Helping primary pupils to understand the cell
Ayudando a los alumnos de primaria a comprender la célula

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Abstract

The present study investigates the effectiveness of an intervention concerning the fundamental concept of the cell in connection with relevant biological concepts, on Greek primary school students' knowledge. Participants were 1328 students in the two last grades of primary education, aged 10/11 and 11/12 years respectively. 527 of these students comprised the experimental group, where the intervention took place, whereas the rest formed the control group. For both groups, students' knowledge was examined during two assessments, the fist a month before and the second a month after the period of intervention. The results show that: (a) a significant number of students appeared to have false pre-existing ideas about the cell, (b) the intervention was followed by a significant increase of correct responses for the students of the experimental group and (c) the responses of the students of the experimental group, post-intervention, were overall more accurate than those given by students of the control group.

Key words*: cell, biological concepts, primary education.*

Resumen

El presente estudio muestra la eficacia de una intervención didáctica para la mejoría de la comprensión del significado fundamental de la célula y de relativos significados biológicos. La investigación se realizó a 1.328 alumnos de los últimos cursos de educación primaria, de 10 a 12 años, en Grecia. Los 527 de estos alumnos formaron un grupo experimental, el que aceptó la intervención didáctica, mientras que los demás formaron el grupo de control. Para los dos grupos, realizamos evaluación de sus conocimientos a los temas de interés dos veces: la primera evaluación se hizo un mes antes y la segunda un mes después de la intervención didáctica. Los resultados de la evaluación muestran que: (a) un importante número de alumnos parece que tienen ideas erróneas preexistentes sobre la célula, (b) la intervención didáctica tuvo como resultado el importante estadísticamente aumento de las respuestas correctas que fueran dadas por los alumnos del grupo experimental y (c) las respuestas de los alumnos del grupo experimental, después de la intervención, fueron en conjunto más exactas que las que fueron dadas por los alumnos del grupo de control.

Palabras clave: célula, significados biológicos, educación primaria.

INTRODUCTION

Students' understanding of the cell has been the main objective of a number of studies during the past decades. However, these studies are usually orientated toward secondary education, mainly because of the complexity of the cell itself and its relation to other concepts. Even in secondary education, students retain a number of misconceptions, which inhibit the understanding of what a cell really is. Lewis and Wood-Robinson (2000) suggest that many students have not realized that each cell has a particular structure and that cells are in fact the basic units of organisms. According to Simpson (1984), many students aged 14-15 years old, confuse the concept of the cell with the molecule or/and the atom. The majority of a sample of 249 students believes that proteins consist of molecules and cells. Only one half of the sample thought that a biscuit is made of molecules, whereas a 30% of them believe that it is made only of cells. Arnold (1983) provided additional evidence indicating that students tend to confuse these two concepts, the cell and the molecule. When Arnold asked 14-15 year-old students to draw molecules, drawings rather represented cells than molecules – they were characterized by the author as *"cell-molecules"*.

A vast majority of the above students (ARNOLD, 1983) stated that living organisms and objects are both made of cells. The question of where a cell could be found seems to be in general another part of the whole problem. TREGIDGO and RATCLIFFE (2000) suggest that some students believe that cells are parts only of the human body. Dreyfus and JUNGWIRTH

(1988) found that a number of 15/16 year-old students retain the idea that "the cell is the basic unit of all living organisms…but only some parts of the body are made of cells, while others are not". As PRICE (1999) suggests, the problem is related to the trend of the students to often obediently memorize relevant information about the cell without having understood this concept.

However, the relation of the cell to its parts and other parts of an organism seems to be an even bigger problem. Students' understanding of the relation between the components of the cell and their functions seems to be very difficult (ZAMORA & GUERRA, 1993). Students usually fail to consolidate such functional relations and thus, it is more difficult for them to understand procedures related to respiration, reproduction, metabolism, genetic mechanisms or photosynthesis (LEWIS & WOOD-ROBINSON, 2000; FLORES et al., 2003). As a result, the understanding of more complex concepts of biology, like the structure and the functions of an organism, seems to be even more difficult.

Since the understanding of the cell is a prerequisite for the teaching and learning process of other more complex biological concepts, the timing of its introduction to the educational curriculum is a crucial question. DORI et al., (1995) report that the concept of the cell is a subject matter for students in the first year of Israeli secondary schools. Authors underline the need of introducing the cell at the earliest possible stage of education, supporting the aspect that, learning about cell is a vital presupposition for understanding the structure and functions of all living organisms. Thus, teaching about cells in primary education is possibly a way to avoid further misconceptions later on.

