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Abstract

This deliverable reports the second set of evaluation activities of the DynaLearn by IBER. The evaluation activities were carried out with high school students in Sofia Mathematic High School and Panagurishte Professional School. The main feature that was assessed was '*Conceptual modelling'* with a special focus on Learning spaces (LSs) 1, 2 and 4. The instruments which are used in this study were pre- and post- tests, statements about modelling and models and motivation questionnaire. The results are discussed together, because of the same design of this evaluation.

Internal reviewers

- Andreas Zitek (BOKU)
- Michael Wißner (UAU)

Acknowledgements

We would like to thank to all our students. Also thanks to the Directors and teachers of the schools we visit for letting us to run evaluation activities within the schools. Thanks also to Rachel Or-Bach who provided us statements about modelling and models. Thank you to Bert Bredeweg for his valuable comments on the initial results. Thanks to Galia Georgieva for the technical support. Finally, thank you to Andreas Zitek and Michael Wißner who provided useful comments on this document.

Document History

Version	Modification(s)	Date	Author(s)
01	Initial data	2011-12-01	P. Borisova, J. Liem, Y. Uzunov
02	Draft for review	2012-01-20	P. Borisova, J. Liem, Y. Uzunov
03	Final draft	2012-01-31	P. Borisova, J. Liem Y. Uzunov

Contents

1. Introduction

This deliverable reports the evaluation activity of the DynaLearn performed by the Institute of Biodiversity and Ecosystem Research in Bulgaria.

"Task 7.3 Evaluation of DynaLearn final software: Based on the finished "Curriculum and content models' (WP6), each case study beneficiary will develop lessons and an evaluation plan focusing on several different topics in the curriculum (including at least some of the advanced models they have developed themselves). Each case study will focus on different aspects of the curriculum and features of the final DynaLearn software. Using the prepared lessons and evaluation plan, each beneficiary will evaluate the DynaLearn prototype and the curriculum in real educational settings." (Description of Work).

The activities were designed to address one main question: What are the effect of DynaLearn's conceptual modelling environment on students' learning concepts and modelling skills?

In total two evaluation activities were conducted. The results are discussed together, because of the same evaluation design, equal results and small groups of students.

Conceptual modelling was the only DynaLearn functionality covered by IBER for this deliverable. The main reason for this was the only stable functionality available during the evaluation period. The other reason was lack of students when the software had a stable version.

Evaluation activities explored the development of the understanding natural and technological phenomena, mastering natural and modelling language, identifying the information presented in different contexts, integrating knowledge from different areas. These skills were already discussed in Deliverable 7.1 (*Mioduser et al.*, 2010).

The goal to motivating learning environment that supports learners in actively dealing with theoretical concepts to develop their understanding of how systems behave was achieved. One of the answers of the students shows that:

"*The simulation result helps me, because I start to think deeper about some problems. Now I want to know more things, more details. For example the model which I built about urbanisation makes me think more about the problem with pollution. Now I know that it is my fault that nature is so polluted! I will make an effort to decrease that*."

~Student

The interpretation of this answer could be following:

-Student is more interested and motivated:

"I start to think deeper about some problems. Now I want to know more things, more details."

-Modelling a problem makes the student think more deeply about it:

"The model which I built about urbanisation makes me think more about the problem with pollution"

-The student can make a connection with daily life and his own role in it:

"Now I know that it is my fault that nature is so polluted! I will make an effort to decrease that."

Deliverable organisation

This deliverable presents the results of one design of evaluation activity conducted with two groups of students. Their results are presented together. The document is organised as follows:

Knowledge transfer between topics by learning system thinking is described in section 2. The method of this activity is presented in section 2.1, which described the participants (section 2.1.1), analytical skills (section 2.1.2), and hypothesis (section 2.1.3). The evaluation design and instruments are presented in section 2.1.4, the implementation in section 2.1.5 and finally, data analysis in section 2.1.6. The results are presented in section 2.2. They are separated in three subsections: Motivation questionnaire (section 2.2.1), Statements about models and modelling (section 2.2.2) and Pre- and Post-tests (section 2.2.3). The results obtained from the evaluation activity in general are discussed in section 3. In section 4 are presented the concluding remarks of this evaluation activity.

2. Knowledge Transfer between Topics by Learning System Thinking

A course in Qualitative Modelling was conducted with students from two High schools in Bulgaria. 16 students were participants from "Sofia Mathematic High School" at Sofia and 7 students from "Panagyurishte Professional School" at Panagyurishte. The course lasted 12 teaching sessions during the 3 days. The research questions we focused on were:

1. Does modelling improve understanding of a known topic?
2. Does modelling of a known topic teach analytical skills, which can be applied to an unknown topic?
3. Does modeling of an unknown topic teach analytical skills?

2.1. Method

2.1.1. Participants

Participants involved in the studies were 16 students form Sofia Mathematics High School and 7 students form Panagyurishte Professional School. The age of the students was between 15 and 17 years old.

- *Sofia Mathematics High School*: Only 9 students (from total 16) filled out all tests and questionnaires. The results of the other 7 students are not discussed here.
- *Panagyurishte Professional School*: The data from this activity is complete. In total 9 students were participants in this evaluation activity.

Due to the small number of the participants, the results from these studies was calculated and presented here as one evaluation activity.

The total number of the participants from the both activities was 16 students.

2.1.2. Analytical skills

After modelling activities the students had to:

• **A1:** Identify a system in a scientific text (not measured).

• **A2:** Identify key concepts in a scientific text.

• **A3:** Identify the structure (entities and configurations) and behavioral aspects (quantities) of a system.

• **A4:** Identify the processes and state variables.

Topics which we were explored:

- T1: Biodiversity (known topic for the students)
- T2: Urbanisation (unknown topic for the students)

With these two topics (Biodiversity and Urbanistaion) IBER team tried to teach students that rivers and lakes are not simply volumes, which contain water, but they are an environment for tremendous biological diversity of aquatic ecosystems (Living World) in the same time, and use to provide humans with various ecosystem services. Humans and their societies (Human population) explore commonly the water as a renewable resource (Energy resources & consumption) losing sight of fragility of aquatic ecosystems and threatening the capacity of water bodies to provide further these services (Land & Water Use) by polluting the waters (Pollution) and/or changing the natural water circles (Global Changes) (*Salles et al*., 2009).

2.1.3. Hypothesis

Hypotheses:

• **H1**: After modelling students will identify more of the key concepts in a text about the same topic.

• **H2**: After modelling students will identify more of the key concepts in a text about a new topic.

• **H3**: After modelling students will identify more of the key concepts in a text about the same topic correctly as structure (entities and configurations) and behaviour (quantities).

• **H4**: After modelling students will identify more of the key concepts in a text about a new topic correctly as structure (entities and configurations) and behaviour (quantities).

• **H5**: After modelling students will identify more of the quantities in a text about the same topic correctly as processes and state variables.

• **H6**: After modelling students will identify more of the quantities in a text about a new topic correctly as processes and state variables.

2.1.4. Evaluation design and instruments

The following instruments were used:

1. Pre- and Post- Tests
    a) Short text about:
        - Biodiversity
        - Urbanisation
2. Attitude Questionnaires
    a) Statements about models and modeling
    b) Motivation questionnaire

The design which was used in this evaluation is presented in figure 1.

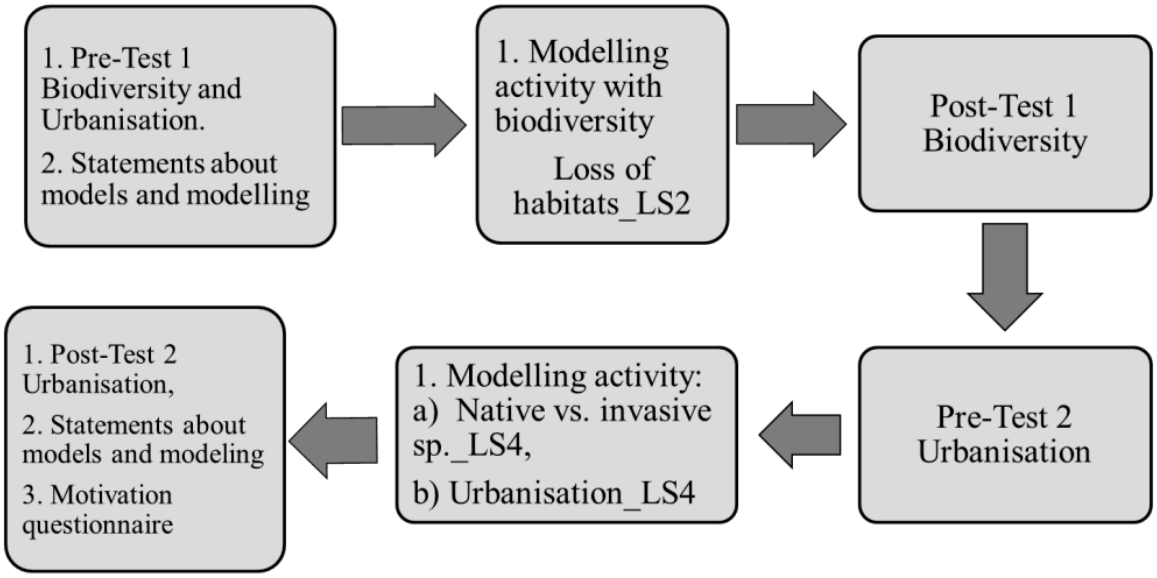


Figure 1 Evaluation design

2.1.5. Implementation

Following evaluation activities were conducted during the study:

1. **Pre-test 1:** Text1 about biodiversity (Food web and loss of biodiversity) and Text1 about Urbanisation (Change in urban water cycle).
2. **Post-test 1:** Text2 about biodiversity (Anthropogenic activity leads to loss of biodiversity).
3. **Pre-test 2:** Text2 about urbanization (Reasons for occurs the urbanisation).
4. **Post-test 2:** Text3 about Urbanisation (Levels of urbanisation).
5. Motivation questionnaire.
6. Statements about models and modeling.

The examples for Pre- and Post-tests are presented in Table 1.

