Analyzing Students’ Shared Activity while Modeling a Biological Process in a Computer-Supported Educational Environment

Marida Ergazaki, Vasso Zogza & Vassilis Komis
University of Patras, Greece
Introduction to the study

- This study aims at highlighting the shared activity of two high school students modeling the complex biological process of plant growth in the computer-supported educational environment ‘ModelsCreator’

- Our focus is set on how the collaborating students are engaged in the computer-supported modeling activity

- Our analysis concerns the process of collaboratively creating a plant growth model in the environment of ‘ModelsCreator’, as well as a biological aspect of this process
Theoretical background

- In the framework of social constructivism, investigating students’ mental models is an essential element for teaching and learning.

- Science education research is interested in identifying those elements within students’ descriptive or explanatory constructs about natural word, that possibly raise epistemic and cognitive obstacles towards the construction of scientific models.

- Thus, science education researchers explore students’ expressed models before attempting to elaborate, transform or radically re-construct them in appropriately designed educational environments.
Theoretical background

- Research on students’ mental models about photosynthesis & plant nutrition has revealed a series of cognitive obstacles some of which derive from applying the animal model of ‘heterotrophic nutrition’ to plants.

- Not grasping ‘food’ as a source of energy and building blocks for growth and maintenance to life, students frequently identify ‘minerals’, ‘oxygen’, ‘carbon dioxide’, ‘water’ as plants’ food mainly on the basis of their environmental origin.

- Sunlight is understood in terms of ‘heat’ which is vital to all living things and not in terms of ‘light energy’ which only plants can make available to all living things by transforming it into ‘chemical energy’.

- ‘Air’, ‘soil’ and ‘chemical reaction’ are also conceptually problematic. It is difficult for students to think of an unobservable gas and a liquid within the ‘solid’ and ‘compact’ soil as taking part in the photosynthetic mechanism of the plant to finally become plants’ ‘food’.
Theoretical background

- In the perspective of the didactical use of students’ mental models about natural world, researchers need insights to them.

- Computer-supported dynamic modeling is one of the probing -as well as learning- techniques and it is often employed in collaborative settings.

- Mediating students’ collaborative activity on expressing, negotiating and elaborating their own mental models, dynamic modeling becomes a significant parameter of the collaborative activity itself.

- The ‘activity-theory’ provides a powerful theoretical framework for studying the peers’ shared activity by analysing it on the low level of basic, tool- and context-bound operations which subsequently shape higher level cognitive actions.
Theoretical background

- In this study peers are collaboratively engaged in dynamic modeling within the environment of ‘ModelsCreator’.

- This belongs to a special category of computer-supported tools that allow for semi-quantitative modeling in order to facilitate students’ gradual shift from the spontaneously expressed qualitative reasoning to the much more demanding mathematically-informed reasoning.

- Within ‘ModelsCreator’ students may create models that represent processes and phenomena of the natural world, explore their behaviour in the perspective of refining them and also explore the limits of their validity with testing tools like simulations, bar charts, graphs or tables.
Objectives & Research Questions

- The objective of the study is to highlight the ways in which the collaborating students are engaged in the computer-supported modeling activity in the context of the biological process of plant growth.

- The research question addressed is
  - ‘How do collaborating students construct their plant growth model in the computer-supported educational environment of ‘ModelsCreator’?’

- More specifically
  - In which cognitive actions are they engaged and how?
  - Do they seem to follow a modeling pattern shaped by these actions?
  - On which level do they prefer to reason when modeling plant growth?
    - the macro-phenomenological level of environmental factors or the micro-conceptual level of photosynthesis, food and energy?
  - Do they shift between levels to meaningfully integrate photosynthesis in the context of plant growth or not?
Methodology: The setting

- The case study takes place in the lab with two 14-year old female high school students collaborating on a plant growth modeling task in the computer-supported educational environment ‘ModelsCreator’

- After a 10-minute demonstration of ‘ModelsCreator’, peers are asked to
  - ‘create a model that describes the environmental factors interfering with plant growth and also explains the way in which each of them does so’