However, Greek education has stayed far from this approach for a long time. Only in 2006 did the National Curriculum for the Greek Primary Education introduce the cell for the first time in the 6th grade (Greek Pedagogical Institute, 2006; CHANTZIS et al., 2006). A simple form of instructions, which is applied so far, in combination with traditional teaching methods, is proved to be insufficient to cope with the existing problems of alternative student ideas (MAVRIKAKI et al., 2003). As a result, a more systematic introduction of this concept seems to be necessary.

METHODOLOGY

Aim of the study

In the context of the above, we designed an hourly teaching intervention, the main focus of which was on the understanding of the concept of the cell in connection with relevant biological concepts that pupils have usually been taught in Greek schools. The intervention was intended to incorporate the principles of cooperative learning. The main purpose of this effort was to explore in which way, and to what extent, this intervention could improve their understanding of the cell. Relevant pupils' misconceptions were also examined.

Sample and Assessments

The study took place in a number of primary schools of Thrace, Northeastern Greece, and 1328 pupils of the two upper grades of the Greek primary education (the 5th and the 6th) participated. The concepts of the cell and its structure were not included in their syllabus. Five hundred and twenty seven of the pupils (292 boys and 235 girls) attended a one-hour lesson according to the teaching instructions (experimental group), whereas there was not any intervention for the rest 802 pupils (control group, 421 boys and 381 girls). In order to have representative results, the whole sample was chosen on the basis of the method of the proportional distribution at layers (GRAWITZ, 1996). In both experimental and control groups, the first assessment took place right after the beginning of the academic year. Approximately a month later, the intervention took place for the pupils of the experimental group. The second assessment took place for the control group, as well as for the experimental group using the same evaluation process (see description below) as in the first assessment; this happened one month after conducting the intervention in each one of the schools that participated in the study.

Teaching instruction and method

The central idea of the teaching instructions was the understanding of a) the cell as a basic unit of life and b) its relation to other parts of living organisms as well as to its main components.

With respect to the first point (a), instructions focused on the description of the cell, its importance for life, the distinction between multi- and single- cellular organisms and where one could find it. Cellular structure of multicellular organisms was further discussed (nucleus, cytoplasm, cellular membrane for animal cells, cellular wall and chloroplasts for plant cells).

As for the second point (b), the instructions were designed in order to clarify the hierarchy and the relations between the levels of the multicellular structure, i.e. cell – tissue - organ - organic system - organism, as well as the role of the main components of the cell, their relevant functions and the relations between them.

The instructions were applied in the context of cooperative learning (DORI et al., 1995). Pupils in each class were divided into groups of three to work together. At the beginning, the teacher (one of the researchers) posed questions about the main objectives of the instruction, as described above. The students gave possible answers after discussing these questions in groups; in this way, the teacher aimed at revealing and using pupils' pre-existing ideas. Then a discussion followed, for all the class, in order to give the opportunity to pupils to actively construct more scientifically correct ideas with the guidance of the teacher.

In order for the instruction to be more effective, multiple representations were used in the context of the instructions (TSUI & TREAGUST, 2003, 2007). Thus, a video (HUANG & ALOI, 1991; BAGGOT & WRIGHT, 1996) was used for the better understanding of the basic structure of the cell (nucleus, cytoplasm and cell membrane), its importance for the life and its existence in all living organisms as the basic unit of life. A PowerPoint presentation was also used, focusing on: the distinction between multicellular and single-celled organisms, the structural levels of multicellular organisms (cell - tissue - organ - organic system - organism), the internal structure of the cell (nucleus, cytoplasm, cellular membrane), cell morphology (e.g. different cellular forms like muscle and nervous cells), as well as the similarities and the differences between animal and plant cells. Also, clay models of animal and plant cells (circa 12 cm in diameter) were used in order to provide better understanding of the internal structure of the cell, as the nucleus, the cytoplasm, the cell membranes and the cellular organelles were visualized in 3D (chloroplasts and cell wall were demonstrated only in the plant cell model). Additionally, the components of cells were presented through colorful drawings.

Finally, at the end of the instruction, pupils went back to group work to summarize and review the basic concepts they had learned about. They were asked to draw and describe cells, in groups, and a discussion followed to summon up the instruction.

