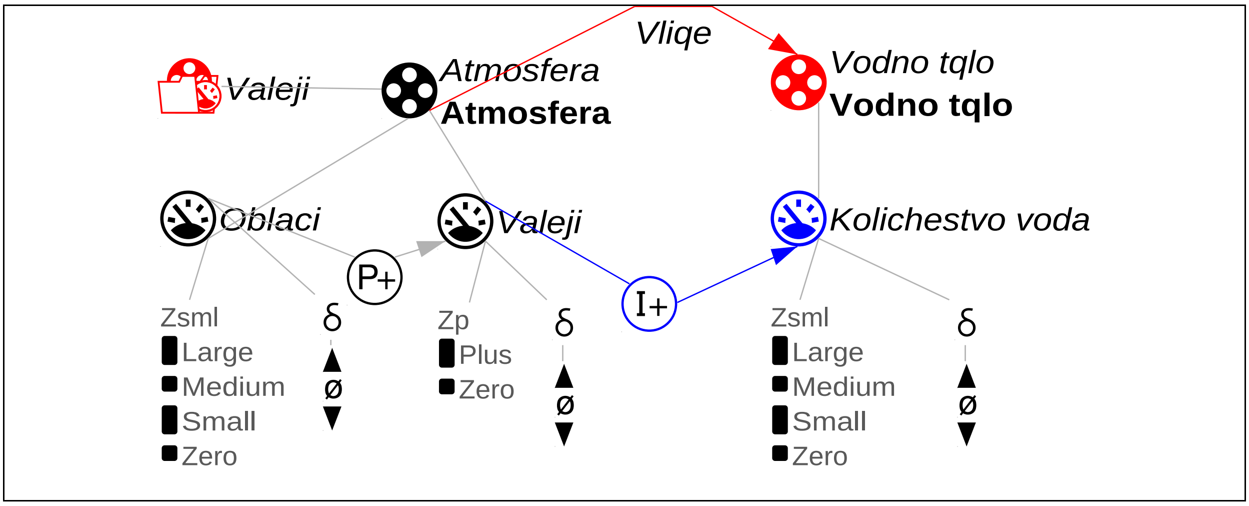
1. What do you remember after this course? S1: I learned working with DynaLearn software that showed how QR works on representation of system and their behavior; S2: The basic idea of conceptual modeling can be applied in different areas; S3: Yes, how to work with DynaLearn; S4: Yes, how to work with different software – DynaLearn; S5: No answer;
2. How you evaluate Qualitative Reasoning? What is your main impression? S1: High efficiency in description of the system without numerical Values, clear illustration of the system's functions and causal relationships between the components; S2: The possibility of easy ordination of objects; S3: The possibility of easy ordination of elements in different systems with aid of QR; S4: Ordination of elements; S5: I realized that actually we used QR and basic ideas every day in our work;
3. **Would you like to apply qualitative reasoning in your current education? Where might this approach find appropriate applicability?** S1: In my opinion Qualitative Reasoning could be find appropriate application in any other biological disciplines, as in other scientific area not only in biology, industrial processes, management schemes etc.; S2: Yes, I can use QR in my education. This approach can be used in education in different biological, biochemical, hydrological etc., process and disciplines; S3: This approach can be used in education in different biological, biochemical, hydrological etc., process and disciplines; S4: In education and representation of different cycles or tasks connected with different pathways (scenarios); S5: Very useful and I would like to use QR in my education. Also in different scientific areas;

4. Do you use any specific software in your current education? S1: Geographic information system – Arcmaps;; S2: Land shaft, GIS; S3: Land shaft, GIS; S4: Only in presentation, but not working practically; S5: Not practically;
5. Is the DynaLearn software difficult to use? S1: Yes in the beginning because of language barrier and technical design of this software, but in the working process I am starting to understand; S2: After the initial education, it becomes easier; S3: No; S4: No at all; S5: The software is constructed very friendly and is not so difficult;
6. In your opinion will you continue to use DynaLearn software in scientific graduation? S1: Yes, because software represents in clear and effective way different relationships between components of given system /process/production etc., which enable better management; S2: Can be used in representation of different cycle processes. Trace the connections between the different elements of the cycle; S3: Can be used in representation of different processes; S4: Could be; S5: DynaLearn gives facilities in understanding of different processes in ecosystems, and capture the relationships between the elements;
7. Would you recommend DynaLearn software as a tool for education in other biological courses? S1: DynaLearn software can find application in many other biological disciplines: Hydrobiology, water monitoring, biodiversity, biotechnology, management of biological resources; S2: Yes, widely; S3: Yes, widely; S4: Yes in Ecology, Master programs of hydrobiology; S5: Applicability in biotechnological and as educational tool for easy understanding of the processes and different control of the processes;

8. Would you continue to use QR and related software and after this course? S1: Yes; S2: Yes. Every time when it could be possible; S3: Yes; S4: Yes; S5: Yes, with pleasure;
9. Could you please give us your recommendation? They are important for us! S1: Provided educational hours for working with the software was insufficient. Technological resources in Biological Department are strictly insufficient. The materials of self-education is insufficient; Cyrillic in DynaLearn software; S2: Option of using Cyrillic; And supporting Bulgarian menu in software S3: Option of using Cyrillic; S4: Option of using Cyrillic; And supporting Bulgarian menu in software could facilitate understanding; S5: Option of using Cyrillic; Duration of the course is not enough. The materials of self-education is insufficient;