- The collaborative activity is carried out in the presence of a facilitator providing technical and cognitive support when necessary

- The students have already been lectured on photosynthesis and plant growth at school, since these topics are included in their syllabus
Methodology: The setting

- ‘ModelsCreator’ provides students with a set of 5 *objects*, each having a subset of *properties*:
  - PLANT: growth / food / energy
  - SOIL: water / minerals
  - SUN: light / warmth
  - AIR: oxygen / carbon dioxide
  - LEAF: carbon dioxide / water / photosynthesis / glucose / oxygen

- Students are also provided with a set of *semi-quantitative relationships* (i.e. ‘increases-increases’, ‘increases-decreases’ or ‘increases-increases less’) upon which they draw to define the *inter-connections* of the given structural elements in a more systematic manner.
Methodology: The setting

The interface of ‘ModelsCreator’
Methodology: The setting

- An inter-connection of soil water and plant growth may be tagged with a purely qualitative verbal description:
  - ‘the water contributes to plant growth’

- A relationship selected from the set within ‘ModelsCreator’ necessarily involves a more ‘mathematically’-informed description:
  - ‘there must be plenty of water available in the soil, to have plenty of plant growth taking place’

- Peers create their model by
  - selecting objects and moving them in the working space
  - selecting properties for each object
  - connecting the properties with relationships selected from the give set

- The activity is videotaped and the collected data concern
  - peers’ discourse, the software-generated log-file and peers’ final model
Methodology: The analytic tool

- The analysis of the modeling process is carried out with a two-level analytic tool.

- The tool has been derived in the theoretical framework of ‘activity theory’ by refining the OCAF scheme for basic modeling operations (Avouris et al., 2003) and merging it with an elaborated version of the scheme of Stratford et al. (1998) for cognitive strategies in modeling.

- This makes possible for us not only to monitor the basic operations that peers perform (i.e. proposing, justifying, challenging or manipulating objects, properties and relationships), but also to reconstruct the higher-order cognitive actions characterizing the modeling process (i.e. analysis, synthesis, test-interpretation).
Methodology: The analytic tool

- The analytic scheme is consisted of 57 categories that fully describe peers’ *lower-order* modeling operations - verbal or practical.

- These can be categorized in 4 major groups according to the cognitive action they serve:

  1. *Analysis on the level of objects and properties* (1-13)
  2. *Synthesis on the level of inter-connections and relationships* (14-41)
  4. *Technical and cognitive support* (46-55)
Methodology: The analytic tool

- *Analysis* has to do with breaking the target phenomenon into parts
  - *objects*, realistic or symbolic entities representing real world
  - *properties*, context-bound concrete or abstract concepts

- *Objects & properties* are the building blocks for the model’s construction

  But before these can be conceptually synthesised into a representation of the target phenomenon, their *inter-connections* need to be identified, described and elaborated to finally take the form of *relationships*

- Thus, *synthesis* is carried out on two levels
  - the level of qualitatively described *inter-connections*
  - the level of mathematically-informed *relationships*
Methodology: The analytic tool

- **Testing & interpreting** concerns the content and the behaviour of the model under construction. It may consist in
  - requiring or performing testing of behaviour with built-in tools
  - requiring or performing interpretation of the model’s behaviour / content

- **Technical support** has to do with explanations on
  - the manipulating level of the given constructs and tools
  - organizational issues in regard with peers’ collaboration

- **Cognitive support** has to do with the topic itself. It may consist in
  - facilitator-driven domain-bound questions for peers to explore
  - peer-driven domain-bound questions for the facilitator to clarify
  - requiring and giving information on the topic
  - explaining the task
4. Technical & Cognitive Support

- 55. Giving info on the subject
- 54. Requiring info on the subject
- 53. Responding to a question of cognitive support
- 52. Posing a question of cognitive support
- 51. Giving organizational instructions
- 50. Reading the task
- 49. Giving explanations on the tools or the manipulating level
- 48. Requiring explanations on the tools or the manipulating level
- 47. Manipulating (or requiring manipulation of) objects-properties-relationships
- 46. Explaining the task