Table 1 Example for Pre-Post Test: A) The students have to fill out the table. B) Correct answers: Key concepts- Total: 10, Entity- Total: 4, Quantity- Total: 6, Processes- Total: 3, State variables- Total: 3

A. Key concepts T2	Type	B. Key concepts T2	Type
Urban area		Urban area	Entity
Rural area		Rural area	Entity
Urbanisation		Urbanisation	Process
Urban population		Urban population	Entity
Size		Size	State variable
Sewage production		Sewage production	Process
Nutrients		Nutrients	State variable
Fish community		Fish community	Entity
Mortality rate		Mortality rate	Process
Number of fish		Number of fish	State variable

T1 -Topic Biodiversity, T2 – Topic Urbanisation

The course and modeling activities with details were integrated in the course's plan shown in Table 2.

Table 2 Course plan

Day	Activity	Evaluation/Task
17.05.2011	**14:00- 14:45** Introduction in the project and explain what we will do in the next few days (10 min). Pre- test 1 (35 min).	**Pre- test 1** Before modeling activities (both, same and unknown topic). Text 1 describes Biodiversity and text 1 describes Urbanisation. Q1: Identify the key concepts in the text.Q2. Identify the key concepts as entity and quantity.Q3. Identify the quantity as processes and state variables.Statement about models and modeling
	14:45- 14:55 Break	
	14:55-15:40 Continue with presentation about Learning spaces LS1-4. Modelling activity.	Modelling session with LS2 Loss of habitats.
	15:40-15:50 Break	
	16:00 -16:45 Modelling session with LS2.	Modelling session with LS2 Loss of habitats.
19.05. 2011	**14:00- 14:45** Introducing and work with LS4 . Modelling session.	Modelling session with LS4 Invasive species.
	14:45- 14:55 Break	
	14:55-15:40 Work with LS4. Post-test 1, Pre-test 2.	**2. Post- test 1 After modeling** activities (same topic)Text 2 describes Biodiversity Q1: Identify the key concepts in the text.Q2. Identify the key concepts as entity and quantity.Q3. Identify the quantity as processes and state variables.3. Pre-test 2 Unknown topic after modeling activities with same topic. Text 2 describes Urbanisation.Q1: Identify the key concepts in the text.Q2. Identify the key concepts as entity and quantity.Q3. Identify the quantity as processes and state

		variables.
	15:40-15:50 Break	
	16:00 -16:45 Modelling session with LS4 Urbanisation.	
30.05.2011	**14:00- 14:45** Modelling session	LS4 Urbanisation.
	14:45- 14:55 Break	
	14:55-15:40 Modelling session	LS4 Urbanisation.
	15:40-15:50 Break	
	16:00 -16:45 Post –test 2. Motivation questionnaire.	**4. Post- test** 2 Unknown topic after modeling activities. Text 3 describes Urbanisation. Q1: Identify the key concepts in the text.Q2. Identify the key concepts as entity **and quantityQ3. Identify the quantity as processes** and state variables.Motivation questionnaire. Statements about models and modeling (exactly the same as previous one).

2.1.6. Data analysis

Result analysis: Data is consistent with hypothesis H2, H4 and H6 if:

- Pre-test Topic T1 < Pre-test T2

Desired conclusions:

- Students learn better if H1, H3 and H5 are consistent with the data
- Students learn faster if H2, H4 and H6 are consistent with the data

Data is consistent with hypothesis H1, H3 and H5 if:

- Pre-test Topic T1 < Post-test T1
- Pre-test Topic T2 < Post-test T2

Research questions

1. Does modeling improve understanding of a known topic?
    - *(Pre-Test T1< Post-Test T1)*
2. Does modeling of a known topic teach analytical skills, which can be applied to an unknown topic?
    - *(Pre-Test 1 T2 < Pre-Test 2 T2)*
3. Does modeling of an unknown topic teach analytical skills?
    - *(Pre-test 2 T2 > Post-test 2 T2)*
4. Do students understand topic learned in school better than topic not taught?
    - *(Pre-test 1 T1 > Pre-test 1 T2)*

2.2. Results

2.2.1. Motivation questionnaire

The motivation questionnaire was given to the students in the end of course to measure the motivational aspects. The questionnaire contained a set of items separated in following five parts:

- Part I. Learning by Modelling
- Part II. Learning Spaces
- Part III. Simulation
- Part IV. Ease using the DynaLearn
- Part V. Personal opinion/Motivation

The answers of the motivation questionnaire of the students are given in Appendix A.

Students were asked to respond, on a scale from 1 (strongly disagree/very difficult) to 5 (strongly agree/very easy) to the items.

The analysis of the motivation questionnaire shows highest agreements for the applicability by DynaLearn to other scientific domains. All students indicated as easy the qualitative modelling used in classes. Most of them were positively and agreed that working with DynaLearn is very interesting. In their opinion working with different levels available in DynaLearn is very important, especially starting first with LS2 and then continue with the LS3 and 4. All of the students agreed that LS4 contributes most with understanding of the concepts represented. They said that in the end of the course their understanding on the explored topics (biodiversity and urbanisation) was better than in the beginning.

All students found the simulation results interesting:

"For me it was interesting to see all possible paths and how I achieve them. You can see where are your mistake and to improve the model. This needs to more thinking!"

"Building the model is not enough to me. The simulation gives me opportunity to see how one thing influence on other one. If the result is bad (in our case loss of biodiversity) then we can take decision how we can solve this problem. Solution of the problem with DL is very interesting to me."

"Simulation result helps me, because I start to think deeper about some problem. Now I want to know more things, more details. For example the model which I build about Urbanisation makes me think more about the problem with pollution. It is my faults that nature is so pollutant. I will make effort to decrease this."

"I like when I see the result for my effort."

All students indicated that 15 hours is too short to really work through four LS and to fill out different questionnaire (pre- and post- tests, motivation questionnaire, statement about models and modelling).

All of the answers of the students are available in Appendix A.

2.2.2. Statements about models and modelling

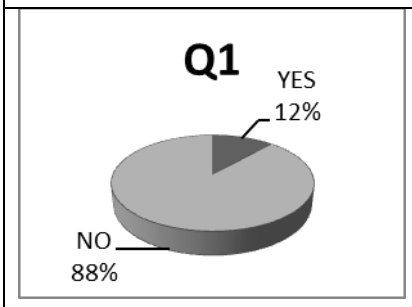
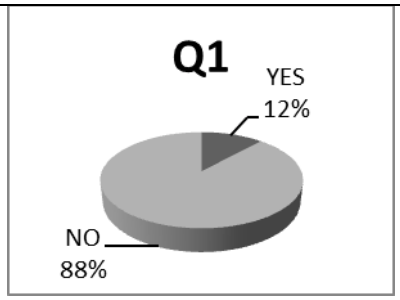
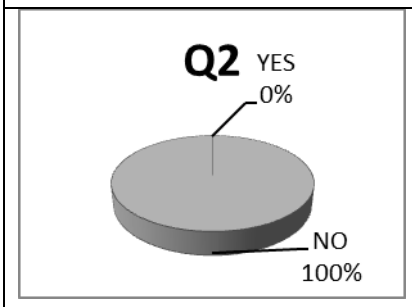
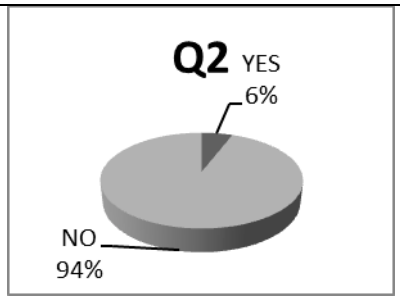
The statements about models and modeling are presented in Appendix B. The statement is composed of 14 open-ended questions. However, it is challenging to participants to fully articulate their views in 15 minutes.

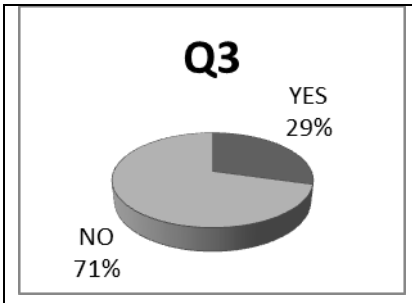
This questionnaire was created for capturing student views about modeling and models and the added value of working with DL to change it. It seems especially interesting with students that are already in a science track (in upper high school and maybe even university beginners).

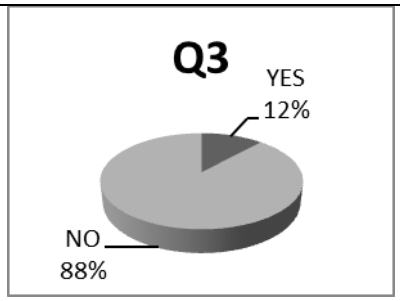
For the students it was interesting to fill out this questionnaire and to explain why they felt this way. This questionnaire was filled out by the students two times (in the beginning and at the end of the course). The main idea was to capturing student views about modeling and models after working with DynaLearn. The answers of the students given in % are presented in Table 3.

The answers of the students during the pre- and post- tests are shown in Appendix B.

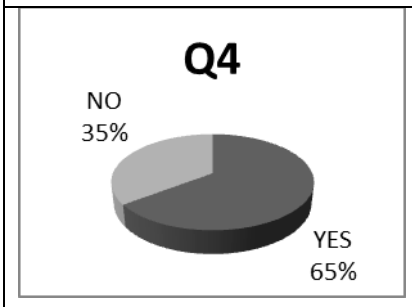
Table 3 Answers of the students in % during the pre-and post-test statements.

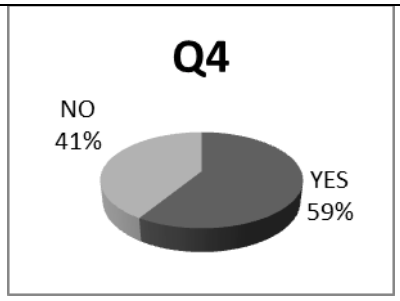
Pre- statements	Post- statements
Statement 1. A model can capture the structure of something but not capture the processes.	
	
Statements 2. A scientist uses a model as a last resource, when all other options cannot be used.	
	
Statements 3. Building models is actually the essence of a scientist work.	