Appendix A2 – Example model



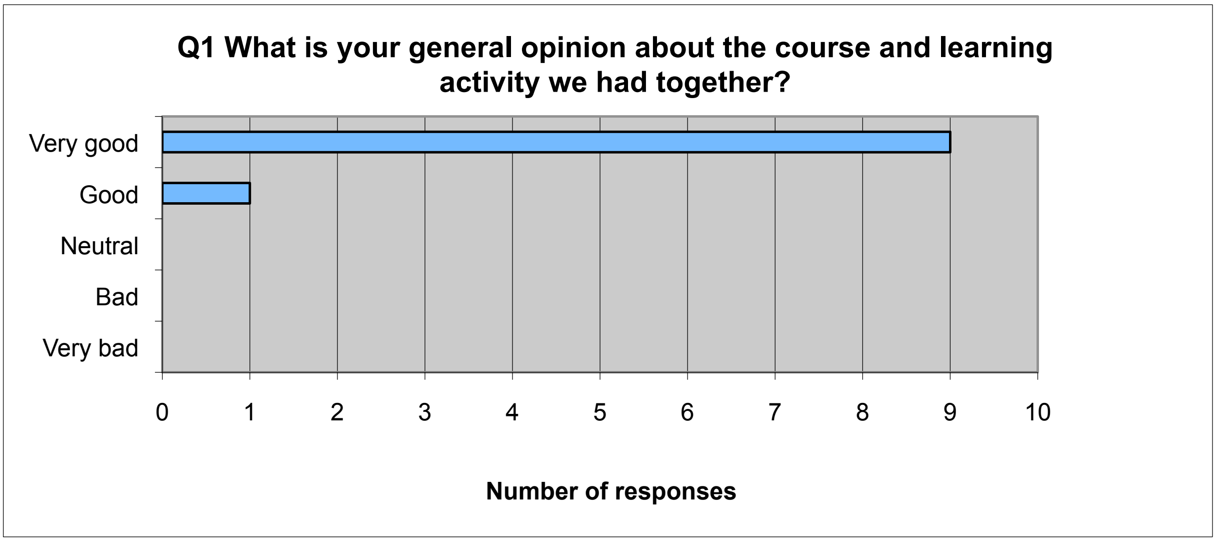


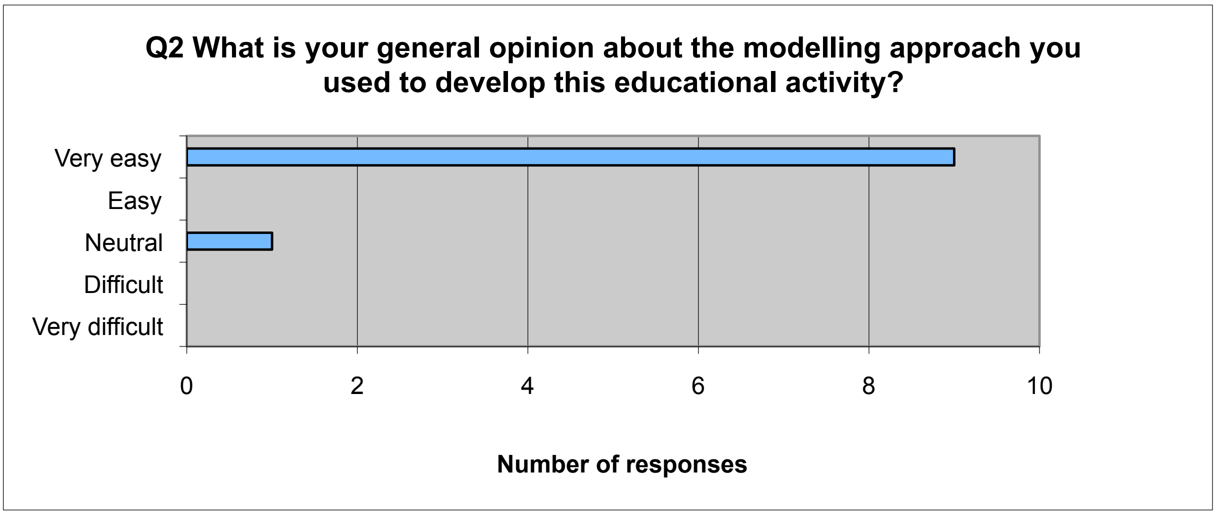
Legend:

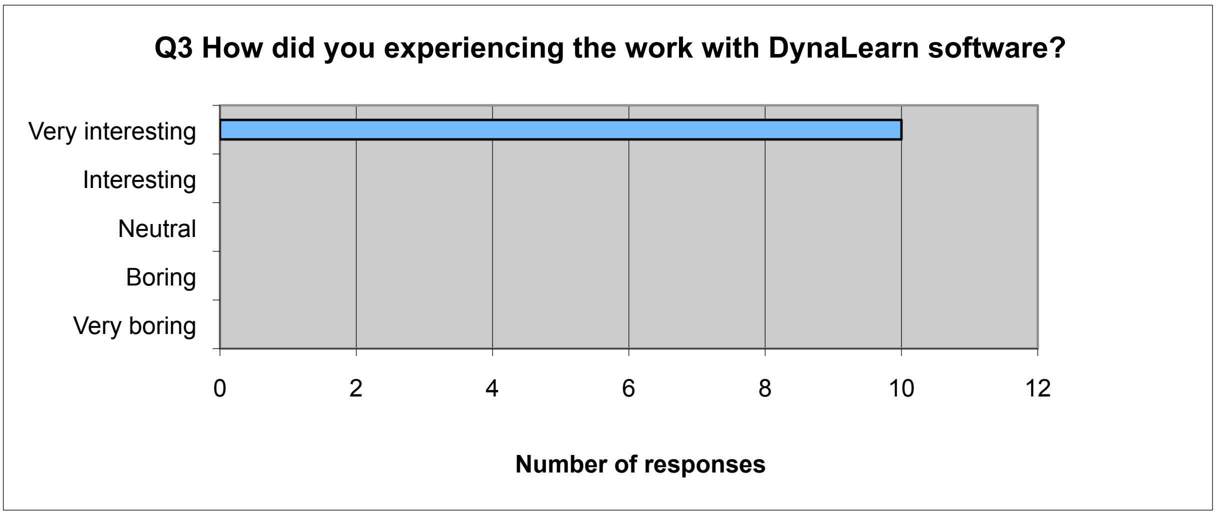
Vodno tqlo	Water body
Kolichestvo voda	Water amount
Atmosfera	Atmosphere
Kondenzacia	Condensation
Oblaci	Clouds
Valeji	Rain
Vodni pari	Water vapor
Vliqe	Above

