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Classify students' conceptions about the mutations' site to anticipate their knowings' mobilization before designing an experimental procedure

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Abstract:
In high school, students have difficulties to understand and to learn genetics in general and DNA structure and mutations in particular. These difficulties are partly due to the different biological levels. Several studies showed that students have difficulties to differentiate these levels and that they are not able to order them in the right biological hierarchy. We studied students' conceptions on a specific question to get knowledge on their misunderstanding of these levels. To do that we asked students the following question: where (at what level) in the body, mutagen agents act. After a literature review, we defined six biological levels (organism, cell, nucleus, chromosome and DNA). Students were separated in three groups depending on whether they had studied the DNA structure and mutations or not (both notions, just the DNA structure or none). Analysis of students' productions confirmed our six predefined levels, but with an unequal distribution, some levels being ignored by students. Moreover, distributions were different for the different groups of students. The goal of this study is to know how students could mobilize their knowings about DNA and mutation, and use this knowledge to design a laboratory work session scaffolded by an intelligent learning environment.

1) Background, Framework, and Purpose

Our aim was to identify and to discriminate students' conceptions about the genetic mutations' site. The ultimate goal of this research is to anticipate the mobilization of students' knowings when they design an experimental procedure in a laboratory work session (self citation, 2008). The knowledge domain at stake is genetics, i.e. genetic mutations and the structure of DNA that is the support of the genetic information.

Several studies showed that genetics is one of the most difficult topics in biology both for teaching and learning (Johnstone, Mahmoud, 1980; Bahar, Johnstone, Hansell, 1999). Bahar (1999) explained that one of the difficulties of this domain is the different biological levels. Marbach-Ad and Stavy (2000) indicated also this difficulty and characterized three of these levels: organism, cell and molecule. They explained that students have difficulties to differentiate the levels, which led to erroneous interpretations of the interactions between these levels.
The DNA structure and genetic mutations lead to additional difficulties for students. These notions are defined at the molecular level and their effects can be seen at other levels. Pfriedrichsen and Stone (2004) found that students confused DNA molecule with cells and chromosomes. Some students had no ideas about the structure of DNA molecule, and other knew that DNA is like a ladder with rungs, but they had no ideas about the structure with bases, phosphate and ribose. Students had difficulties to differentiate the biological objects and levels, and to organize them into a hierarchy. Moreover, students make some confusions with the term mutation. The general meaning of the term is "change". However, it is a polysemic term that depends on the context. Its meaning is different in everyday context (in French: changes at adolescence, work transfer) and in scientific context (mutation is sometimes wrongly used instead of metamorphosis) (Albaladejo, 1988).

2) Rationale

All of these international studies (but no studies in France) explained that students' difficulties in genetics are partly due to confusions about the different biological levels. To our knowledge no studies provide a classification and identification of students' conceptions. Furthermore, some studies tried to help students to understand the hierarchical organization of biological levels, but never in a laboratory work session. In our research, we tried to identify and discriminate students' conceptions about the site where a mutagen agent acts. The categorization of students' answers will help us in the next part of our study, that is, to anticipate the mobilization of students' knowings when they design an experimental procedure (self citation, 2007).

3) Methods

From the literature review and after a knowledge analysis (not shown here), we focussed on six biological levels: organism, cell, nucleus, chromosome, gene and DNA. We proposed students an exercise that allows us to discriminate, classify and quantify their answers into these six levels.

In this exercise, students completed a diagram (a circle representing an animal cell) and indicated where a ray can act. They were asked to complete their answer in written text. The participants were 102 students, aged 16-17. They were separated into three groups (A-B-C). In group A (27 students), students had never studied the DNA structure and mutations notions. In group B (49 students), they had studied the DNA structure the week before, and in group C (26 students), they had studied all notions (one month before).