3. Testing - Interpreting

- 45. Requiring comments-interpretations of content or behaviour
- 44. Commenting on-interpreting content or behaviour
- 43. Testing behaviour
- 42. Requiring testing of behaviour

1. Analysis: Objects & Properties

- 13. Deleting Object
- 12. Exploring Objects
- 11. Exploring objects' properties
- 10. Requiring exploration of objects' properties
- 9. Accepting Property
- 8. Accepting object
- 7. Deleting Property
- 6. Deleting Object
- 5. Justifying Object
- 4. Selecting Property
- 3. Inserting Object
- 2. Proposing Property
- 1. Proposing Object

2. Synthesis: Inter-connections & Relationships

2.2 Relationships

- 41. Rejecting a Relationship
- 40. Inserting a Relationship
- 39. Accepting a Relationship
- 38. Explaining a Relationship
- 37. Challenging a Relationship
- 36. Requiring selection of a relationship
- 35. Selecting a Relationship
- 34. Changes the description of a Relationship
- 33. Deleting a Relationship
- 32. Describing a Relationship

2.1 Inter-connections

- 31. Exploring extra inter-connections for a property
- 30. Requiring exploration of a property's extra inter-connections
- 29. Rejecting justification for inter-connection
- 28. Challenging justification for inter-connection
- 27.1. Accepting justification for inter-connection
- 27. Requiring justification for inter-connection
- 26. Changes description for inter-connection
- 25. Rejecting description for inter-connection
- 24. Doubting description for inter-connection
- 23.1. Accepting description for inter-connection
- 23. Requiring description for inter-connection
- 22. Inserting description for inter-connection
- 21. Inserting inter-connection
- 20. Rejecting inter-connection
- 19. Accepting inter-connection
- 18. Explaining inter-connection
- 17. Challenging inter-connection
- 16. Justifying inter-connection
- 15. Describing inter-connection
- 14. Proposing inter-connection
Results: The modeling process

- In the beginning of the activity, the facilitator takes a short time to explain the task of modeling plant growth to the students and provide them with technical and organizational instructions on how to cope with it.

- Peers themselves require explanations directly on the level of manipulating objects, properties and relationships within the given environment and perform manipulating operations as well.

- The analysis is initiated right after with both students proposing objects from the plant growth library of the software and selecting among properties available for each object.
Results: The modeling process

- Peers analyze the task in 3 distinct phases, each followed by a phase of *synthesis*, where inter-connections and / or relationships are discussed and by a phase of *testing-interpreting* the model’s behaviour or content with the provided testing tools.

- The sequence of the 3 cognitive actions is repeated for different sets of structural elements, giving rise to a 3-step pattern in the modeling process.

- The first phase of *analysis* where peers focus on the *macro* dimension of plant growth exploring its dependency on environmental factors is clearly followed by a phase of *synthesis* where peers are directly concerned with *relationships* rather than first discussing possible *inter-connections*. 
Results: The modeling process

- A rather brief phase of *testing-interpreting* closes in turn a first cycle in the modeling process.

- On the contrary, the next two phases of *analysis* where peers focus on the micro dimension of plant growth exploring its dependency on photosynthesis and mostly modeling the latter itself, are followed by more extended and intense phases of *synthesis & testing-interpreting*.