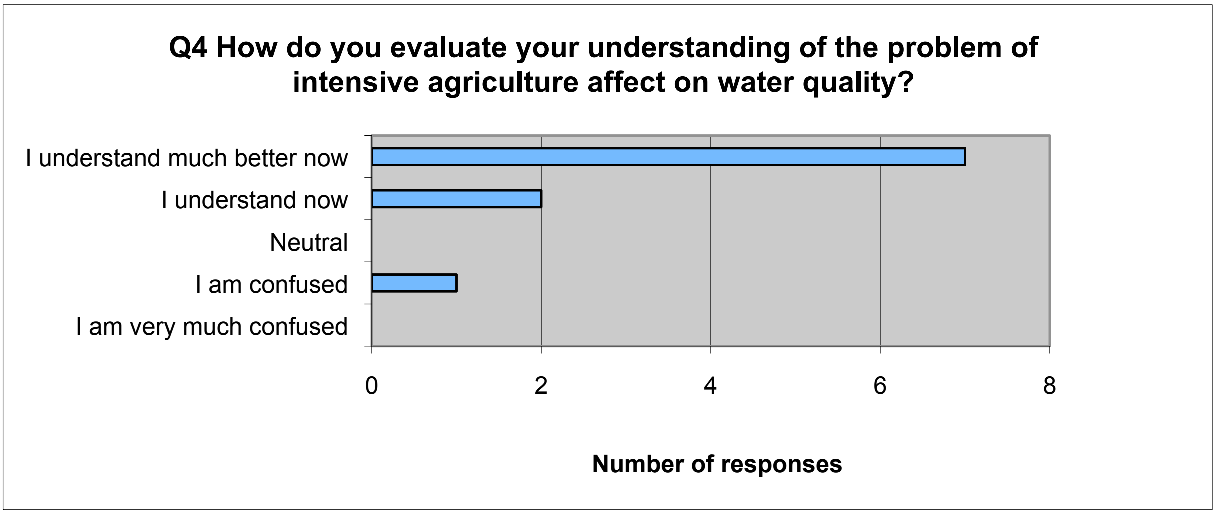
Appendix B – Results of second evaluation activities in Bulgaria

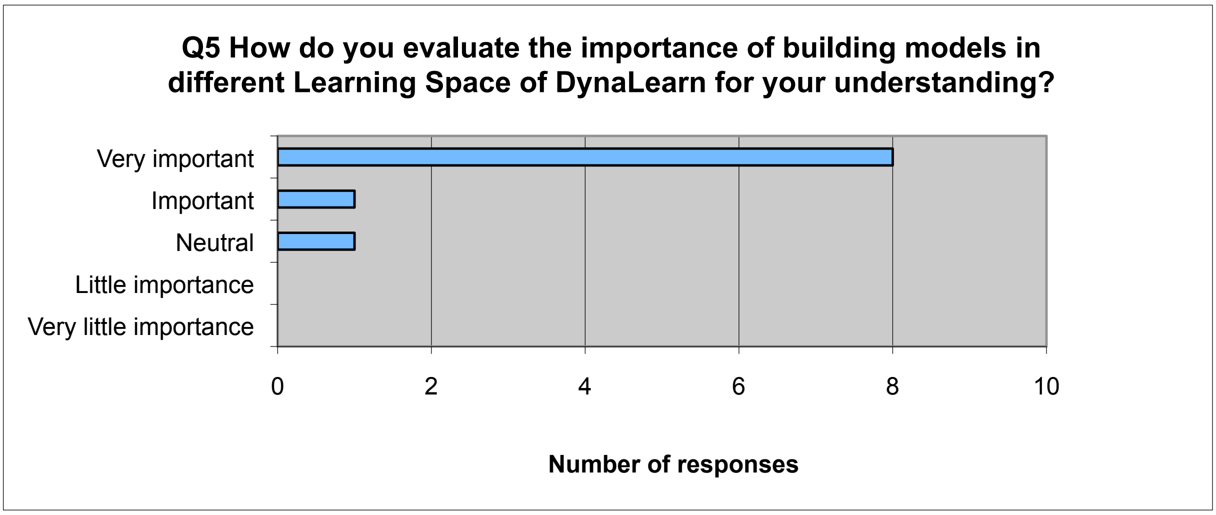
Appendix B1 Results of motivation/attitude questionnaire