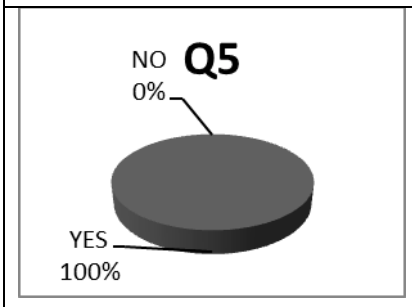


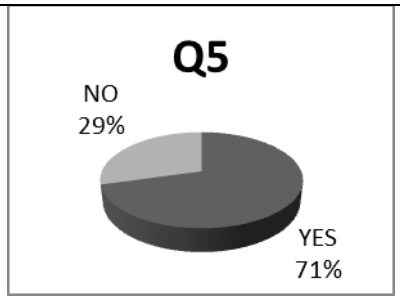
Statement 4. Much of the scientist work is to modify models according to his research goals.



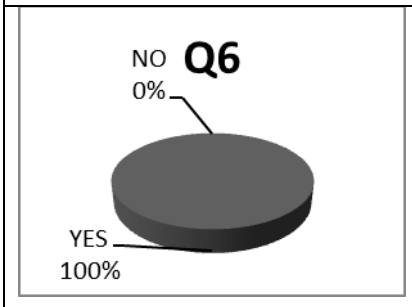


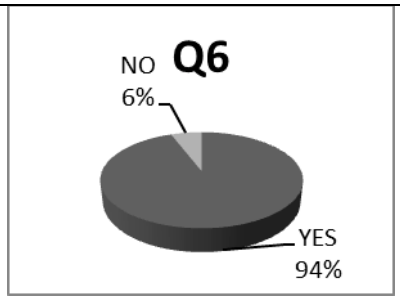
Statement 5. A model is better if it resembles the real world as much as possible.





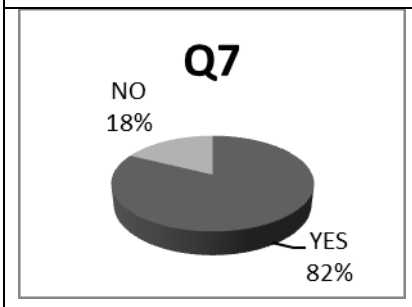
Statement 6. There might be different models for the same phenomenon.

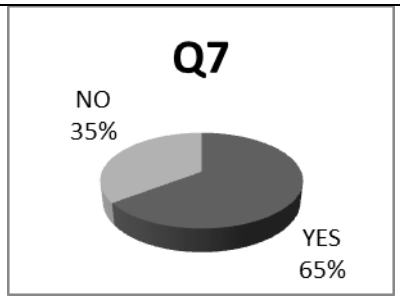




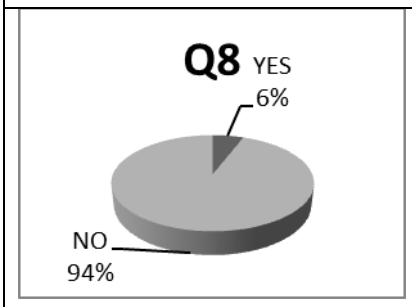
Statement 7. A model is better when it can be used for describing

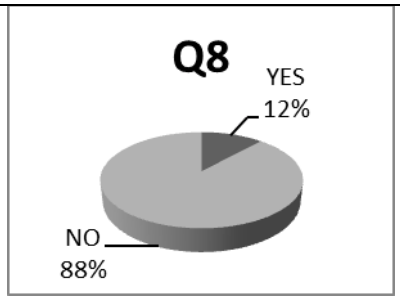
as many things as possible that are related to the phenomenon.



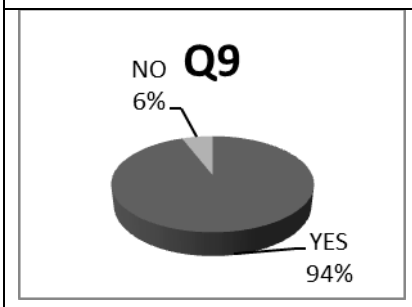


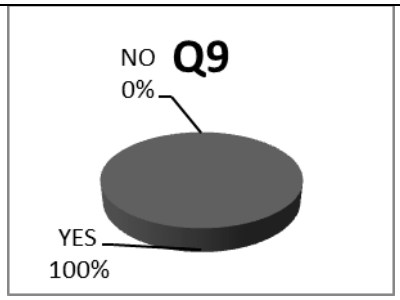
Statement 8. Models can be used only to describe the scientist's current knowledge and not for learning new things.



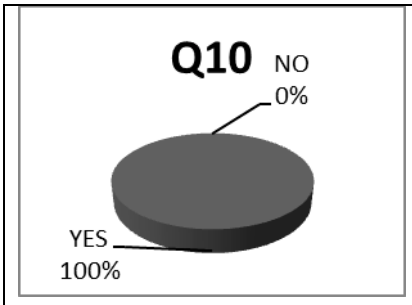


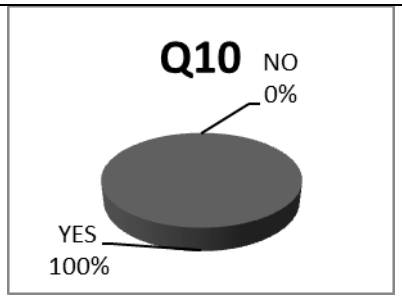
Statement 9. While simulating (executing/running) a model a scientist might learn things s/he did not know before.



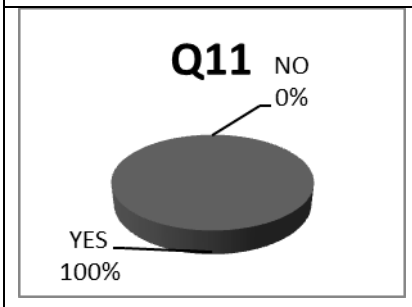


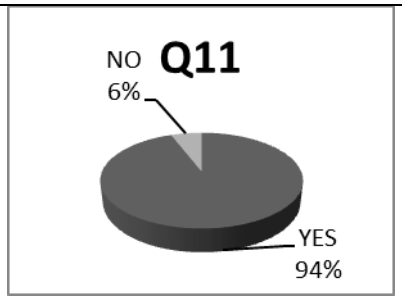
Statement 10. The results of the simulations might bring a scientist to rethink and change his theory.



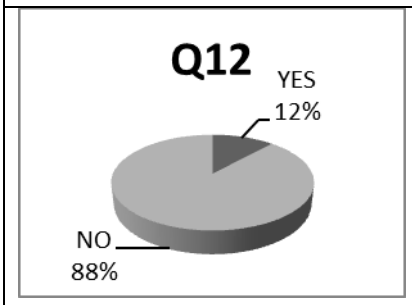


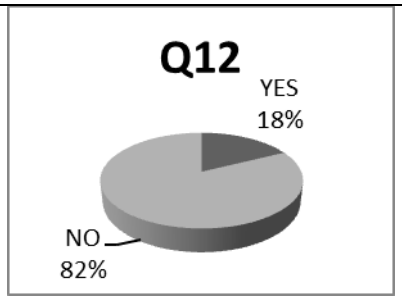
Statement 11. Models are used by scientists to communicate, share ideas and collaborate with other scientists.



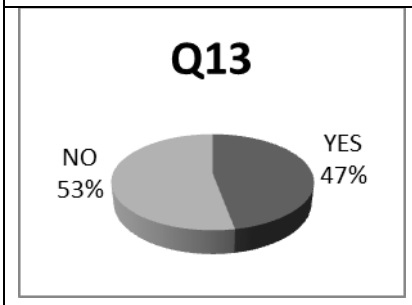


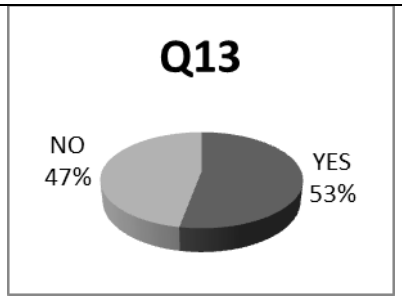
Statement 12. Scientists construct models only when they know a lot about the phenomenon, not in order to explore a phenomenon and learn more about it.

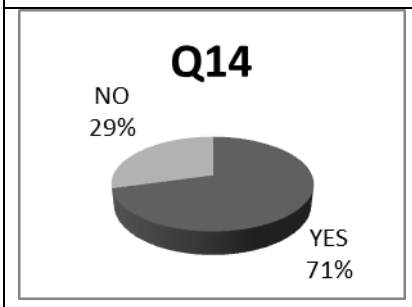
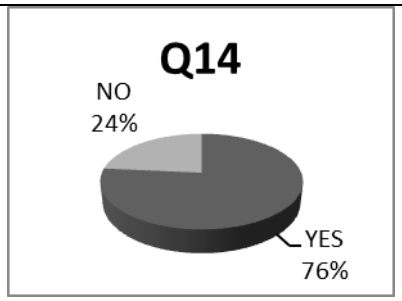




Statement 13. A model constructed for one topic can be used to explain a phenomenon related to another topic/discipline.





Statement 14. A model constructed for a biology phenomenon can be used to predict outcomes of a phenomenon in another discipline.	
	

Statements 5 and 7 show biggest changes:

- S5. A model is better if it resembles the real world as much as possible.
- S7. A model is better when it can be used for describing as many things as possible that are related to the phenomenon.

During the pre-test all the students indicated that the model is better if it resembles the real world as much as possible. Some of the students changed their opinion during the post-test. 29% of the students thought that hypothetical things also can be presented with DL. Also the students think that with DynaLearn the phenomena can be predicted.