To differentiate students' answers, the most meaningful data were their written justifications, where they explained their drawing. With these data, we were able to classify students' answers into six biological levels. For each level, we grouped answers that talked about different components of the level (e.g. for cell: cell's membrane, “inside of the cell”). For example, student answer “Rays modify cell's membrane” was classified in the Cell level. Some student cited several levels. If they indicated an order between these levels, we considered only the lowest level. In “ Rays act on the chromosome which carries a gene. Rays modify the DNA sequence and the gene is modified.” the level was set as DNA because there was a clear indication of order. However, if students cited two levels without ordering them or giving any relationship between them, we put this answer in two levels. For instance, the answer: “Rays act on nucleus and on organelles.” was classified in Nucleus and in the level Other (organelle was not set as a separated level). For this reason, there were more answers than the number of students.

4) Results

After the classification of all students' answers, we calculated a percentage for each level (Table 1).

Table 1: Students' answers (A: notions never studied, B: DNA structure studied, C: DNA structure and mutations studied).

Group	A		B		C		Total	
	n = 28	%	n =56	%	n = 26	%	n =110	%
Organism	0	0	1	1,79	0	0	1	0,91
Cell	10	35,71	9	16,07	7	26,92	26	23,63

Nucleus	16	57,15	19	33,93	3	11,54	38	34,54
Chromosome	0	0	1	1,79	0	0	1	0,91
Gene	0	0	2	3,57	3	11,54	5	4,55
DNA	1	3,57	19	33,93	10	38,46	30	27,27
Other	0	0	5	8,92	0	0	5	4,55
No answer	1	3,57	0	0	3	11,54	4	3,64

Adding answers from the three groups, the most frequent levels were: Nucleus, DNA and Cell. One can see that the percentage of answers for Nucleus level is almost divided by two when changing group: A>B>C. For DNA level, there is the opposite phenomenon: A<<B<C. Furthermore, one can look at the distribution of answers in each group. Group B gave answers in each of the six levels. Answers of group C were in four levels. The least knowledgeable group, group A, provided answers in three levels and mostly in two.

5) Conclusions and Implications

Our situation allowed us to categorize students' answers based on their textual and drawing descriptions and explanations about the site in an unspecified organism where rays (a mutagen agent) act. There were only four students on 102 who did not answer.

An important point of this study was the classification of students' answers. All of the six levels defined in our analysis and based on the literature review appeared in the data. The answers' distribution among levels was far from uniform. Two levels had only one answer: Organism and Chromosome. The diagram to complete was a cell, which could have discouraged students to give an answer about a higher level. As for the Chromosome level, this was a rather unexpected result since this level was introduced to them the year before.

There were also differences between groups for a given level. This difference could be due to the moment where the exercise was given: before, during and after the teaching of the notions. Students' answers at the molecular level (Gene or DNA levels) are more numerous in groups B and C than in group A where most students talked about cellular levels (Cell or Nucleus). The origin of this difference could be the recent study of DNA structure. The study of mutations had also an effect (comparing groups B and C). Students of group C gave more answers at the DNA level (which could be due to the fact that students in this group studied nucleotides' mutations), at the Gene level (they studied genetic diseases), and at the Cell level (they did a laboratory work where they observed cell mutations after an UV radiation). To confirm these results, we plan to use this situation with a larger number of students.

For the next step of our study, we make hypothesis about students' reasoning when they chose one or other level. For example, a student described the ray's action on cell as follows: “Membrane is used to protect cell, and if rays act on it, it will be destroyed”. This notion of membrane's destruction was a reference to a mutation cause: loss of something and at the Cell level. For the Nucleus level, one justification was often given: “Rays act on nucleus and divide it in two parts”. This explanation referred to the nucleus' doubling as the mutation's origin, and showed a confusion with two other notions, mitosis and meiosis. Two other origins were present in answers: substitution (crossing-over like rays' action on chromosomes) and addition (one gene more).

Our aim is now to understand how (under what conditions) students can have a conceptual change from the cellular (submicroscopic) paradigm to the molecular (microscopic) paradigm. In other word, introduce the fact that genetic mutations are modifications in the succession of nucleotides bases that are organised in sequences. The main notion needed to understand this

is the genetic code organization. In a new study, we will propose a problem-based learning situation designed to allow conceptual change from a cellular to a molecular level. This situation will involve a laboratory work session and will be scaffolded by an intelligent learning environment.

6) Bibliography

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Added 2 self citations.