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Models Role within Active Learning in Biology. A Case Study

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Abstract: In order to integrate ideas and information creatively, to motivate students and activate their thinking, we have used in Biology classes a series of active methods, among which the methods of critical thinking, which had very good results. Still, in the case of some intuitive, abstract, more difficult topics, such as the cell structure, microscopic processes, the transmission of hereditary features etc., the methods of critical thinking can be insufficient, because they stimulate students' imagination, whereas this does not always conform to real, correct representations. We wanted to compensate this weakness through the integration of the model method in the strategies of active learning. By using teaching materials like models that provide information in more ways (visual, tactile, auditory), the students can better infer phenomena, processes that happen at an intangible, everyday life (cellular division, processes inside the living organisms etc.). In this study we shall present the results obtained by students in the Biology class after introducing the model-technique in the active learning strategies, results which have proved to be superior to those obtained by traditional methods.

Zusammenfassung. Im Hinblick auf die Integration von kreativen Ideen und Informationen wir wollen die Schüler motivieren und aktivieren in ihren Denken, deswegen haben wir in Biologie Klassen eine Reihe von aktiven Methoden benutzt, unter denen die Methoden des kritischen Denkens, mit sehr gute Ergebnisse. Dennoch, bei einigen intuitiven, abstrakten, schwierigere Themen, wie z. B. die Zellstruktur, mikroskopische Verfahren, usw., die benutzten Methoden des kritischen Denkens sind unzureichend. Ein erste grund dafur ist auch die Phantasie der Studenten, diese ist nicht immer gleich mit die Realitat.Deshalb wollen wir , um diese Schwäche zu reduzieren, eine Reihe von Integrative „Modell-Methode“ in den Strategien des aktives Lernenprozess benutzen. Durch die Verwendung von Lehrmaterialien, Modelle, Möglichkeiten (visuell, taktil, auditiv), können die Schüler besser erkennen Phänomenen, Prozessen in den Alltag (zb.Zellteilung, Prozesse in der lebenden Organismen etc.). In dieser Studie werden wir presentieren die Ergebnisse der Schüler in der Biologie-Klasse nach der Einführung des Modell-Technik in der aktives Lernens. Die Ergebnisse haben bewiesen, dass sie überlegen viel mehr uber die verwendung von traditionellen Methoden.

Key words: model-based learning methods, active learning, biology lesson

1. Introduction

The educational process includes methods and techniques that offer the students the necessary information in a way that helps them assimilate it as easily as possible, facilitate the direct access of the students to different sources and stimulate creativity and team work.

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Throughout our teaching practice we have noticed that expositive, traditional methods offer the right amount of input, but the students cannot always assimilate or understand it because it may be monotonous, because of lack of interest for the topic, because of its complexity. These methods do not ensure that a large volume of knowledge will stay imprinted in students' minds for a long time and offer only partially the possibility to use it in new situations, due to the fact that automatic, mechanic learning prevails. Therefore these methods are not always an efficient way of promoting learning.

To remove monotony, to stimulate motivation and activate students' thinking, we have used active methods such as the methods of critical thinking, with very good results, methods promoted through the educational project *"Reading and Writing for the Development of Critical Thinking"* (RWCT). Through the use of such active methods that motivate all the students with their psychical capabilities, ideas and information are reinforced and students are able to recover and use them later to formulate opinions, solve problems, and integrate them creatively.

In the case of some intuitive, abstract, more difficult topics, such as cellular structure, microscopic processes, the transmission of hereditary features etc., the methods of critical thinking can be insufficient, because they stimulate students' imagination, whereas this does not always conform to real, correct representations. Thus, I tried to compensate this weakness through the integration of the model method in the strategies of active learning. By using teaching materials like models that provide information in more ways (visual, tactile, auditory), the students can better infer phenomena, processes that happen at an intangible level in everyday life (cellular division, processes inside the living organisms etc.).

In this study we shall present the results obtained after introducing the model technique (which is intuitive – representative) in the active learning strategies, results which have proved to be superior to those obtained by traditional methods.

2. Methods

Using models is an active method that helps the Biology teacher train the students' thinking, because the models represent simplified biological objects and phenomena, reduced to their essential aspects, easy to understand by the students. Models are based on the analogy between the built model and the original system it represents. Teaching with models supposes "acting with models" [2] p. 230.