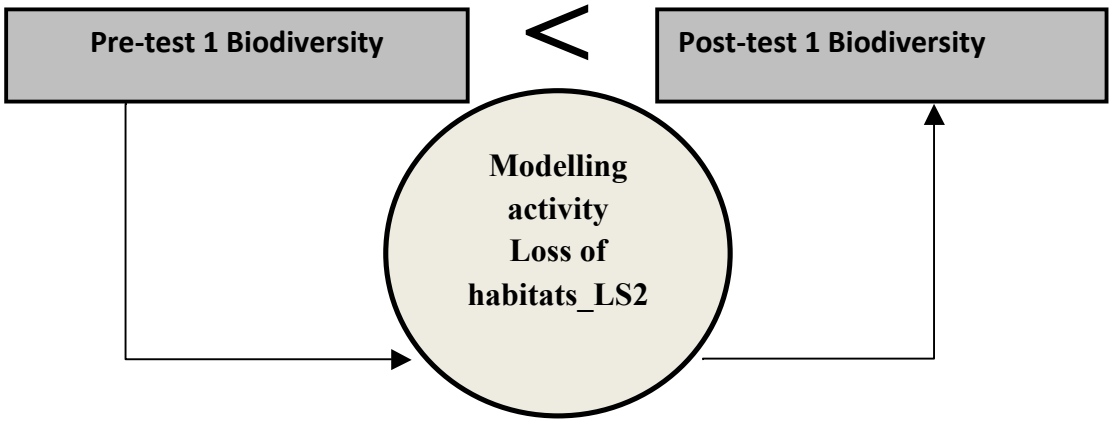
Big change shows also post-test of statement 7. In the beginning 82% of the students thought that the model is better when it can be used for describing as many things as possible that are related to the phenomenon. In the end 65% of the students gave this answer. According to the rest 35% of the students, the model has to present only one phenomenon with fewer things related to this phenomenon. They thought that in this way the model is more clear and understandable.

2.2.3. Pre- and Post- Tests

2.2.3.1. Research Question 1: Pre-test T1< Post- Test T1

For analysing the results from pre- and post- tests Wilcoxon signed-rank test was used.

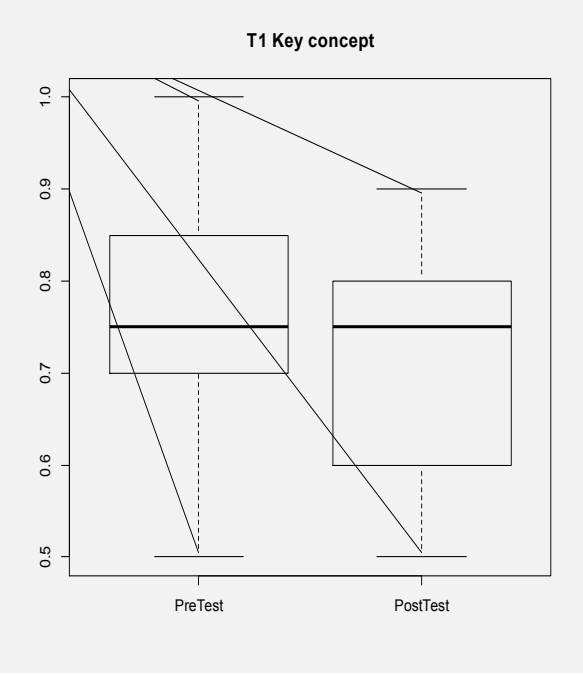
To give answer of the first research question (Does modelling improve understanding of a known topic?) the following design was used:



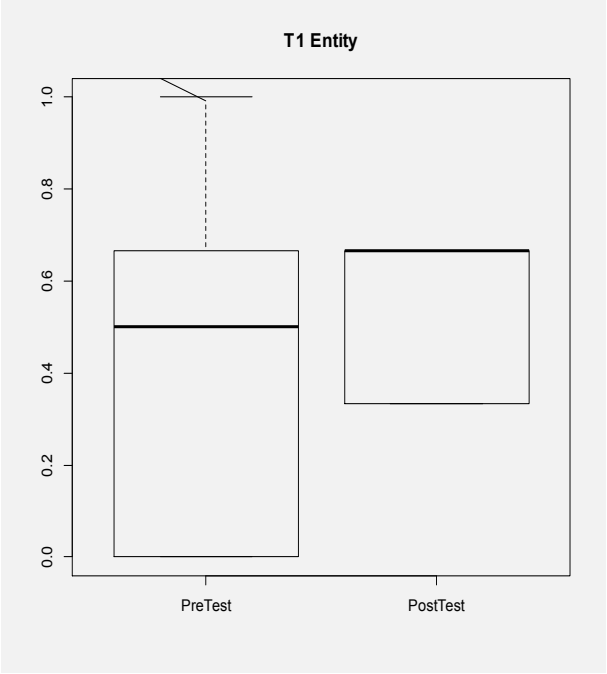
In the beginning of the course the students fill out test (Pre-test 1 Biodiversity) with text which was known for all of them. The result of this test shows the students' understanding for this topic. After this the students had to start modeling activity with the same topic (biodiversity). All of them built a model about "Loss of biodiversity due to loss of habitats". For all the students this task was not difficult. The reason was because the topic was already taught at school. Also working with DynaLearn software seems not difficult to the students and only two students asked for support from the teacher. After the modeling session the students fill out post-test. Their task was to find the key concepts, entities, state variables and processes in the known text for them. The result of this test is given in Figure 2 and Table 4.

Table 4 Wilcoxon test for significance (p-value)

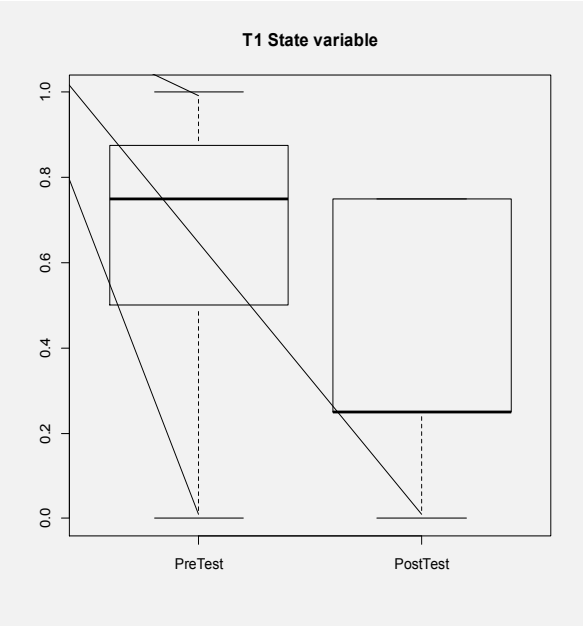
Pre-test T1 and Post-test T1	p
Key concept	0.3755
Entity	0.1625864
State variable	0.02899
Process	0.004181



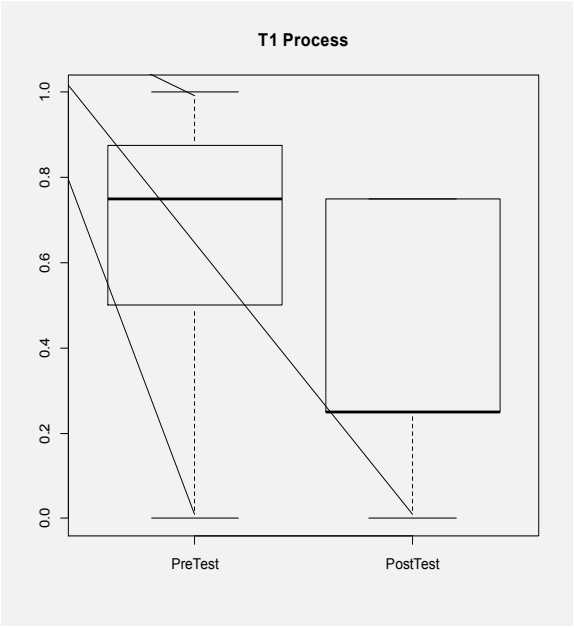
a)



b)



c)



d)

Figure 2 Boxplots with the result from pre- and post-tests: a) Key concept, b) Entity, c) State variable, d) Process.

For the key concept, entity and state variable the significant result was not found. The student was confused to found easy these ingredients. Only the process have the p-value less than 0.05. The short interaction with the software could be the reason for that.

2.2.3.2. Research Question 2: Pre-test 1 T2 < Pre-Test 2 T2

Research question 2 - Does modeling of a known topic teach analytical skills, which can be applied to an unknown topic? was answered with results from pre-test 2 (urbanisation). After modeling activity with topic biodiversity the students had to fill out test about new topic (unknown for them). The results are shown in Figure 3. The significant results (see Table 5) was not observed. The reason could be that the number of students is too small. Also the interaction time was too short to see an effect.