Description of the evaluation process

The evaluation process consisted of two parts. In the first part, pupils were asked to write a text about the cell – explain what a cell is, as well as describe it in detail and in relation to other relevant concepts or things that they knew. In the second part pupils were asked to draw a cell and all of its components. The time available for both parts was 45 minutes.

Data analysis

Data was analyzed applying Content Analysis (CARLEY, 1990). Pupils' responses to the first part of the evaluation process were classified, by two independent researchers, in categories (see next section) according to the points they focus on, their correctness and their completeness. In case a pupil's response focused on more than one distinct point, then it could be classified in more than one category. A similar categorization took place for the second part of the evaluation process. Pupils' drawings were categorized according to the same criteria by the same researchers. Taking into account pupils' categories in each one of the two parts, each pupil was categorized in one or more final categories. The percentage agreement between the two researchers reached, after discussion, 100%. After this procedure, a quantitative statistical analysis took place. For both quantitative and qualitative content analyses a number of relevant works was exploited (PALMQUIST, 1990; WEBER, 1990; GRAWITZ, 1981; STEMLER, 2001; KRIPPENDORF, 2004).

RESULTS AND DISCUSSION

The effect of the intervention

Based on the data analysis described above, the final categories resulted from both the text and the drawings of the pupils and are summarized as follows:

Category 1: Size of the cell. Pupils' responses with reference to the size of the cell, e.g. *"the cell is something very small" or "cells are small organisms that circulate in our blood".*	***Category 6: Differences between cells.*** Pupils' responses that focus on the differences between kinds of cells are categorized here, like plant cells *vs.* animal cells, or blood cells *vs.* nerve cells.
Category 2: Shape of the cell. Distinct references to the shape of cells, e.g. *"the cell is a triangular thing"* or *"the cell is a cylindrical thing in the organism…".*	***Category 7: The cell as an organism.*** Pupils' responses which consider a cell autonomous as an organism fall into this category, e.g. *"a cell is an amoeba"* or *"cell is a micro-organism in our body".*
Category 3: Division of the cell. References to the cell division during its reproduction, e.g. *"as a human become older, the number of cells become bigger by the division of each cell into two".*	***Category 8: Relation to higher systems/ organs.*** Includes pupils' responses like *"many of the cells make up an organ".*
Category 4: Where the cell could be found. Responses, which report that cells could be found in humans, animals, plants, in all the living organisms or even in inorganic materials, e.g. *"the cell is a part of the human body. It exists in men and women".*	***Category 9: Use of biological terms.*** Responses, which include biological terms and expressions related to other lessons that students had attended. They usually concern phrases that pupils had memorised without really understanding them, believing that they had something to do with the cell. Examples are *"the cell is a basic reproduction factor"* or "*cell is an organ that participates in the mechanism of the humans' body functions".*
Category 5: Components of the cell. Includes responses with reference to the components and the structure of the cell, like its membranes, nucleus, etc (e.g. *"the cell has nucleus, cytoplasm, membrane and particles").*	***Category 10: No answer.*** Includes the absence of any answer or the presence of few words making no sense.

Figure 1. Categories of pupil responses.

Pupils' distribution into these categories for both experimental and control groups, pre- and post- intervention, is presented in **Table 1**, whereas **Table 2** presents the statistical data concerning the same categories for the experimental group, pre- and post-intervention. There was generally a significant improvement of pupils' knowledge about the cell for the experimental group in almost all the categories (1st, 2nd, 4th, 5th, 6th, 7th and 8th). However, unexpectedly, there was at the same time a small significant improvement of the pupils' competence for the control group in categories one and four. This could be probably due to the fact that control group students had got accustomed to the evaluation procedure and were less hesitant to give answers during the second assessment.

The 1st and the 2nd category refer to the external characteristics of the cell and are significant because they help pupils picture the cell. As Zamora et al. (1993) and Dreyfus and Jungwirth, (1988) reported, although of great importance, it is difficult for pupils to picture the cell. The percentage of pupils of the experimental group who responded correctly over doubled after the intervention.

In the category of cell division (the 3rd one), the statistical significance of the increase of the pupils' competence was not very high for the experimental group (p=0.042). This probably indicates that the division of the cell is not considered by the pupils as one of the important points to describe the cell. Besides, it is a quite complex concept and it could be approached only after introducing more fundamental concepts concerning the cell.