The techniques of critical thinking: "Critical thinking is the result of well-conceived lessons whose purpose is the encouragement of critical thinking" [7], p.7. It contributes to the "formation of people who think maturely, who can assimilate knowledge, who can collaborate with each other and apply the accumulated knowledge, which means educating comprehension and not memorizing" [1], p. 27.

These are some of the strategies from the RWCT that we have used in Biology lessons: clusters, study guides, group brainstorming, pair work, think/work/communicate in pairs, establishing event succession, key terms, the Venn diagram, gallery tour, I know/I want to know, the cube etc.

3. Formative teaching experiment

We started from the hypothesis that *the integration of models in active learning strategies based on critical thinking* leads to more successful school results, to a stronger motivation for study, to the formation of people who think critically, who can assimilate knowledge, collaborate and apply the assimilated knowledge.

Statistics shows that the success of the learning process for 90% of the students is conditioned by the teaching methods used. In order to select the method that is adequate to the learning situation "we must go deep towards the identification of the mental mechanisms that are activated in the process. The knowledge thus becomes an intellectual instrument that functions in real situations and transforms ideas and preexistent representations progressively" [6] p. 26.

We have conceived a prototype model of the lesson based on critical thinking in which we integrated the model-based method following the aspects below:

A. The teaching stages:

A.1. Establishing the operational objectives (formulating them clearly, avoiding an exaggerated number of objectives (we mainly set 4-5 objectives), the existence of at least one formative objective, their correlation with the learning content and the assessment).

A.2. Establishing activity types and teaching methods

In the lessons we have tried to combine individual, whole class and group work activities in different **active methods, based on critical thinking** (the methods were chosen according to the learning content and the particularities of the student group). Each lesson plan includes **the model-based method** in one of the learning stages (Appendix 1).

A.3. Establishing the teaching materials and methods so as to achieve of the aimed objectives, while integrating **models** where it was possible.

A.4. The evaluation of the students' activity consisted in written and oral tests, portfolios, problem solving exercises etc. We also took into consideration students' activity in achieving tasks, individual observations, and usage of specific language.

B. Lesson stages:

The lesson stages were developed according to the ERR strategy in which we used interactive techniques frequently, in about 50-80% of the class time and we integrated the model method in the learning sequences, in about 60% of the lesson time (see Appendix 1).

B.1. For the **revision stage** we used activities meant to reinforce previous knowledge related to a certain topic and to catch students' attention, to help them ask questions and set their own learning goals.

B.2. The stage for inferring meaning

We subscribe to Stiggins' assertion [8], p. 257, according to which "the most valuable lesson that we have learned in the latest years from those who study cognitive processes is that mechanic memorizing does not ensure comprehension of the material and, consequently, it is not an efficient way to promote learning". Starting from this stage of inferring meaning we used teaching strategies that would require students' thinking, maintaining their interest and maximizing the process of understanding.

In the lesson *Cellular division. Mitosis* (Appendix 1) for this stage we used the method **think/work in pairs/communicate**, computer assisted **modeling**, drawn models, **the lecture.** During the activity the students investigate and identify in textbooks or on models the different stages of the mitosis, the cellular components that participate in the cellular division (the construction of the ideal model).

B.3. The reflection (extension) stage

For this stage we also tried to integrate models in different active strategies, to consolidate knowledge, to form representations in accordance to reality, to ensure collaboration between students, language development, forming competences and integrating knowledge in logical schemas.

An example of reflection subject was proposed in the lesson *The eukaryote cell. The cellular shell,* as follows: students are asked to create individually (in 10 minutes) **-** by using the poster created in the stage of inferring meaning as a **model** – a **cluster** through which to represent everything that they remember related to the topic *The cellular shell at eukaryotes*. Such a cluster can be seen in Appendix 2.

C. The experimental model unfolded in more **stages**:

C.1. The ascertaining stage – the administration of the initial test – the same for all the students.

C.2. Introducing of change in the teaching strategy in the form of the prototype model lesson, namely the changes aimed for the experimental class (IX B).

C.3. Administrating, analyzing and interpreting the final test results

C.4. Interpreting the results of the pedagogical experiment.