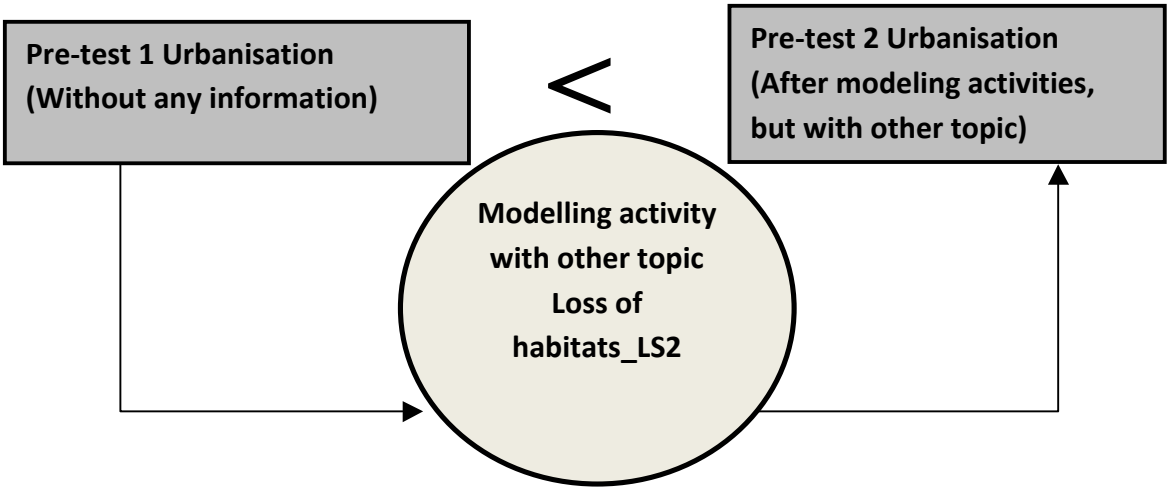
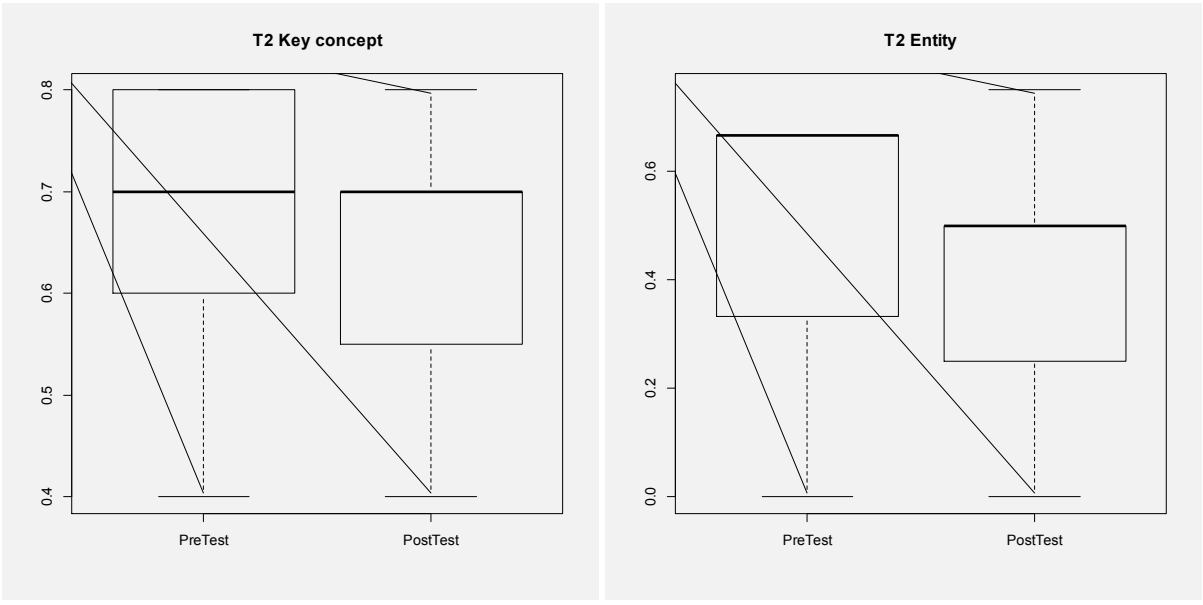
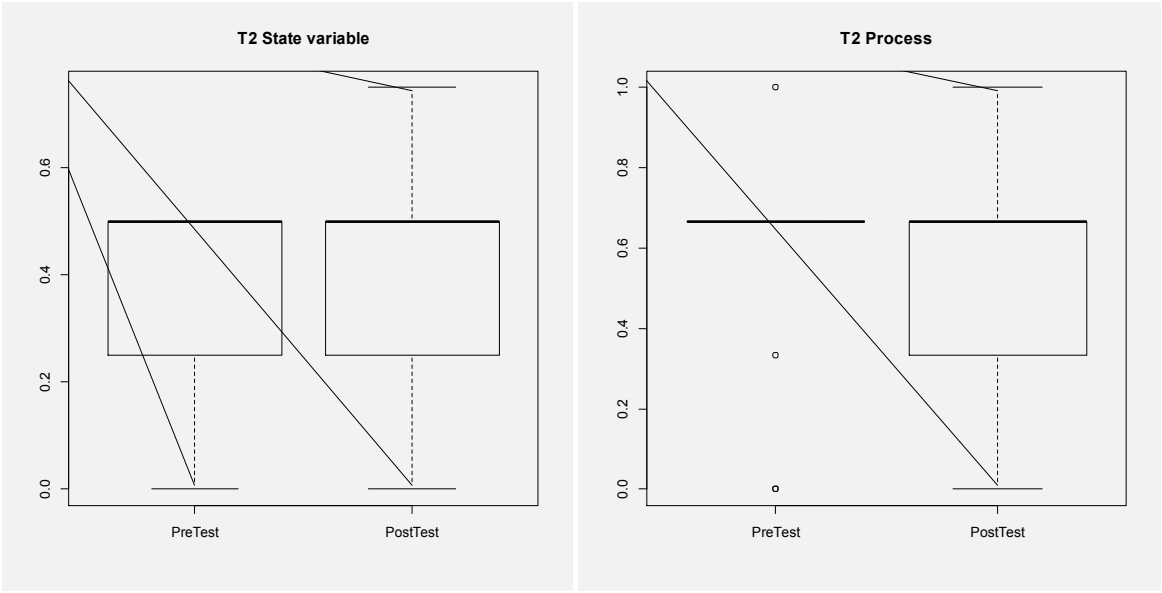


Table 5 Wilcoxon test for significant (p-value)

Pre-test 1 T2 and Pre-test 2 T2	p
Key concept	0.1297
Entity	0.4954
State variable	0.782
Process	0.7057



a) b)



c) d)

Figure 3 Boxplots with the result from pre- and post-tests: a) Key concept, b) Entity, c) State variable, d) Process.

2.2.3.3. Research Question 3: Pre-test 2 T2> Post- Test 2 T2

The post-test about urbanisation was given to the students after modeling activity with this topic. The task for the student was to built a model about invasive and native species in LS4 which was known topic for them. The goals of building the model with the known topic was to give time to the students to adapt working with LS4. After that they had to start modeling session with urbanisation model. The result was not significant (See Table 6 and Figure 4).

RQ3. Does modeling of an unknown topic teach analytical skills?

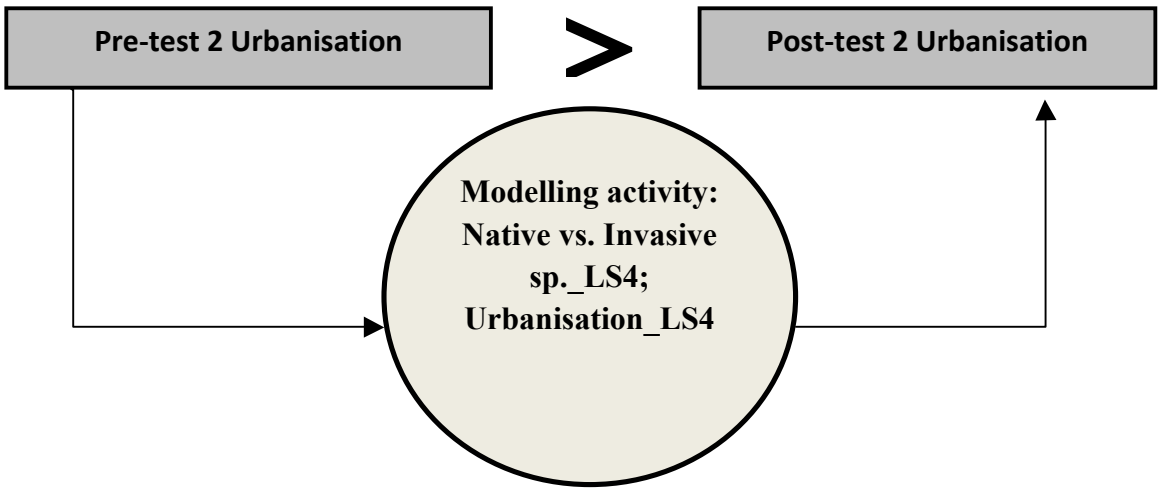
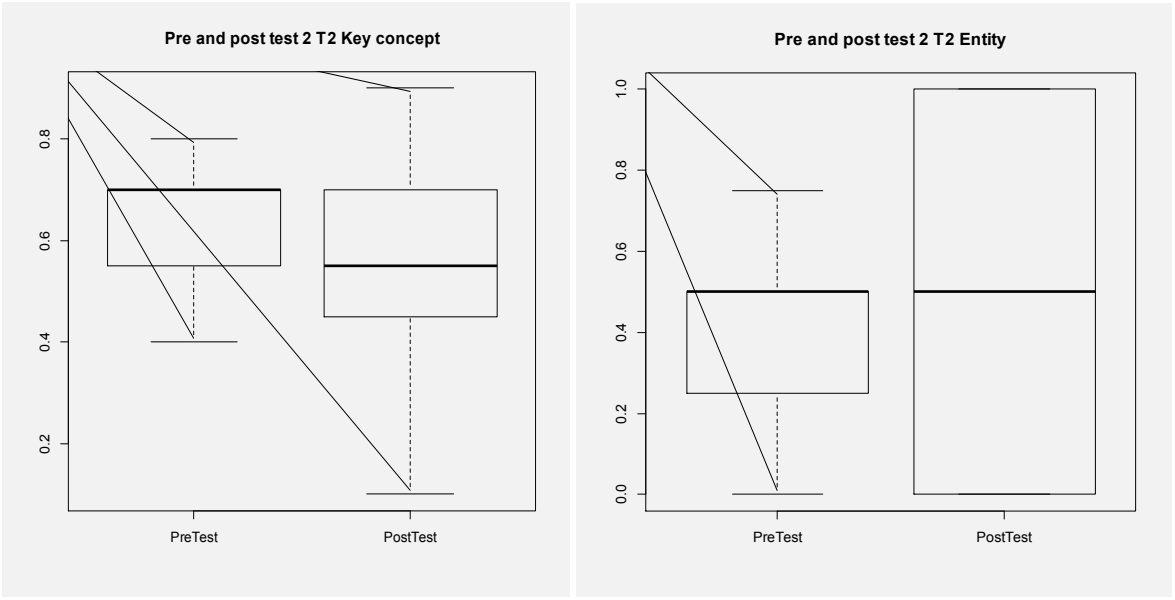
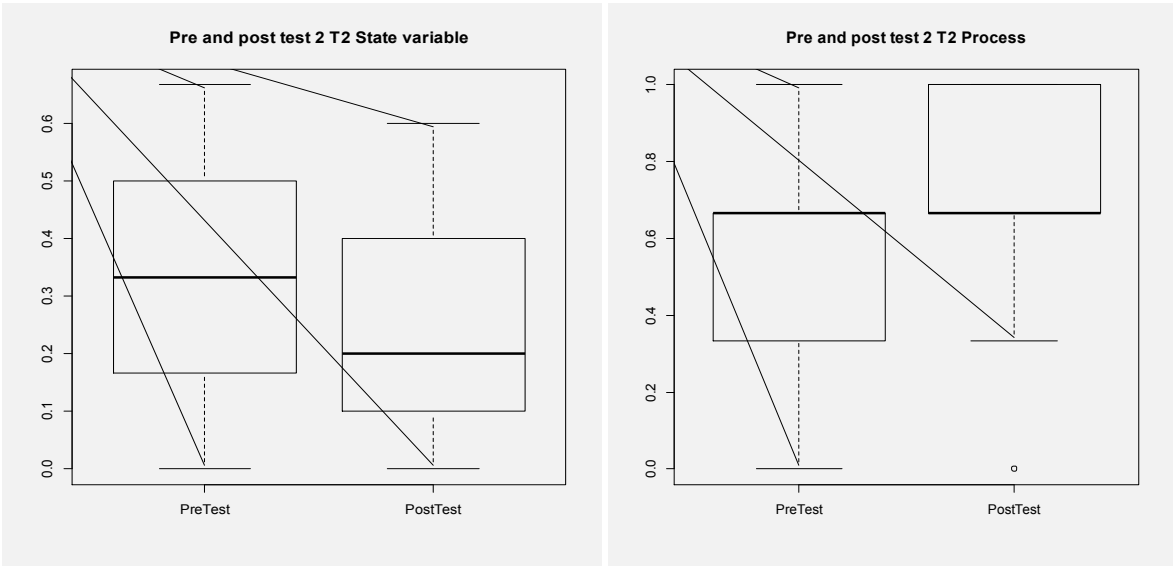


Table 6 Wilcoxon test for significant (p-value)

Pre-test 2 T2 and Post-test 2 T2	p
Key concept	0.01309
Entity	0.1591
State variable	0.1297
Process	0.02899



a) b)



c) d)

Figure 6 Boxplots with the result from pre- and post-tests: a) Key concept, b) Entity, c) State variable, d) Process.