- Rich ‘*peer-to-peer*’ as well as ‘*peer-to-facilitator*’ exchanges characterize these phases in the second & third cycle of the process.
55. Giving info on the subject
54. Requiring info on the subject
53. Responding to a question of cognitive support
52. Posing a question of cognitive support
51. Giving organizational instructions
50. Reading the task
49. Giving explanations on the tools or the manipulating level
48. Requiring explanations on the tools or the manipulating level
47. Manipulating objects-properties-relationships
46. Explaining the task
45. Requiring comments-interpretations of content or behaviour
44. Commenting on-interpreting content or behaviour
43. Testing behaviour
42. Requiring testing of behaviour
41. Rejecting a Relationship
40. Inserting a Relationship
39. Accepting a Relationship
38. Explaining a Relationship
37. Challenging a Relationship
36. Requiring selection of a relationship
35. Selecting a Relationship
34. Changes the description of a Relationship
33. Deleting a Relationship
32. Describing a Relationship
31. Exploring extra inter-connections for a property
30. Requiring exploration of a property's extra inter-connections
29. Rejecting justification for inter-connection
28. Challenging justification for inter-connection
27.1. Accepting justification for inter-connection
27. Requiring justification for inter-connection
26. Changes description for inter-connection
25. Rejecting description for inter-connection
24. Doubting description for inter-connection
23.1. Accepting description for inter-connection
23. Requiring description for inter-connection
22. Inserting description for inter-connection
21. Inserting inter-connection
20. Rejecting inter-connection
19. Accepting inter-connection
18. Explaining inter-connection
17. Challenging inter-connection
16. Justifying inter-connection
15. Describing inter-connection
14. Proposing inter-connection
13. Deleting Object
12. Exploring Objects
11. Exploring objects' properties
10. Requiring exploration of objects' properties
9. Accepting Property
8. Accepting object
7. Deleting Property
6. Deleting Object
5. Justifying object
4. Selecting Property
3. Inserting Object
2. Proposing Property
1. Proposing Object
Results: The modeling process

- The **analysis** of the task represents a small part of peers’ activity
  - 16,23% of the total number of operations

- The interaction among the participants is not as dense as it is during synthesis or testing-interpreting

- There are often operations sequentially performed by the same actor *(dotted lines)*, mostly by the owner of the mouse

- The facilitator does not intervene in the **analysis** except for only twice when asking peers to explore the properties of an object
## Results: The modeling process

<table>
<thead>
<tr>
<th></th>
<th>Student A</th>
<th>Student B</th>
<th>Facilitator</th>
<th>Total</th>
<th>%</th>
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<tbody>
<tr>
<td>Analysis</td>
<td>50</td>
<td>16</td>
<td>2</td>
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<tr>
<td>Synthesis</td>
<td>76</td>
<td>49</td>
<td>20</td>
<td>145</td>
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<tr>
<td>Test/Interpretation</td>
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<td>17</td>
<td>22</td>
<td>61</td>
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</tr>
<tr>
<td>Technical Support</td>
<td>52</td>
<td>26</td>
<td>50</td>
<td>128</td>
<td>30.55%</td>
</tr>
<tr>
<td>Cognitive Support</td>
<td>7</td>
<td>1</td>
<td>9</td>
<td>17</td>
<td>4.06%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>207</strong></td>
<td><strong>109</strong></td>
<td><strong>103</strong></td>
<td><strong>419</strong></td>
<td></td>
</tr>
</tbody>
</table>
Results: The modeling process

- **Synthesis** represents a significant part of peers’ activity  
  - 34.61% of the total number of operations

- It is the most rich and dense part in regard with ‘peer-to-peer’ and ‘peer-to-facilitator’ interactions

- **Synthesis** on the level of *inter-connections* is carried out almost exclusively by the students, since the facilitator intervenes only 4 times for accepting peer-proposed *inter-connections*

- On the contrary, the facilitator is much more involved in *synthesis* upon *relationships*, mainly by asking peers to come up with meaningful descriptions for them in the given context

- This is rather justified since reasoning with semi-quantitative relationships is expected to be more demanding for peers
Results: The modeling process

- **Testing - interpreting** represents a small part of the activity, similar to that of the *analysis*: 14, 56% of the total number of operations.

- These operations are performed by all three participants, which actually indicates the contribution of the facilitator. For instance, the facilitator
  - requires a test of model’s behaviour 7 times and requires or provides comments on the model’s content and behavior 10 times in total.

- Thus, peers are often triggered by the facilitator to be engaged in this action which is supported by the tools provided within ‘ModelsCreator’.