The experiment took place at the Technical College “Raluca Ripan” in Cluj-Napoca, in the first semester of the school year 2007-2008, at 9th graders level (IX A and IX B). The focus was on the teaching of some lessons from the units “*The cell – the structural and functional unit of life”* and *“The heredity and variability of the living world”* from the 9th grade school curriculum.

For the result analysis we used statistical methods: frequency tables, *the arithmetical average and the standard deviation „σ”* calculus; graphical representations: *the frequencies polygon.*

In the results interpretation phase we used *the significant difference between the arithmetical averages value* of the studied collectives data. In order to determine the significant difference value between the arithmetical averages of the two classes, we calculated the standard deviation *„σ”* with the relation:

$$\sigma = \sqrt{\frac{\sum_i f_i \cdot |x_i - M|^2}{N}}$$

where: σ is the standard deviation, i are the individual values, f is the grade frequency, N is the total number of students, x is the grade obtained by students; M is the arithmetical average, obtained by the formula:

$$M = \frac{\sum_i f_i \cdot x_i}{N}.$$

The mathematical statistics [5] p.56, show us that the difference between the arithmetical averages of the two groups (experimental and witness) is *significant* if the relation is true:

$$|M_A - M_B| > 2 \cdot \sqrt{\frac{\sigma_A^2}{N_A} + \frac{\sigma_B^2}{N_B}}$$

The initial test given to the students was the same for both high school classes (IX A and IX B) in order to know the initial level and to appreciate the homogeneity of the classes.

The final test tracked the progress.

4. Results

The results and the statistical parameters are shown in the **Table 1** and **Table 2**.

Marks	The initial test				The final test			
	IX A		IX B		IX A		IXB	
	no. students (frequency)	% students	no. students (frequency)	% students	no. students (frequency)	% students	no. students (frequency)	% students
1	0	0,00	0	0,00	0	0,00	0	0,00
2	0	0,00	0	0,00	0	0,00	0	0,00
3	1	3,57	2	7,41	1	3,57	0	0,00
4	7	25,00	6	22,22	3	10,71	1	3,70
5	8	28,57	9	33,33	6	21,43	3	11,11
6	7	25,00	6	22,22	7	25,00	4	14,81
7	3	10,71	3	11,11	4	14,29	7	25,93
8	2	7,14	1	3,70	3	10,71	7	25,93
9	0	0,00	0	0,00	3	10,71	3	11,11
10	0	0,00	0	0,00	1	3,57	2	7,41

Table 1.*The results obtained by students of the two high school classes at the initial and the final test*

	The initial test		The final test	
Parameters / Class	IX A	IX B	IX A	IX B
Arithmetical average	$M_A = 5{,}36$	$M_B = 5{,}19$	$M_A = 6{,}29$	$M_B = 7{,}22$
Standard deviation	$\sigma_A = 1{,}260$	$\sigma_B = 1{,}218$	$\sigma_A = 1{,}729$	$\sigma_B = 1{,}499$

Table 2. *The arithmetical average and the standard deviation of the results obtained at the initial and final test*

In the initial test case we see that the difference between the arithmetical averages $|M_A - M_B| = 0.17$ **is not** higher than $2 \cdot \sqrt{\dfrac{\sigma_A^2}{N_A} + \dfrac{\sigma_B^2}{N_B}}$ = 0,668, so the **difference** between the two classes **is not significant,** which allowed us to perform the pedagogical experiment.

In the case of the final test we can see that $|M_A - M_B| > 2 \cdot \sqrt{\dfrac{\sigma_A^2}{N_A} + \dfrac{\sigma_B^2}{N_B}}$; 0,93 > 0,872 there is a **significant statistical difference** between the "control" group and the "experimental" group, where the results are clearly superior in the experimental group (IX B), where the prototype model lesson was applied.

There is a very small number of grades above 6 in all the students at the initial test, the majority of the students finding themselves around grade 5. We can notice here that the initial level of the two classes is low and similar.

It is just at the end of the semester that the difference between the grades obtained by the students of the two classes appears:

- in the case of the "control" group, the arithmetical average of the grades has increased (Table 2), and the grade curve has shifted from grade 5, in the initial test, towards grade 6, in the final test (Figure 1).
- in the case of the "experimental" group, the arithmetical average has grown significantly (Table 2), and the grade curve has shifted from grade 5, in the initial test, towards grades 7 and 8 in the final test (Figure 1).