The significant result was observed with the key concepts and processes. The reason for the better result during the post-test could be the long interaction with DynaLearn.

The initial data form all the students are given in Appendix C.

3. Discussion

An experiment was designed to measure the learning of analytical skills by students through modeling. The experiment consisted of two modeling sessions in which students developed models about biodiversity and urbanisation. Before each modeling session, the students filled in a pre-test and afterwards they completed a post-test about the topic they were modeling. The results of the experiment were analyzed using the Wilcoxon signed-rank test implemented in the software package R.

The results of the studies described in this document indicate that the development of better reasoning skills need of more time than was available in the current settings.

Motivational aspect

The answers given by the students indicate that they found it an interesting and challenging activity and some of them indicated that they found modeling a motivating activity.

- Learning by Modelling.

- Most of the students think that working with DynaLearn is interesting way to learning.
- Their opinion was that learning with DL also requires continuing teacher support.
- The students think that is helpful to start first with LS2 and then move to LS4 instead to starting directly at LS4.
- The students indicated that DynaLearn software is easy to use.

- Simulation

- For most of the students the simulation results were interesting and also provided them better understanding of the behavior of the system.
- Building the model seemed easy for the students, but checking where their mistakes are and why the model does not work was difficult.
- Defining the correct relations (Is or Ps) between the quantities was not so easy task.

- Motivation

- For all questions in the motivation part of the questionnaire, the students gave very positive answers.
- Students report that they understand the topics better.
- Students' perception on science and modeling is unchanged.

Statements about models and modeling

The big change in students' opinion was not observed. It seems that for students to capturing the views about modeling and models and the added value of working with DL it was already known. It seems especially interesting with students that they are already in a science track.

For the students was interesting to fill out this statements and to explain why they thinks this. This questionnaire was filling out from the students two times (in the beginning and at the end of the course). The main idea was to capturing student views about modeling and models after working with DynaLearn. The answers of the students are shown in Appendix B.

Pre- and Post- test results

The statistical analysis shows inconsistent results. In most cases (8 out of 12), no significant result was found. In 3 of the 12 cases, the students significantly underperformed on the post-test compared to the pre-test. In 1 of the 12 cases, the students performed better significantly in the post-test compared to the pre-test.

It is not possible to draw conclusions about the statistically insignificant results. It could be that there is really no effect, or that the number of students is too small, or that the interaction time is too short to see an effect.

The significant results pose a challenge in the analysis. We found more significant results than would be expected by chance. Given a P-value of 0.05, expect a significant result by chance once in every 20 comparisons. In our results, we see 4 significant results in 16 comparisons, which are more than expected by chance alone. Those results are contradictory, as in 3 cases the students seems to have decreased in performance, while in 1 case the students seem to have increased.

It is not possible to draw strong conclusions with these results. It seems that the students are changing their mind with regard to how to classify different concepts. There could be an initial confusion which results in poorer performance before students fully gain the analytical skills which are being taught. This could be the reason that in the final test, the students perform better.

In order to draw stronger conclusions, more experiments are needed with longer interaction time with the students (and preferably larger groups). Our expectation is that with more time, the confusion effect will disappear and their results will improve. However, more research is needed in order to test this hypothesis.

4. Conclusion

Our overall conclusions on the experiments are that interaction with DynaLearn strongly motivates the students. Moreover, students reported that they have gained a better understanding of the topics that they have modeled. However, in our experiments we have not observed this better understanding in the results of the students. In 3 of the 4 significant results, the students actually performed poorer. We expected that the short interaction time was the main cause of this confusion. The fact that the last post-test showed an improved understanding seems to support this expectation. However, for more conclusive evidence more research is needed with longer interaction times.

References

[1] Bredeweg, B. *et al.* (2008a) DynaLearn – Engaging and informed tools for learning conceptual system knowledge. DynaLearn, EC FP7, STREP Project no. 231526, Description of Work (DOW). [2]

[2] Mioduser, D., Salles, P., Noble, R., Zitek, A., Benayahu, Y., Zurel, D., Leiba, M., Zuzovsky, R. and Nachmias, R. 2010. *Lessons and assignment schemata*. DynaLearn, EC FP7 STREP project 231526, Deliverable D7.1.

[3] Salles, P., Pedro Assumpção Costa e Silva, Isabella Gontijo de Sá, Richard Noble, Andreas Zitek, Yordan Uzunov, and Davi Mioduser, (2009), D6.1 DynaLearn environmental science curriculum requirements.

Appendix A Motivation questionnaire

Learning by Modeling

To what extent do you agree:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. The process of modeling motivated me to learn more about the phenomena.					
2. Learning with software requires continuing teacher support.					
3. The software enables me to learn by myself.					
The DL approach as presented during the last days represents a new and interesting way of learning 5. If it was helpful for them to start with LS2 and then move to LS4 instead of starting directly at LS4? 6. Whether they think that it might have been more helpful to start the Urbanization also with LS2?					

2. Learning Spaces in DynaLearn

Which of the learning spaces contribute mostly to achieve the following aims:

Mark with a "x" all relevant Learning Spaces	LS1	LS2	LS3	LS4		
Learning about the structure and components of an environmental system.						
Representing the relationships between active factors in the system.						
Understanding the behavior of the system.						

Simulations in DynaLearn

Which of the learning possibilities of simulations contribute mostly to your understanding?

To what extent do you agree:	Strongly	Disagree	Neutral	Agree	Strongly

	Disagree				Agree
The possibility to run simulations motivated me to build a model.					
Seeing the simulation results provide me with a better understanding of the system behaviour					
Inspecting the simulation path and the values of the quantities helped me to understand the changes in the system.					
I liked the possibility run simulations.					
Why did you like the simulations? Please, explain your answer to item 4.					

Ease in Using the Software

I found easy to use DL	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Identifying and describing "entities" in the system.					
Defining quantities.					
Identifying and representing positive and negative causal relations in the system.					
Defining processes and rates.					
Running simulations and identifying relevant paths that appear in the simulation.					
Interacting with the interface and using the features of the software.					
What were the most complicated things when you used DynaLearn? Please describe					

Motivation

Motivation					
What is your general opinion about the course	**Very bad** 1 2 3 4 5 **Very good**				

and learning activity we had together?	
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**
How did you experiencing the work with the DynaLearn software – boring or interesting?	**Very boring** 1 2 3 4 5 **Very interesting**
How do you evaluate your understanding of the problem after exploring the topic in DynaLearn?	**I am very much confused** 1 2 3 4 5 **I understand much better now**
How do you evaluate the importance of building models in different specific use-level of DynaLearn for your understanding?	**Very little importance** 1 2 3 4 5 **Very important**

Results of the students in Sofia Mathematic High School

Part I. Learning by Modelling

Learning by Modeling	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**
1. The process of modeling motivated me to learn more about the phenomena.	SA	A	A	A	SA	A	A	SA	SA	SA	A
2. Learning with software requires continuing teacher support.	A	A	SA	SA	A	A	A	A	A	A	A
3. The software enables me to learn by myself.	A	A	SA	A	A	A	N	A	A	A	A
4. The DL approach as presented during the last days represents a new and interesting way of learning	SA	A	N	SA	SA	SA	A	A	SA	SA	SA

Legend: **SA**-*Strongly agree*, **A**-*Agree; S1, S2, S3…….S11 – Student 1, Student 2 etc.*

Part II. Learning Spaces

Learning Space	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**
I. Which of the learning spaces contribute mostly to achieve the following aims:											
1. Learning about	LS2	LS1	LS1	LS1	LS2	LS2	LS1	LS1	LS4	LS4	LS4

the structure and components of an environmental system.											
2. Representing the relationships between active factors in the system.	LS4	LS3	LS4	LS3	LS4	LS3	LS2	LS3	LS4	LS4	LS1
3. Understanding the behavior of the system.	LS4	LS4	LS4	LS4	LS4	LS4	LS4	LS2	LS4	LS4	LS4
4. Do you think that it might have been helpful to start with LS2 and then move to LS4 instead to starting directly at LS4?	Yes		Yes	No. I prefer to start with LS4. The Is and Ps helps a lot to understand the relations. The model is much more interesting.	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Part III. Simulation

Simulations in DynaLearn	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**
1. The possibility to run simulations motivated me to build a model.	A	A	SA	A	A	SA	A	A	A	SA	A
2. Seeing the simulation results provide me with a better understanding of the system behaviour	SA	A	SA	SA	SA	SA	A	N	SA	A	A
3. Inspecting the simulation path and the values of the quantities helped me to understand the changes in the system.	SA	A	A	A	SA	A	A	N	SA	S	A
4. I liked the possibility run simulations.	SA	A	SA	D	A	SA	A	N	A	SA	A

Legend: **SA**-*Strongly agree*, **A**-*Agree*, **N**-*Neutral*

5. Why did you like the simulations? Please, explain your answer to item 4.

S1 Looking the simulation result we can find our mistakes and improve the model.