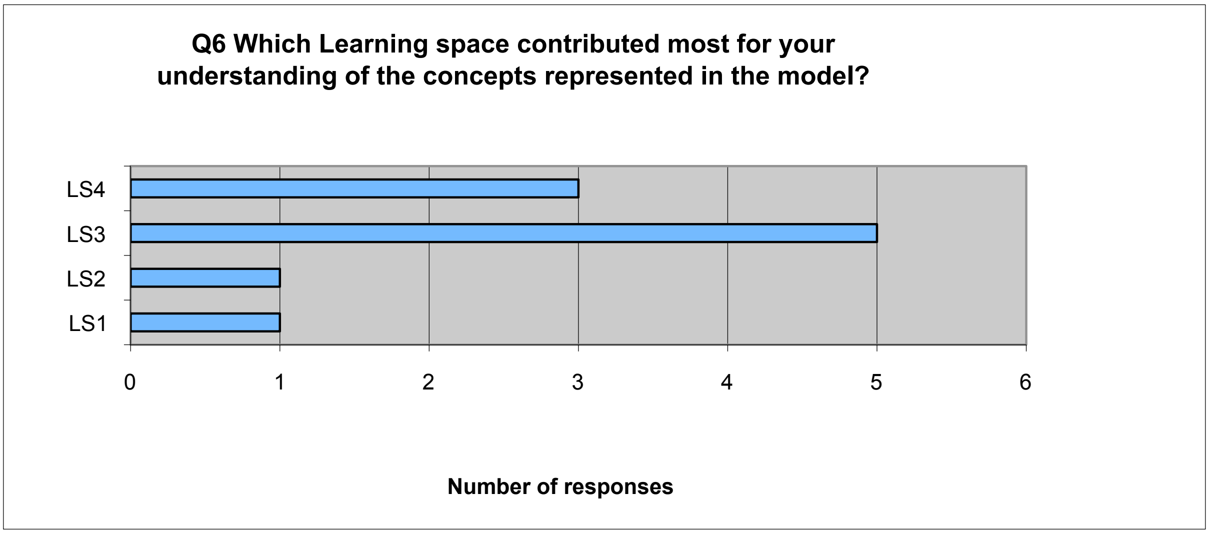


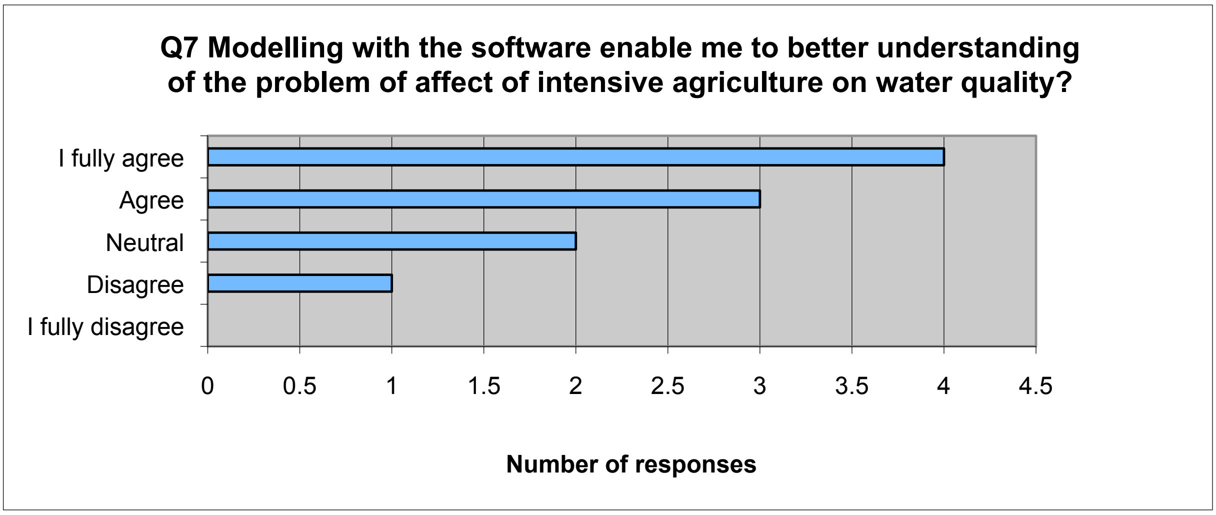


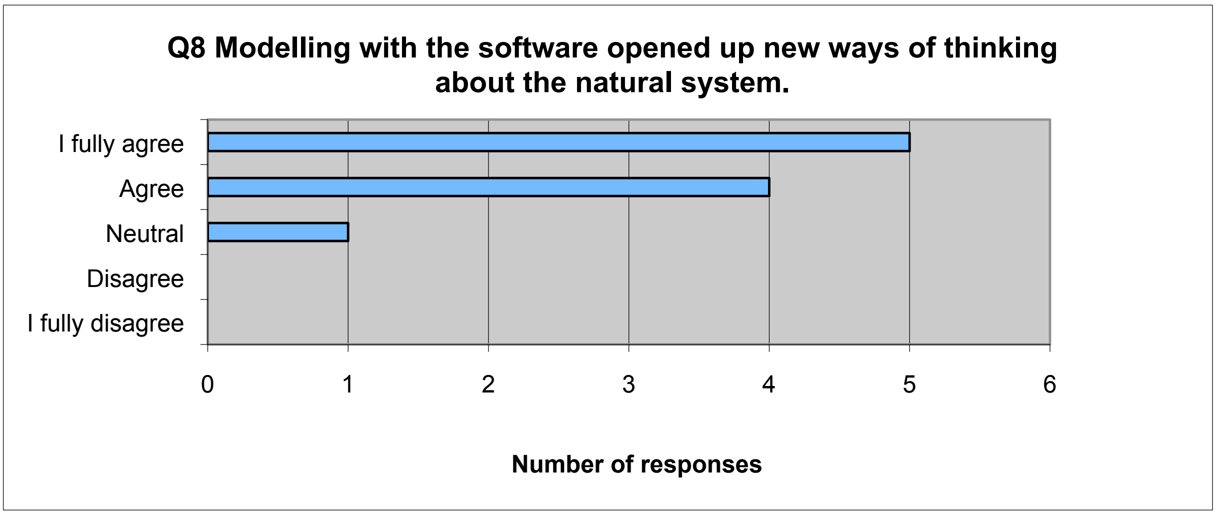


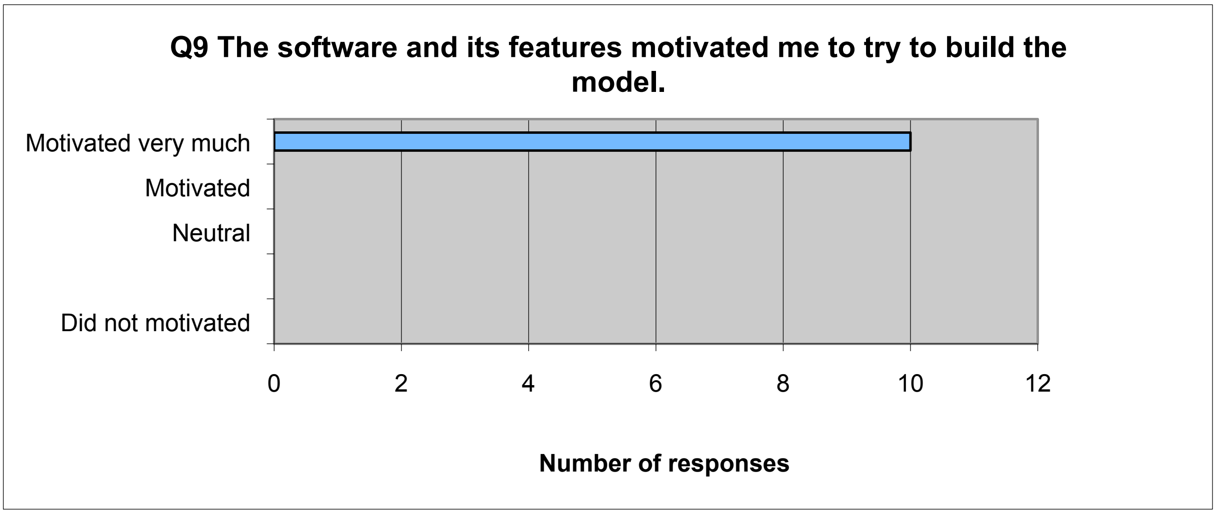

Q4 How do you evaluate your understanding of the problem of intensive agriculture affect on water quality?
I understand much better now
I understand now
Neutral