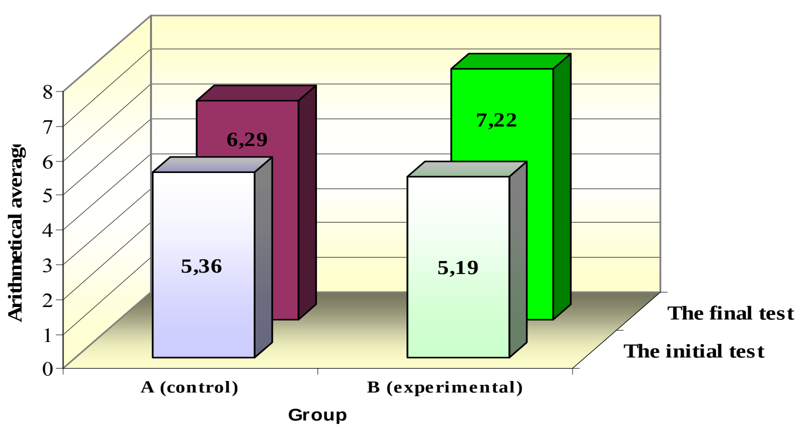

Figure 1. *Frequency polygons for "control" group A and "experimental" group B*

A better representation for highlighting the progress in the experimental class, as opposed to the control class can be found in the Figure 2.

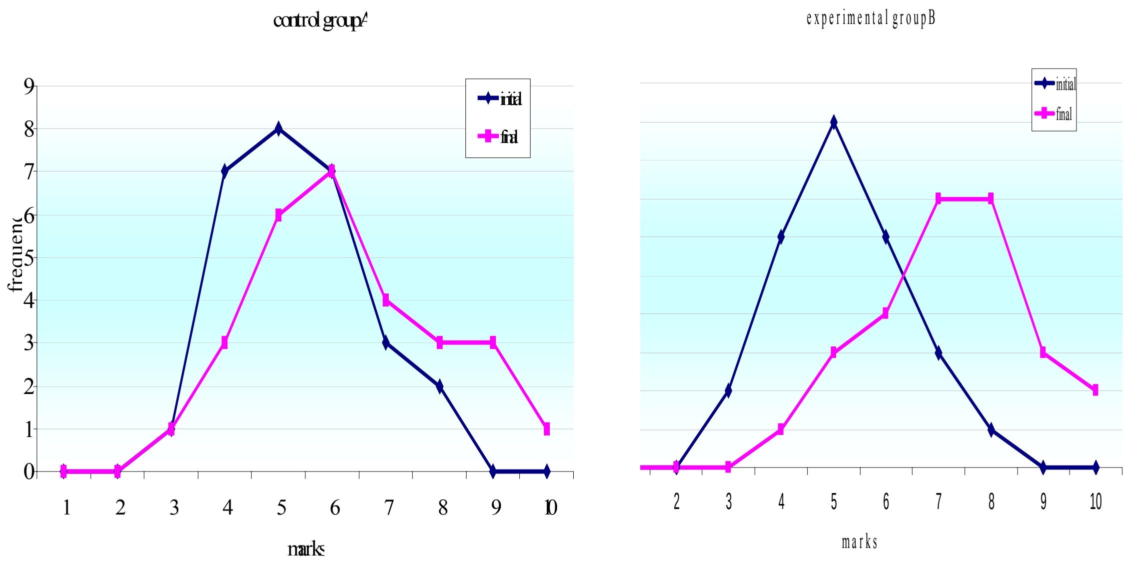

Figure 2. *The graphical representation of the arithmetical averages obtained at the initial and final tests*

4. Conclusion

At the experimental class I found an increase of interest for the study of Biology, a better collaboration between students, a higher level of involvement and adaptation to face new situations.

The model-based method, that has the role to remove overloading lessons and students' minds with insignificant, useless data and to form representations in accordance with reality, completes the strategy based on critical thinking through a systemic vision in which the contents are represented unitarily and synthetically.