- They mainly make use of the optical representations provided by the simulation of the model’s behaviour and by the direct manipulation of the properties’ value sliders.
Results: The modeling process

- *Technical and cognitive support* correspondingly represent – 30.55% and 4.06% of the total number of operations.

- The high percentage of technical support may be attributed to the fact that peers had no previous experience with *‘ModelsCreator’*.

- The operations of manipulating objects, properties or relationships and requiring or providing relevant explanations are performed throughout the modeling process.

- Rather expectedly, the latter as well as the operation of posing questions of cognitive support is mainly performed by the facilitator, while responses to such questions are primarily given by the students.
Results: A biological aspect of the process

- Shifting our focus on the biology of the modeling process, we note that peers’ first step is building a relationship of plant growth on the macro-phenomenological level of the environmental factors:
  - sun / light $\rightarrow$ plant / growth

- Attempting to explain it further, peers shift on the micro-conceptual level appealing to photosynthesis:
  - sun / light $\rightarrow$ leaf / photosynthesis

- Nevertheless, peers’ unique plant growth macro-relationship is not fully reconstructed on the micro-level, since they miss the crucial link that would connect photosynthesis to plant growth
  - leaf / photosynthesis $\rightarrow$ plant / growth
Results: A biological aspect of the process

- Plant growth is actually left out of focus, since peers are engaged in exploring the photosynthetic reaction itself:
  - leaf / photosynthesis → leaf / glucose → plant / food
  - soil / water → leaf / photosynthesis
  - leaf / photosynthesis → air / oxygen
  - air / carbon dioxide → leaf / photosynthesis

- Peers build a new relationship without projecting it upon plant growth
  - plant / food → plant / energy

- Sun / warmth and soil / minerals are left out

- The relationship ‘increases – increases’ appears to be dominant, while peers recognize some of the underlying assumptions of its use in the specific context. The direction of the built relationships is defined without any particular discussion
Results: A biological aspect of the process

The final model
Discussion

- *ModelsCreator*’ seems to be an appropriate environment for coping with open modeling tasks such as the one in question.

- Although peers are not very familiar with the tool and the setting, the emerging technical or organizational issues do not inhibit the modeling process in the light of the facilitator’s technical support.

- Provided with the necessary structural elements, peers do not seem to encounter significant difficulties in the analysis of the task.

- Their emphasis is primarily put on expressing the candidate *inter-connections* in a semi-quantitative way by selecting among the provided *relationships*.

- Thus, peers seem to take one step closer to a more formalistic way of reasoning since they come up with more informed descriptions of the model’s *inter-connections* supported by the facilitator.
Discussion

- Peers’ are engaged in testing and interpreting triggered by the facilitator and supported by the environment’s testing tools.

- The simulation of the model’s behaviour and the properties’ value sliders the direct manipulation of which results in an optical representation of objects’ behaviour seem to have the main role in this phase.

- Along with the facilitator’s support, the testing tools shape a framework for peers to attempt interpreting and to accordingly organize the modeling process by moving on to another cycle with a new set of structural elements or reconsider the previous one.
Discussion

- Students tend to focus much more on the photosynthetic reaction rather than on plant growth they are supposed to model.

- They mainly reason on the biochemical process of photosynthesis without really attempting to project their reasoning on plant growth.

- In other words, peers seem to forget the target of plant growth and are engaged in enriching their model with autonomous *inter-connections* or *relationships* of photosynthesis.

- This probably indicates a ‘novice strategy’ in coping with the task.
Discussion

- Peers’ incapability of shifting between the macro-phenomenological level of environmental factors and the micro-conceptual level of photosynthesis, food and energy may be interpreted as an absence of a meaningful link between photosynthesis and plant growth.

- The construction of such a link, which would result in the development of reasoning loops or two-level stepwise serial strands, cannot but be included in the basic teaching & learning objectives when studying the topic in question.

- Thus, this observation may be seriously considered in the development of didactic approaches in the specific context.
Acknowledgements

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