I am confused
I am very much confused
0
2
4
6
8
Number of responses

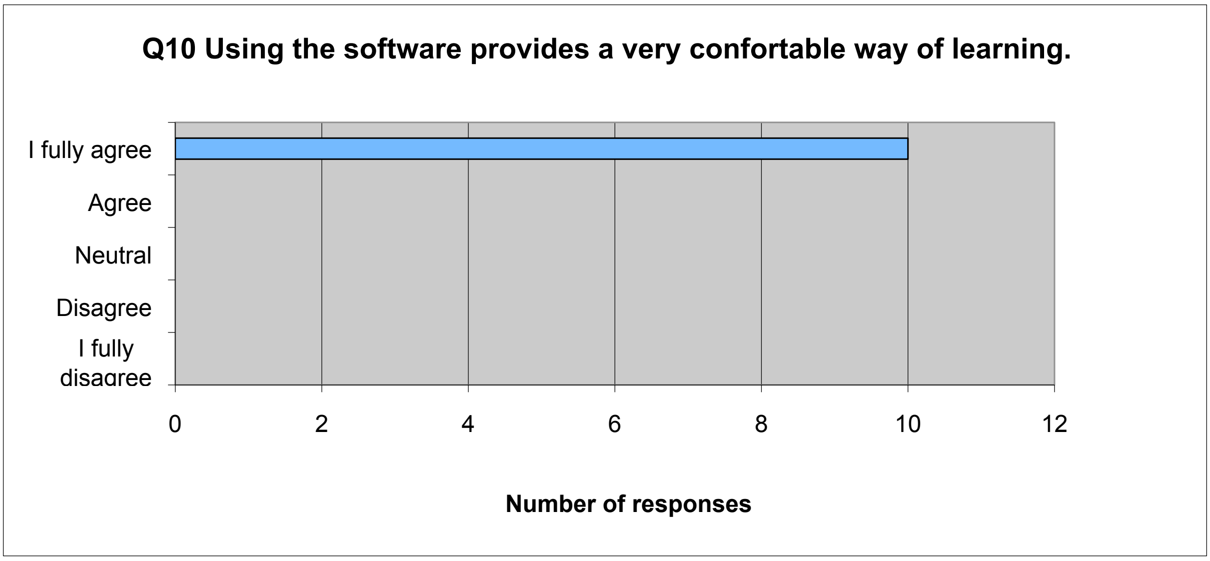

Q5 How do you evaluate the importance of building models in different Learning Space of DynaLearn for your understanding?
Very important
Important
Neutral
Little importance
Very little importance
0
2
4
6
8
10
Number of responses