The students of the class where we applied the prototype model of the lessons have real progress as opposed to the students who have not had this privilege. Thus, in grade IX B (experimental), the arithmetical average of the final test increased by 2.03 points from the initial test, whereas in grade IX A (where traditional methods were applied), the increase of the arithmetical average was only of 0.93 points from the initial test. The learning progress is seen in: the quantity and quality of the information acquired, the usefulness of the knowledge, the development of intellectual competences, therefore the formative-informative learning. In other words, *the lesson based on integrating models in the active learning strategies* leads to the increase of efficiency in achieving teaching objectives.

The results of the research obtained after the final test confirmed *the efficiency of the integration of models in the active learning strategies* in Biology, by obtaining significant statistical differences between the results of the two groups of students (the "control" group and the "experimental" group) in favor of the "experimental" group.

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Appendix 1

LESSON PLAN

Subject: Biology
Lesson: Cellular division. Mitosis
Lesson aim: Assimilating knowledge and forming team work skills
Class: 9th
Scientific notions: *somatic cells, mitosis, interphase, prophase, metaphase, anaphase, telophase*
Operational objectives: at the end of the activity the students will be able to:

O1. Notice and specify the stages of a cellular cycle using the textbook;

O2. Identify the stages of mitosis on models or on microscopic slides, after the teacher has explained mitosis using the AEL programme;

O3. Discover the importance of mitosis in the growth and development of the organism and the regeneration of some organs;

O4. Design logical schemas for the stages of mitosis based on their own investigations.

Activity types and teaching methods:

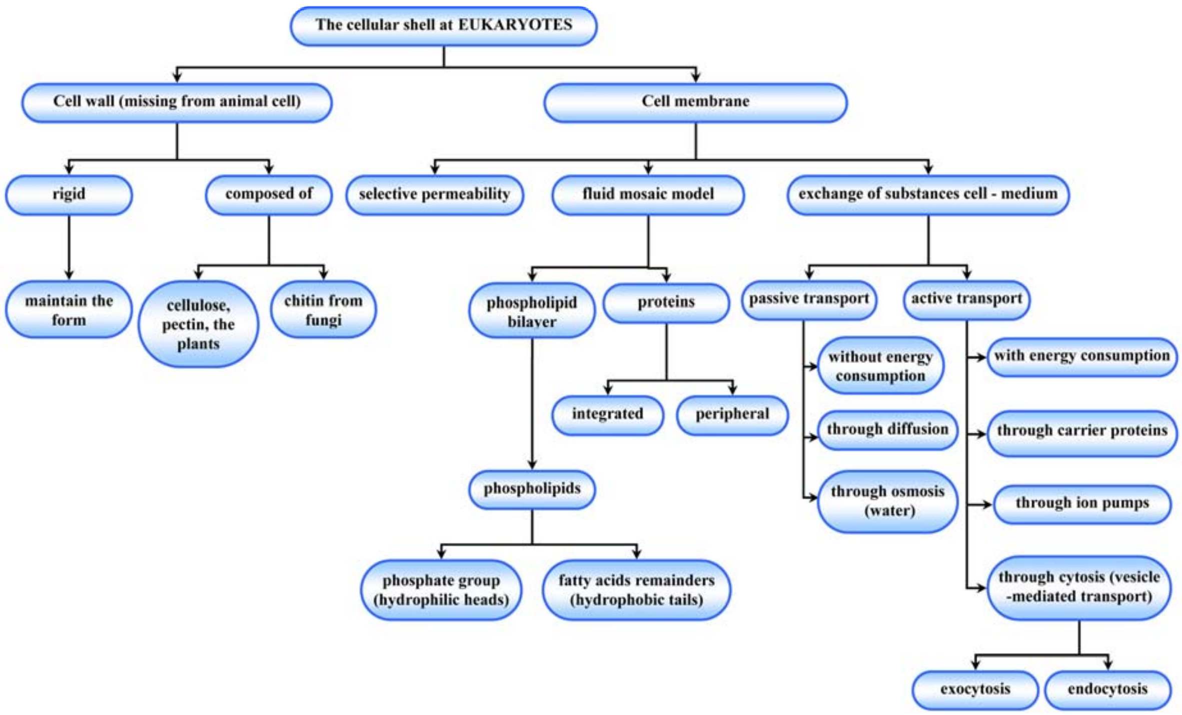
- whole class: group brainstorming, conversation, explanation, modeling, lecture, establishing events succession;
- group work (3 students): think/work in pairs/communicate, controlled observation, modeling, learning by discovery;
- individual work: modeling the phases of mitosis in their notebooks.