Table 1

Pupils' contribution into the final categories (experimental and control groups, pre- and post- intervention)

	Pupils' categories Pupil percentage (number of pupils)			
	Experimental group		Control group	
	Pre-	Post-	Pre-	Post-
1. Size of the cell	26.0 (137)	52.9 (279)	25.6 (205)	8.0 (305)
2. Shape of the cell	0.9 (5)	6.8 (36)	1.5 (12)	1.6 (13)
3. Division of the cell	0.9 (5)	2.8 (15)	0.5 (4)	0.7 (6)
4. Where the cell is found	5.5 (29)	50.1 (264)	3.7 (30)	11.1 (89)
5. Components of the cell	0.9 (5)	69.4 (366)	0.2 (2)	0.2 (2)
6. Differences between cells	4.7 (25)	14.8 (78)	3.6 (29)	5.6 (45)
7. The cell as an organism	23.7 (125)	54.5 (287)	21.4 (172)	27.7 (222)
8. Relation to upper systems	3.8 (20)	14.6 (77)	4.5 (36)	5.1 (41)
9. Use of biology terms	3.2 (17)	1.1 (6)	1.9 (15)	0.2 (2)
10. No answer	47.1 (248)	4.9 (26)	49.8 (399)	32.4 (260)

Table 2

Statistical analysis concerning the final categories for the experimental group, pre- and post-intervention

	Pre Intervention		Post Intervention				
	Mean	SD	Mean	SD	X^2	Df	P
1. Size of the cell	0.26	0.439	0.53	0.500	127.442	1	<0.001
2. Shape of the cell	0.10	0.097	0.07	0.253	25.714	1	<0.001
3. Division of the cell	0.01	0.097	0.03	0.166	5.000	1	0.042
4. Where the cell is found	0.38	0.486	0.74	0.440	233.004	1	<0.001
5. Components of the cell	0.00	0.000	0.69	0.461	355.068	1	<0.001
6. Differences between cells	0.05	0.213	0.15	0.355	45.831	1	<0.001
7. Cell as an organism	0.24	0.426	0.54	0.498	150.703	1	<0.001
8. Relation to upper systems	0.04	0.191	0.15	0.354	55.018	1	<0.001
9. Use of biology terms	0.03	0.177	0.1	0.106	5.261	1	0.022
10. No answer	0.48	0.500	1.00	0.000	201.517	1	<0.001

The key point in category four is the location of the cell. This category presents interesting data about the way that pupils think concerning the places where a cell could be possibly found. Even after the first assessment, many pupils of both experimental and control groups gave a variety of answers. The majority of them had a limited view of the cell existence, believing that the cells could be found only in humans and/ or in plants/animals. **Table 3** shows in details the pupils' distribution in the total number of the responses for this category (4), pre and post intervention for both groups.

Table 3

Pupils' responses of the category 4 for both experimental and control groups pre- and post- intervention

Pupils' categories	Pupil percentage (pupil numbers)			
	Experimental group		Control group	
	Pre-	Post-	Pre-	Post-
1. All living organisms	5.5 (29)	50.1 (264)	3.7 (30)	11.1 (89)
2. Humans and animals	5.9 (31)	2.5 (13)	5.0 (40)	7.7 (62)
3. Humans and plants	0.2 (1)	0.9 (5)	0.5 (4)	0.4 (3)
4. Plants and animals	0.2 (1)	0.0 (0)	0.0 (0)	0.1 (1)
5. Humans only	24.9 (131)	20.3 (107)	27.1 (217)	31.0 (249)
6. Animals only	0.6 (3)	0.0 (0)	0.4 (3)	0.1 (1)
7. Plants only	0.9 (5)	0.0 (0)	0.6 (5)	0.7 (6)
8. Living organisms and inorganic material	0.0 (0)	0.0 (0)	0.1 (1)	0.2 (2)

As we can see, the number of incorrect responses presented a significant decrease for the pupils of the experimental group, post intervention. The number of experimental group pupils who responded that the cell is present in all the living organisms was almost ten times higher in the second assessment than in the first one.