S2 No answer

S3 For me was interesting to see all possible paths and how I achieve them. You can see where are your mistake and to improve the model. This need to more thinking!

S4 No answer

S5 Simulation result give me information about where is possible to make a mistake. Sometimes suggest me what else I can put in the model to be understandable and helpful.

S6 Building the model is not enough to me. The simulation gives me opportunity to see how one thing influence on other one. If the result is bad (in our case loss of biodiversity) then we can take decision how we can solve this problem. Solution of the problem with DL is very interesting to me.

S7 No answer

S8 In general working with DL is helpful and can be useful additional skills. The problem is if you do not understand some phenomena, then I think is impossible to build the model. Maybe if start to build something which you do not understand you can learn this during the building process.....I think the solution of the problem is obvious and building the model is not necessary.

S9 Simulation result helps me, because I start to think deeper about some problem. Now I want to know more things, more details. For example the model which I build about Urbanisation makes me think more about the problem with pollution. It is my faults that nature is so pollutant. I will make effort to decrease this.

S10 Simulation result make me think more and show me where I can found my mistakes

S11 Help me to understand the result.

Part IV. Difficult using the DynaLearn

Difficult Using the Software	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
1. Identifying and describing "entities" in the system.	WP	VE	VE	VE	VE	VE	WP	VE	D	D	E
2. Defining quantities.	E	VE	E	WP	E	VE	WP	VE	E	E	D
3. Identifying and representing positive and negative causal relations in the system.	VE	VE	VE	VE	E	E	D	E	D	D	D
4. Defining processes and rates.	E	VE	E	E	D	E	WP	VE	E	D	E
5. Running simulations and identifying relevant paths that appears in the simulation.	VE	E	VE	E	D	D	D	D	E	E	D
6. Interacting with the interface and using the features of the software.	VE	E	VE	E	VE	VE	D	WP	E	E	D

Legend: **VE**- *Very easy*, **E**- *Easy*, **WP**- *Without problem*, **D**- *Difficult*

7. What were the most complicated things when you used DynaLearn? Please describe.

- **S1** This course was easy to me. I have not problems with founding the main ingredients: entities, quantities etc.

- **S3** Create a quantities is difficult.
- **S4** In general work with DynaLearn is easy, but I had some difficulty. Building the model was easy to me, but check where are my mistakes and why my model does not work was very difficult.
- **S5** To define the relations between the quantities.
- **S6** To find and to define the entities, quantities ets was easy, but the difficult part is to connect these ingredients logistic.
- **S7** The simulation result is difficult to understand.
- **S8** Simulation. For me is more easy to make model on the paper with pen and then to think about it
- **S9** In the beginning was difficult to find the entity and quantity, especially how they related between them. In the end of the course for me is not difficult to do this.
- **S10** Choosing entity is difficult task. You need of knowledge on the problem to do that.
- **S11** Most difficult part was to choose Is or Ps. This needs of a lot of knowledge.

Part V. Personal opinion/Motivation

Personal opinion/Motivation	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**
1. What is your general opinion about the course and learning activity we had together?	5	4	4	5	5	5	5	4	5	5	4
2. What is your general opinion about the modelling approach you used to develop this educational activity?	5	4	4	5	5	5	5	3	4	4	4
3. How did you experiencing the work with the DynaLearn software – boring or interesting?	5	3	5	4	5	5	4	3	5	5	2
4. How do you evaluate your understanding of the problem about loss of biodiversity after exploring the topic in DynaLearn?	4	4	4	5	5	5	4	5	4	4	3
5. How do you evaluate your understanding of the problem about loss of urbanisation after exploring the topic in DynaLearn?	4	4	4	5	5	5	4	5	5	4	4
5. How do you evaluate the importance of building models in different specific learning spaces of DynaLearn for your understanding	4	4	4	4	5	5	4	2	5	5	4

about loss of biodiversity?											
6. How do you evaluate the importance of building models in different specific learning spaces of DynaLearn for your understanding about urbanisation?	4	4	4	4	5	5	4	2	5	5	4

Legend:

- Q1. Very bad 1 2 3 4 5 Very good
- Q2. Very difficult 1 2 3 4 5 Very easy
- Q3. Very boring 1 2 3 4 5 Very interesting
- Q4. I am very much confused 1 2 3 4 5 I understand much better now
- Q5. Very little importance 1 2 3 4 5 Very important

Panagyurishte Professional High School

Part I. Learning by Modelling

Learning by Modeling	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**
1. The process of modeling motivated me to learn more about the phenomena.	A	A	N	SA	A	A	A
2. Learning with software requires continuing teacher support.	N	N	SA	A	A	SD	A
3. The software enables me to learn by myself.	A	A	SD	N	A	A	SA
4. The DL approach as presented during the last days represents a new and interesting way of learning	SA	SA	SA	A	SA	SA	SA

Legend: SA-*Strongly agree*, A-*Agree*, N-*Neutral*, SD-*Strongly disagree*

Part II. Learning Spaces

Learning Space	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**
I. Which of the learning spaces contribute mostly to achieve the following aims:							
1. Learning about the structure and components of an environmental system.	LS2	LS2	LS1	LS1	LS4	LS2	LS2
2. Representing the relationships between active factors in the system.	LS4	LS4	LSS4	LS4	LS2	LS4	LS2

3. Understanding the behavior of the system.	LS4	LS4	LS1	LS3/4	LS2	LS2	LS4
4. Do you think that it might have been helpful to start with LS2 and then move to LS4 instead to starting directly at LS4?				LS4	LS2	LS2	

Part III. Simulation

Simulations in DynaLearn	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**
1. The possibility to run simulations motivated me to build a model.	A	A	SA	A	A	A	A
2. Seeing the simulation results provide me with a better understanding of the system behaviour	A	SA	SA	N	N	A	SA
3. Inspecting the simulation path and the values of the quantities helped me to understand the changes in the system.	SA	A	A	SA	A	SA	SA
4. I liked the possibility run simulations.	A	A	A	SA	A	A	A

Legend: SA-*Strongly agree*, A-*Agree*, N-*Neutral*

5. Why did you like the simulations? Please, explain your answer to item 4.

- S1 Simulation helps me to understand the result.
- S2 It is fun to looking on the simulation result.
- S3 If you give me homework I will be able to make this alone.
- S5 I like it!
- S6 I like when I see result for my effort.
- S7 For each model I have different simulation result. I like to see them and to try to understand them.

Part IV. Difficulty using the DynaLearn

Difficulty Using the Software	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**
1. Identifying and describing "entities" in the system.	VD	D	D	VE	D	WP	
2. Defining quantities.	VD	D	WP	E	WP	E	D
3. Identifying and representing positive and negative causal relations in the system.	WP	E	VD	D	E	VE	VE
4. Defining processes and rates.	WP	WP	E	VD	WP	WP	E
5. Running simulations and identifying relevant paths that appears in the simulation.	WP	D	WP	VD	VE	E	D
6. Interacting with the interface and using the features of the	E	E	D	VD	D	WP	WP

software.							

Legend: VE- *Very easy*, E- *Easy*, WP- *Without problem*, D- *Difficult*, VD-*Very difficult*

7. What were the most complicated things when you used DynaLearn? Please describe

- S1 In the beginning is difficult to define the key concepts. DynaLearn is very interesting and helps to learning. If we work more hours then everything will be easy.
- S2 Nothing is difficult. Just we need of more time (not only few hours)
- S3 Everything is easy if someone explain in understandable way.
- S5 To make distinguish between entity and quantity.
- S6 The most difficult part was adding the information in the beginning. Just I need of more time.
- S7 To understand the simulation.

Part V. Personal opinion/Motivation

Personal opinion/Motivation	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**
1. What is your general opinion about the course and learning activity we had together?	5	5	5	4	5	5	5
2. What is your general opinion about the modelling approach you used to develop this educational activity?	5	4	3	5	5	5	4
3. How did you experiencing the work with the DynaLearn software – boring or interesting?	5	5	5	4	5	5	5
4. How do you evaluate your understanding of the problem about loss of biodiversity after exploring the topic in DynaLearn?	4	4	5	4	5	5	4
5. How do you evaluate the importance of building models in different specific learning spaces of DynaLearn for your understanding about loss of biodiversity?	5	4	5	4	5	5	5

Legend:

- Q1. Very bad 1 2 3 4 5 Very good
- Q2. Very difficult 1 2 3 4 5 Very easy
- Q3. Very boring 1 2 3 4 5 Very interesting
- Q4. I am very much confused 1 2 3 4 5 I understand much better now
- Q5. Very little importance 1 2 3 4 5 Very important

Appendix B Statements about models and modelling

TASK Please mark with an X for each statement whether it is true or not and explain your choice.

N	STATEMENTS	YES	NO
1	A model can capture the structure of something, but not processes.		
2	A scientist uses a model as a last resource, when all other options cannot be used.		
3	Building models is actually the essence of a scientist work.		
4	Much of the scientist work is to modify models according to his research goals.		
5	A model is better if it resembles the real world as much as possible.		
6	There might be different models for the same phenomenon.		
7	A model is better when it can be used for describing as many things as possible that are related to the phenomenon.		
8	Models can be used only to describe the scientist's current knowledge and not for learning new things.		
9	While simulating (executing/running) a model a scientist might learn things s/he did not know before.		
10	The results of the simulations might bring a scientist to rethink and change his theory.		
11	Models are used by scientists to communicate, share ideas and collaborate with other scientists.		
12	Scientists construct models only when they know a lot about the phenomenon, not in order to explore a phenomenon and learn more about it.		
13	A model constructed for one topic can be used to explain a phenomenon related to another topic/discipline.		
14	A model constructed for a biology phenomenon can be used to predict outcomes of a phenomenon in another discipline.		

ANSWERS

Q1. A model can capture the structure of something, but not processes.