Material resources: the textbook, mitosis models, microscope, microscope slide of onion mitosis, the lesson "Cellular division" in AEL (teacher's CD), computer.
Evaluation: oral test, written test (in students' notebooks).
Bibliography: Biology textbook, 9th grade [4]; Biology textbook, 9th grade [3]; AEL – teacher's CD (1)
Lesson stages:

Stage	Content	Time	Methods
Revision	- the teacher tells the class the title and the objectives of the lesson - microscopes and microscope slides are handed out for ulterior use - to arouse students' interest, the teacher makes the following statement: "Did you know that the human body weight would double in 50-100 days if cellular division would happen continuously and all the cells would survive?" [3] p.82 - the students will describe the general composition of a cell, of the nucleus and then of the cellular centre, the chromosome. The whole class is involved in the activity of revision of previous knowledge. In pairs, they are asked to answer the following questions: "Which are the components of a cell? What is the nucleus made of? What is the nucleosome and what is it made of? What are the roles of cellular division?" The students will describe the general composition of a cell, will characterize the nucleus and the chromosome, and will issue ideas regarding the role of the cellular division.	5 min.	Group brainstorming
Inferring meaning	- the class is organized in groups of 3 students and the teacher shortly informs them of what will follow - the students are required to represent and explain the stages of the cellular cycle by using the textbook, then the	5 min.	Think/work in pairs/ communicate

	results are presented by students and noted on the blackboard - using the computer programme AEL the teacher introduces the lesson *"The mitosis"* and the students watch the division stages on the computer monitor and listen to the teacher's lecture - the students form groups of 3 again and their task will be to discover the importance of mitosis, to represent in schemas all the phases of mitosis for a cell with 4 chromosomes; students investigate and identify on the microscopic slide, in the textbook or on models the different phases of mitosis, the cellular components that participate in the division (the construction of the ideal model) - students represent in schemas all the phases of mitosis for a cell with 4 chromosomes in their natural order, having as a result the material model-drawings with different phases of mitosis on the basis of the relations in the ideal system; they study, they take notes on the side of the model. - 5 students from different groups each present a phase of the mitosis and another student talks about its importance - students are asked to try to represent very schematically the mitosis for a cell with 2n chromosomes - through analogical reasoning they transfer the conclusions from the model to the original, meaning a somatic mother-cell gives birth to two daughter-cells that have the same number of chromosomes; then they make a general schema of mitosis - to ensure the personalization of the new knowledge, its integration in students' own cognitive system, the teacher will discuss with them the fact that, although somatic cells are of different types and form different tissues, the mitosis happens according to the same phases, it is only their duration that differs	10 min. 20 min.	Model-based learning (computer assisted) Lecture Think/work in pairs/ communicate Model-based learning (achievement of the model product object and the material model drawing analogical, figurative)
Reflection	- the teacher cleans the blackboard and hands out to the students envelopes containing 4-6 pieces of paper on which there are separate events from phases of mitosis. These are extracted one by one and have to be associated to some model-drawings of the different phases of the cellular division. The class is asked to establish the order of events. When the class has agreed to a certain order, the teacher asks them to open their notebook or textbook to see if the events appear there in the same order -the teacher evaluates and grades students' activity.	10 min.	Establishment of the event succession

Appendix 2


The cellular shell at EUKARYOTES
Cell wall (missing from animal cell)
Cell membrane
rigid
composed of
selective permeability
fluid mosaic model
exchange of substances cell - medium
maintain the form
cellulose, pectin, the plants
chitin from fungi
phospholipid bilayer
proteins
passive transport
active transport
without energy consumption
with energy consumption
integrated
peripheral
through diffusion
through carrier proteins
phospholipids
through osmosis (water)
through ion pumps
phosphate group (hydrophilic heads)
fatty acids remainders (hydrophobic tails)
through cytosis (vesicle -mediated transport)
exocytosis
endocytosis