Table 4

Categories of pupils' alternative ideas. Both groups, pre- and post- intervention - Number of pupils and percentages

Pupils' alternative ideas. Categories and relevant description	Pupils' percentage (numbers)			
	Exp. group		Contr. group	
	Pre-	Post-	Pre-	Post-
1. Cell is an (unspecified) organ: The cell is thought to be an organ or something like an organ inside the human body, e.g. *"The cell is a vital organ of humans", "The cell is an organ in our body"*.	4.6 (24)	0.4 (2)	5.4 (43)	5.0 (40)
2. Cell is something inside a particular organ: Vague pupils' responses, e.g. *"The cell is something we have in our tummy", "cell is a thing in the eye", "The cell is close to the heart. The heart can not work without it. I think it is a nerve"*.	6.6 (35)	0.4 (2)	4.5 (36)	5.7 (46)
3. Cell is a part of the genetic system: There is confusion between the cell and the human genetic system, e.g. *"Cell is a small part of humans, which when it is fertilized we make children. But when we smoke too much, it might become cancerous", "Cell is what a man has and when it is fertilized, children are produced"*.	1.7 (9)	0.4 (2)	1.6 (13)	1.7 (9)
4. Cell is a part of the blood circulation system: The cell is thought to be parts of blood circulation system, e.g. *"cells are veins"*.	0.6 (3)	0.0 (0)	0.9 (7)	0.6 (5)
5. Cells are blood components: Cells is confused with blood components, e.g. *"The cell is the smallest part in our blood", "The cell is what helps us heal wounds or fight microbes"*.	4.2 (22)	1.3 (7)	3.6 (29)	4.0 (32)
6. Cell is a plant system: There is confusion here with the genetic system of plants, e.g. *"The cell is something in the flower that is fertilized and we get fruit"*.	0.2 (1)	0.0 (0)	0.6 (5)	0.1 (1)
7. Cell is a kind of inorganic material: Cells are described as inorganic particles (atoms or molecules), e.g. *"The cell is what our blood takes to make combustion and give energy to the body"* (confusion with the molecule of oxygen).	1.5 (12)	0.6 (3)	0.9 (7)	1.5 (12)

Categories five to eight (Tables 1 and 2) are of great importance, since the cell is described in relation to its components, other cells, higher systems and organisms. For category five, which refers to one of the basic objectives of the teaching process, the increase in the correct answers for the pupils of the experimental group after the instruction was remarkable. The same holds true also for category six. It seems that the intervention made clear the differences between cells in such a degree that pupils were considering post intervention, not only their morphology, but also the different functions that the cells perform; according to the places they can be found inside the same organism or according to the organism they belong.

Table 5

Statistical analysis concerning alternative ideas for the experimental group, pre- and post- intervention

Categories of pupils' alternative ideas for the cell	Pre-		Post-				
	Mean	SD	Mean	SD	x^2	Df	P
1. Cell is an (unspecified) organ	0.05	0.209	0.00	0.062	16.962	1	<0.001
2. Cell is something inside a particular organ	0.07	0.249	0.00	0.62	29.257	1	<0.001
3. Cell is a part of the genetic system	0.02	0.130	0.00	0.062	4.000	1	0.039
4. Cell is a part of the blood circulation	0.01	0.075	0.00	0.000	1.333	1	0.250
5. Cells are blood components.	0.04	0.200	0.01	0.115	9.333	1	0.001
6. Cell is a plant system	0.00	0.044	0.00	0.000	0.000	1	1.000
7. Cell is a kind of inorganic material	0.00	0.000	0.01	0.075	1.333	1	250

The intervention seemed to be also effective for the understanding of the relation between cells and higher systems (category eight). Pupils of the experimental group post intervention seemed to have a better understanding about the fact that cells constitute organs, and organs cooperate in the function of the organisms. In fact, the students appeared to connect fractured pieces of knowledge that they already had about the levels of the organization of an organism and to understand these structural and functional levels (cell-tissue-organ-organism).

On the other hand, category seven has the peculiarity of perceiving the cell as an autonomous organism. In a number of cases, this indicates an (incorrect) alternative idea considering the existence of a single-celled organism. However, in the majority of the cases post intervention, there were references to multicellular and single-celled organisms, stressing the ability of a cell to work as an autonomous unit. Thus the increase of the pupils' answers of the experimental group in this category post intervention, shows that pupils seem to have clarified the fact that cells do function as units even when they consist parts of multicellular organism.

Finally, the number of pupils of the experimental group who fall into category nine (use of biological terms) decreased post intervention; this fact is considered to be a positive one too. It seems that, after the intervention, fewer pupils retained confusion between biological terms and showed only limited tendency to use these terms without understanding their meaning.