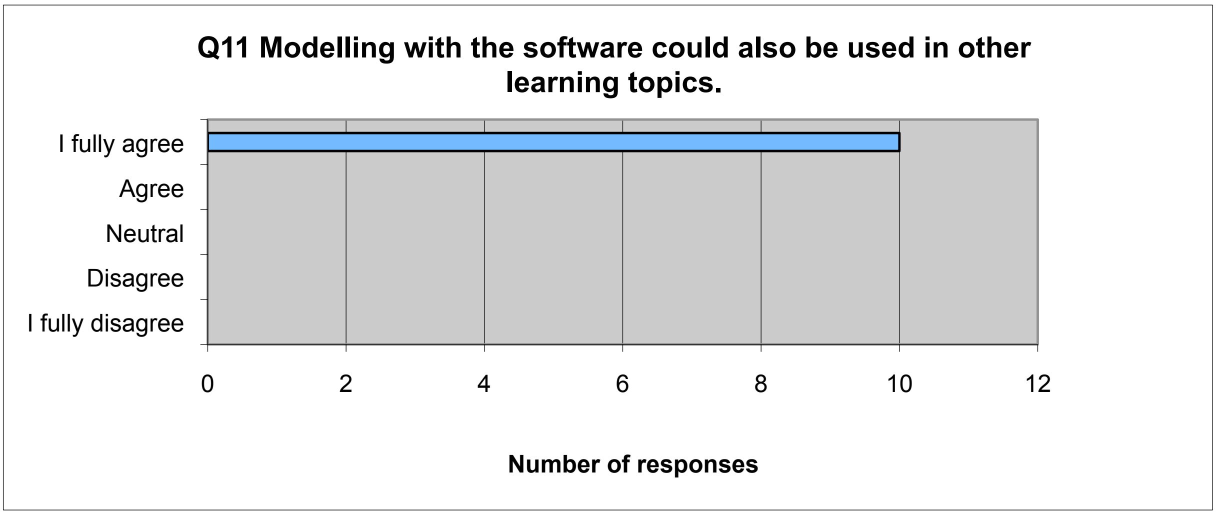

Q6 Which Learning space contributed most for your understanding of the concepts represented in the model?
LS4
LS3
LS2
LS1
0
1
2
3
4
5
6
Number of responses


Q7 Modelling with the software enable me to better understanding of the problem of affect of intensive agriculture on water quality?
I fully agree
Agree
Neutral
Disagree
I fully disagree
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
Number of responses


Q8 Modelling with the software opened up new ways of thinking about the natural system.
I fully agree
Agree
Neutral
Disagree
I fully disagree
0
1
2
3
4
5
6
Number of responses


Q9 The software and its features motivated me to try to build the model.
Motivated very much
Motivated
Neutral
Did not motivated
0
2
4
6
8
10
12
Number of responses





Question 12 Which LS did you like most? Why?

1. LS4 gives the opportunity to see the problem in deeper details.
2. LS4 gives the opportunity to see the problem in deeper details
3. LS2 is the most easy to understand level.
4. LS3 is the best level to show connection between quantities. This level is the easiest to work with.
5. LS4 gives exact and detailed information, and has the most possibilities for work.
6. LS3 is the clearest level and the easiest one to work with.
7. LS4 is the most informative and gives the biggest possibilities.
8. LS4 is the most informative level, but I like all of them, because they give us different potentialities.
9. LS4 gives us the biggest potentialities, but the risk to make a mistake is bigger.
10. LS4 is the most informative and with the biggest possibilities.

Question 13 What did you like?

1. I like the fact that I can describe a process/phenomenon with diagrams/models. In this way the problem is easy to understand.
2. I can describe the problem in my point of view.
3. I can build models of the processes I am interested in.

4. No answer.
5. The way of visualization.
6. The way of visualization.
7. The way of visualization.
8. Exactly representation.
9. I like the fact that I can describe a process/phenomenon with diagrams/models. In this way the problem is easy to understand.
10. The way of visualization. The problem is easy to understand.

Question 14 What did you dislike?