PRE-TEST

Q1. The process can be show in model (S15)

Q1. The model shows the structure and the result from interaction. (S2)

Q1. For each process build his structure. (S8)

Q1. Both structure and process can be illustrated in one model. (S2p)

Q1. I think it is impossible to show process in one model, only the structure. (S5p)

Q1. Of course with model we can show a process. (S7p)

POST-TEST

Q1. The main goals of the model are to represent the process. (S5)

Q1-14. Although, my opinion is the same as previous time, after the course and work with DynaLearn now I know a lot about modelling. I know how can I make a model, how can I used it and how this model will help me. Also I'm mathematics student, so I'll use this model skill in this field. (S6)

Q1. Well, after modeling activity I saw that is posible to show the process as well. (S12)

Q2. A scientist uses a model as a last resource, when all other options cannot be used.

PRE-TEST

Q2. The scientists like to use the facts to explain some phenomena, but at the end they used models (S15)

Q2. The scientists used the models to show easy the processes (S1).

Q2. The model show clear phenomena (S2)

Q2. The scientists used model to explain some phenomena to people without mathematical/ quantitative thinking. (S5)

Q2. The models are clear way to present difficult to understand process (S8)

Q2. I think the scientists should start with building a model. Building the models is innovative, interesting and understandable way to show some new (or old) information. (S2p)

Q2. I think the models can be incredibly useful for scientists. (S7p)

POST-TEST

Q2. Starting with build the model is essential. Then we have knowledge about the problem. (S5)

Q3. Building models is actually the essence of a scientist work.

PRE-TEST

Q3. I think all scientists should use models (S15)

Q3. It is not necessary to used the model. (S1)

Q3. I think have to have scientists only who build model. (S2)

Q3. Using the models is better to learn the process. (S3)

Q3. I think scientist need to know to explain the phenomenon, not to build the model. (S5)

Q3. More changes in one model - more understandable. (S7)

POST-TEST

Q3. To be understandable the scientists have to show their result in qualitative way. (S15)

Q3. I think building the model is only one way to be understandable the scientists' experiments. (S8)

Q4. Much of the scientist work is to modify models according to his research goals.

PRE-TEST

Q4. If we change some model, then we have to be able to explain it (S15)

Q4. I cannot give explanation (S1)

Q4. YES (S2p)

Q4. I think it is better to create our own model for our goals, not using already existing model. (S5p)

POST-TEST

Q4. The model follow the logic thinking of the scientists. If they doing wrong things this will have effect also in their main work and in their model (S12)

Q5. A model is better if it resembles the real world as much as possible.

PRE-TEST

Q5. Fully agree! (S1)

Q5. If the model describe the reality (not hypothetical), then is clear and correct (S2p)

POST-TEST

Q6. There might be different models for the same phenomenon

PRE-TEST

Q6. Making a different models from different people give the different view point on one thing (15)

Q6. Everyone can present the same phenomena in your own way, correctly (S1)

Q6. I think is better if for one phenomenon existing more than one model, but with different perspectives. (S7p)

POST-TEST

Q7. A model is better when it can be used for describing as many things as possible that are related to the phenomenon.

PRE-TEST

Q7. In my opinion, focus on only one aspect can make the model better compare with present of many aspects (15)

Q7. More aspects and ingredients- more correct model. It is better to make universal model. (S1)

Q7. More hole model -more aspects (S2)

Q7. The model is better when used more aspects and details, but is not understandable for everyone. (S3)

POST-TEST

Q8. Models can be used only to describe the scientist's current knowledge and not for learning new things

PRE-TEST

Q8. I think the model should show new things, not already know knowledge (15)

Q8. I learn better new thing when I make a model. It is so easy. (S1)

Q8. It is possible one model to show new aspects, new knowledge (S2)

Q8. Adding a new knowledge in our old model is useful. (S7)

Q8. When we searching information which allows us to build the model, then our knowledge increase a lot. (S2p)

POST-TEST

Q8. We make a model to predict and to learn new things. (S8)

Q9/10. Sometimes a lot of information and data make us blind to see our mistakes. The model easy can show us where we make mistake. (S8)

Q8. To build the model we need of a lot of knowledge. (S12)

Q9. While simulating (executing/running) a model a scientist might learn things s/he did not know before

PRE-TEST

Q9. Of course! Always can happen something which we do not expect. Actually in 90 % this is valid. Typical example is Edison! (S1)

Q9. Model can give you new knowledge. (S2)

Q9. Simulation can show us things which are not so obvious. (S2p)

POST-TEST

Q9/10. Simulation result shows us where we make a mistake. Also this result gives us multiple options to take a decision. (S12)

Q10. The results of the simulations might bring a scientist to rethink and change his theory

PRE-TEST

Q10. The simulation gives chance to the modeller to change the final result. Also before simulation we do not know which result we will get (S15)

Q10. YES! Depend on the result the modeller can rethink his/her model, and even to improved it. (S1)

POST-TEST

Q11. Models are used by scientists to communicate, share ideas and collaborate with other scientists

PRE-TEST

Q11. I'm agree, because through models the scientists can communicate easy and to show their different opinion and point of view (S15)

Q11. Really understandable and easy. (S1)

Q11. The models are easy way to change the information between people from different scientific areas and culture. (S3)

POST-TEST

Q11. Yes, one model can be universal way for communication. (S3)

Q12. Scientists construct models only when they know a lot about the phenomenon, not in order to explore a phenomenon and learn more about it

PRE-TEST

Q12. When you start to build the model, you can learn what else you need. Just the model will show you (S15)

Q12. Mendeleev made his conclusion even that he does not know how he order them. (S1)

Q12. Model= Algorithm (S4)

POST-TEST

Q12. During the modelling we get new knowledge. (S12)

Q13. A model constructed for one topic can be used to explain a phenomenon related to another topic/discipline

PRE-TEST

Q13. Everything is related with everything. Interdisciplinary. (S15)

Q13. It is possible, but we need of more general model. (S1)

Q13. The model is creating to explain only one thing. If explain more-then is not clear. (S5p)

POST-TEST

Q14. A model constructed for a biology phenomenon can be used to predict outcomes of a phenomenon in another discipline

PRE-TEST

Q14. Yes, but after many experiments which shows that is true. (S1)

POST-TEST

Appendix C Pre- and Post- tests

Initial data in percentage (%) with the results of the students in SMHS

Test	Topic	Types/Students	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Pre-test 1	*Biodiversity*	Key concepts	80	90	100	90	70	70	60	80	80	80	60	60	80	90	90	x
		Entity	33.3	66.7	100	66.7	66.7	0	66.7	0	66.7	66.7	0	0	0	66.7	66.7	x
		State variable	0	100	100	75	100	25	50	25	75	75	75	75	75	75	75	x
		Process	66.7	33.3	100	66.7	33.3	33.3	33.3	100	66.7	66.7	66.7	66.7	66.7	66.7	66.7	x
	Urbanisation	Key concepts	50	80	60	80	60	70	70	80	80	60	80	80	70	80	80	x
		Entity	33.3	66.7	66.7	66.7	0	0	66.7	66.7	66.7	33.3	33.3	33.3	33.3	66.7	66.7	x
		State variable	25	50	50	50	50	50	50	50	25	50	50	50	25	50	25	x
		Process	33.3	66.7	66.7	66.7	66.7	66.7	66.7	66.7	66.7	0	66.7	66.7	66.7	66.7	66.7	x
Post-test 1	*Biodiversity*	Key concepts	x	50	80	60	60	80	x	60	x	x	x	90	80	70	60	90
		Entity	x	66.7	33.3	33.3	33.3	66.7	x	66.7	x	x	x	66.7	66.7	33.3	33.3	66.7
		State variable	x	25	75	50	25	75	x	25	x	x	x	75	75	25	50	75
		Process	x	0	66.7	33.3	33.3	33.3	x	0	x	x	x	100	33.3	33.3	33.3	66.7
Pre-test 2	*Urbanisation*	Key concepts	x	60	70	x	60	80	x	80	x	x	x	70	70	70	70	80
		Entity	x	50	50	x	50	50	x	50	x	x	x	75	25	50	50	50
		State variable	x	33.3	66.7	x	33.3	66.7	x	66.7	x	x	x	0	33.3	33.3	66.6	33.3
		Process	x	66.7	66.7	x	66.7	66.7	x	100	x	x	x	100	66.7	66.7	33.3	66.7
Post-test 2	*Urbanisation*	Key concepts	x	10	70	50	60	70	x	70	x	x	x	90	50	60	70	70
		Entity	x	0	100	100	100	50	x	50	x	x	x	100	50	100	100	100
		State variable	x	0	40	20	40	40	x	20	x	x	x	60	20	40	40	40
		Process	x	33.3	100	33.3	66.7	100	x	66.7	x	x	x	100	66.7	100	100	100

Legend:

x - miss the results
Only Pre-test 1
Full tests
Only Post-test 1,2, and Pre-test 2
Students with missing pre-test 2

Initial data in percentage (%) with the results of the students in PHS

Test	Topic	Types/Students	1	2	3	4	5	6	7	Average
Pre-test 1	*Biodiversity*	Key concepts	70	80	80	70	50	70	70	70
		Entity	66.7	66.7	66.7	33.3	33.3	33.3	0	42.86
		State variable	75	75	75	75	0	100	25	60.7
		Process	33.3	66.7	66.7	66.7	66.7	33.3	33.3	52.39
	Urbanisation	Key concepts	60	70	40	70	60	70	60	61.43
		Entity	66.7	66.7	33.3	66.7	66.7	33.3	33.3	61.43
		State variable	25	50	0	50	50	50	25	35.7
		Process	66.7	100	66.7	0	0	66.7	33.3	47.6
Post-test 1	*Biodiversity*	Key concepts	70	80	50	80	80	70	80	72.9
		Entity	33.3	66.7	33.3	66.7	66.7	66.7	66.7	57
		State variable	0	25	0	25	0	50	75	25
		Process	0	33.3	0	66.7	33.3	33.3	33.3	28.6
Pre-test 2	*Urbanisation*	Key concepts	50	50	40	70	50	70	80	58.6
		Entity	25	0	25	25	50	20	75	31.4
		State variable	33.3	0	33.3	33.3	0	0	33.3	19
		Process	33.3	0	33.3	0	33.3	66.7	66.7	33.3
Post-test 2	*Urbanisation*	Key concepts	30	30	50	60	50	40	50	44.3
		Entity	0	0	0	0	100	0	100	28.6
		State variable	0	0	20	40	20	0	20	14.3
		Process	33.3	0	100	100	66.7	66.7	66.7	62

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