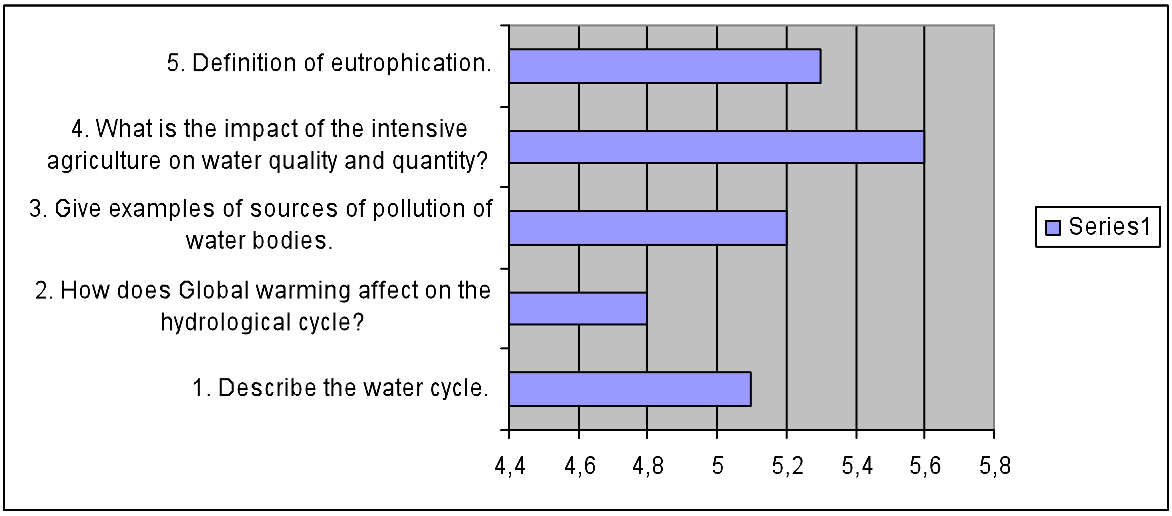
1. I want to copy model from LS3 in to LS4.
2. I like it all.
3. I want to copy model from LS3 in to LS4
4. I think the software needs of elaboration.
5. There are some bugs.
6. The short duration of the course did not allow us to go deep in the program.
7. I want to copy model from LS3 in to LS4.
8. The program has some bugs.
9. Bugs.
10. The software is ok, but the time of the course was not enough.

Question 15 Any ideas for improving the software?

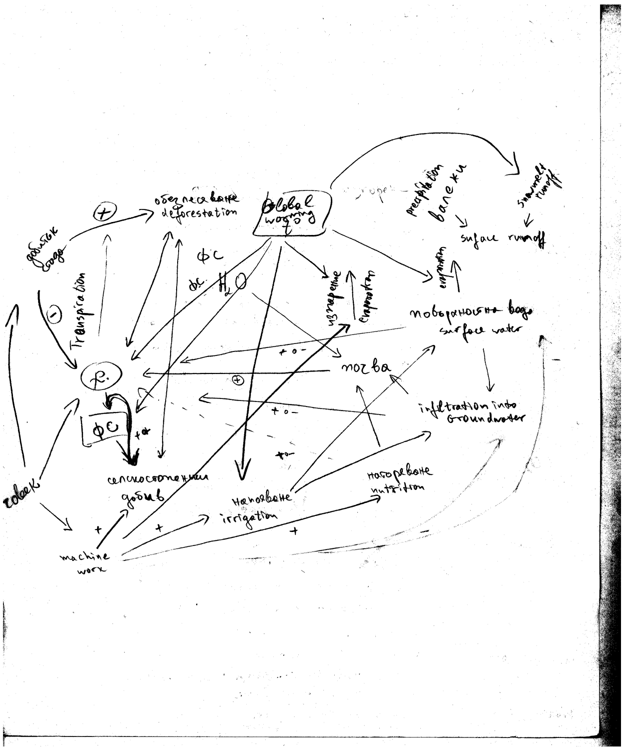
1. I want to copy model from LS3 in to LS4
2. No.
3. No answer.
4. No answer.
5. I would like to use Cyrillic alphabet.
6. No answer.
7. I want to copy model from LS3 in to LS4 and the function “copy-paste”.
8. No answer.
9. Bugs
10. I want to copy model from LS3 in to LS4.

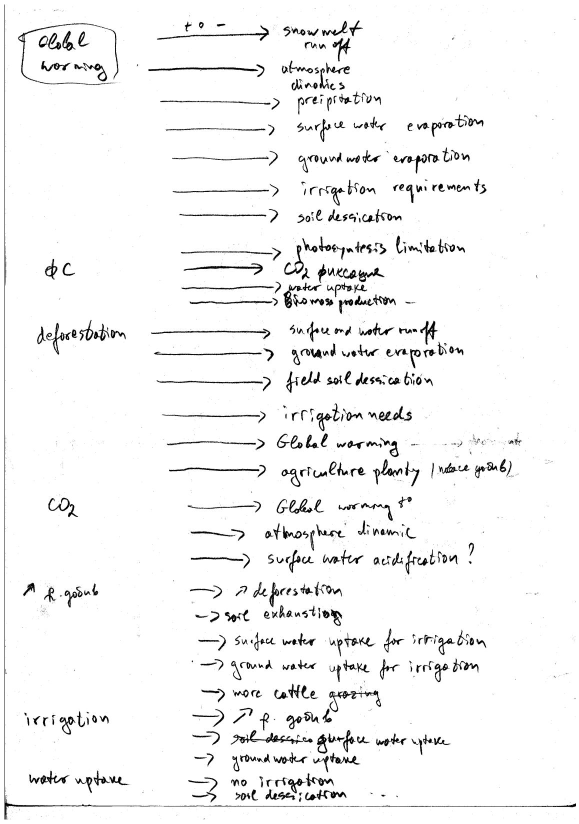
Appendix B2 Results of final questionnaire and students' models

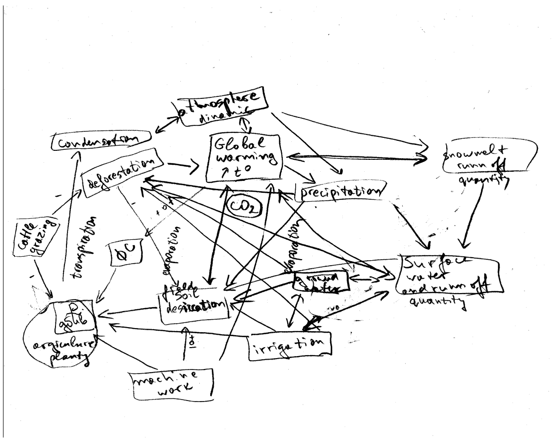
Students performed very well in the topic explored with DL compared to other topics explored in other lectures (success rated from 1 *"not satisfying" to* 6 *"excellent"*).

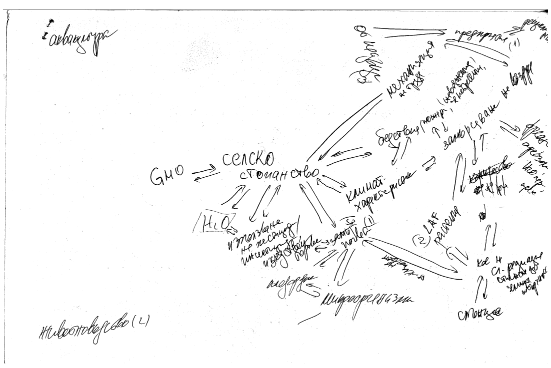


The following are example of concept maps and description made by students.

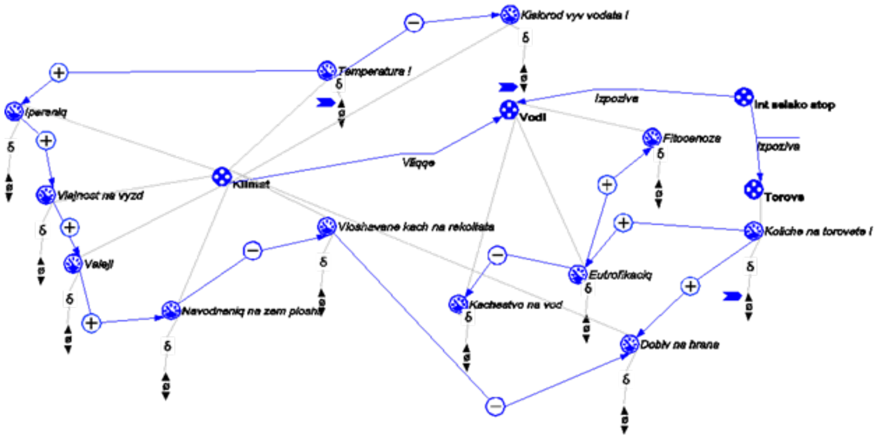




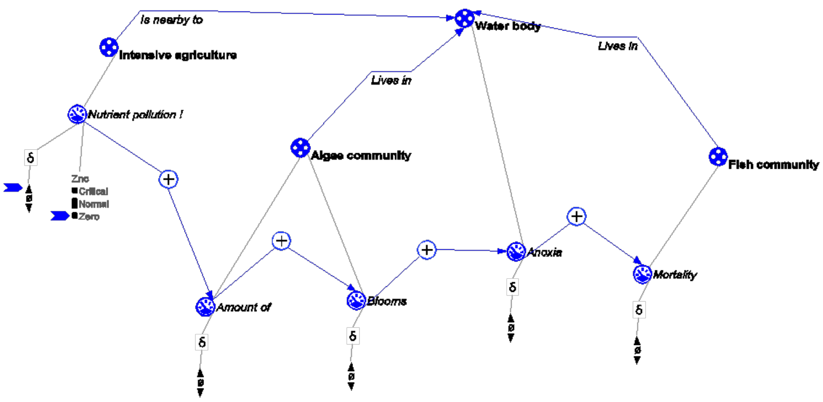




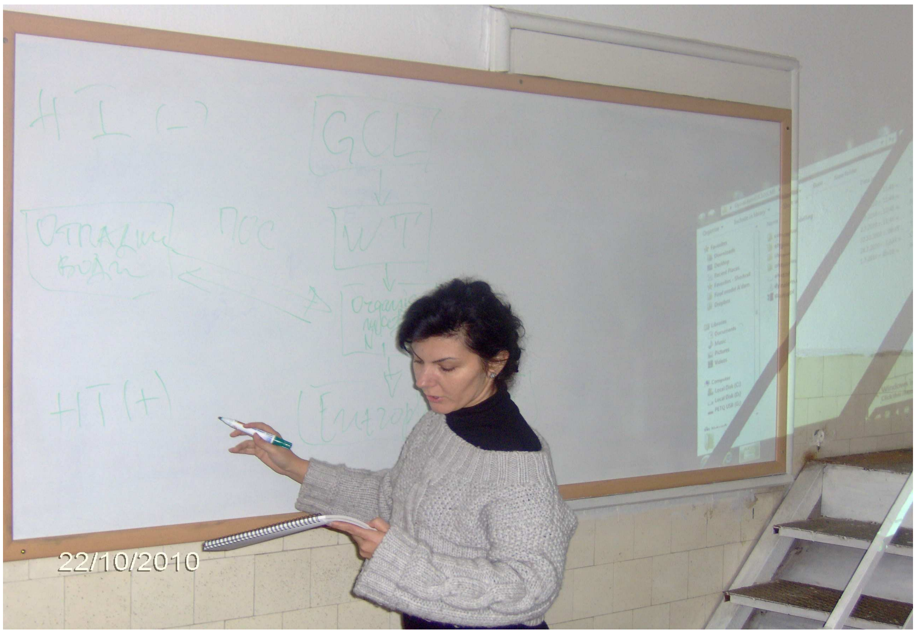
Intensive agriculture, Learning space 2



Intensive agriculture, Learning Space 3



Appendix B3 Pictures – first and second evaluation activities

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