Pupils' alternative ideas

Apart from the categorization of Tables 1 and 2, pupils' responses were also analysed on the basis of their alternative ideas, which could be found as responses falling in any of the categories we described above. **Table 4** presents the distribution of answers into seven groups of alternative ideas for both experimental and control groups, pre- and post- intervention. **Table 5** presents some interesting statistical data concerning the same groups of ideas of experimental group students, pre- and post- intervention.

Looking at Tables 4 and 5, the first impression is that some pupils have the idea that the cell is something located in a certain organ or system; even more importantly, they believe that it is a separate unit that co-exists with the human body and not an essential living unit of it. Some pupils' responses are very characteristic about that: *"Cells are microorganisms in our body. They are not as useful as the heart, but they are still useful". "Cells are various microorganisms in the skin, the blood and some organs. If we do not eat fruit with vitamin C, the cells are destroyed"* Similarly, Zamora et al. (1993) also comment that even older students see the cells as separate units hosted in the human body and do not realize their importance for life.

Another interesting point resulting from Tables 4 and 5 concerns the lack of distinction between living and inorganic material. If we combine this with categories one and two of Tables 1 and 2, we could argue that pupils confuse in fact 'living units' and 'objects' (size and shape are among the main characteristics of an object). An analogous case has been reported by Dreyfus and Jungwirth (1988) who noticed confusion between the size and the functions of proteins, inorganic particles and cells in a similar research concerning older students.

In general terms, alternative ideas, although present in both groups, are significantly less frequent in the case of the experimental group, post intervention. This is another indication for the effectiveness of the intervention. On the contrary, they are still present in the case of the control group and in some categories (2, 5 and 7) seem to be reinforced.

CONCLUSIONS

In an attempt to evaluate the role of the intervention in understanding the concept of the cell, we could argue that it had indeed a positive effect on the pupils of the experimental group. In order to come to this conclusion we evaluated, not only the increase of the pupils' understanding in the experimental group, but also the quality of their answers. Perception of morphological and functional aspects about the cell was significantly improved, whereas alternative ideas were significantly reduced. In addition to that, the majority of the pupils of the experimental group post- intervention were able to describe the relation of the cell to its components and to the higher systems or organs to a satisfying degree; that seemed to help them understand the functions of this unit and its importance for life as well. Thus, the final result seems to be an overall better understanding of the cell. The effectiveness of the instruction can be stressed by the fact that, after all, the progress described above was achieved merely by a one-hour intervention.

In other words, pupils of the experimental group seemed to gain knowledge about the concept of the cell- and this clearly proves that the concept of the cell can be introduced to students at Primary Education level. The above also indicate the effectiveness of the teaching intervention; but what exactly are the key points of this effectiveness?

Although the answer is not simple, it is probably related to both the methodology of teaching and the content of the instructions. On one hand, it is very important that pupils had the chance to get an integrated view of the cell; not just a simple presentation of biological terms, but a functional description of cell characteristics in connection to its role, its relation to upper systems and its importance for life. On the other hand, it is also important that the whole teaching procedure took place in the context of the collaborated method, thus enabling the students to actively participate in the procedure: they could express their pre-existing views, "discover" knowledge themselves, and discuss the facts helping the teacher trace the points that needed to be clarified. The use of visual aids seemed to have a positive effect as well, as we can see from the improved ability of post-intervention students to picture the cell. Overall, the instruction enabled the students to consolidate knowledge and not merely memorize scientific facts as Price (1999) had stressed.

After these promising results, the following step would be to further improve our intervention. Considering what we achieved from merely a one-hour intervention, it is reasonable to believe that a more systematic and extended introduction of the cell could have much better results. A more systematic sequence of instructions, where the cell and relevant biological concepts are introduced progressively, could ensure that the students have the time and opportunity to investigate deeper and consolidate biological concepts and functions. The sequence of instructions could include hints on more complex concepts, like photosynthesis or reproduction, in order to prepare their introduction subsequently. As proposed by CANAL, (1999) and KNIPPELS et al., (2005) the understanding of these concepts are of great importance for the pupils; and our findings indicate a difficulty of understanding the process of cell division. The instructions could also clarify possible connections to other science education topics, as the students seem to have a tendency to confuse them (ARNOLD, 1983).

Finally, it is important to stress the value of considering students' alternative ideas while planning our instructions. ADAMS and GRIFFARD (2001) report that, at the age of ten, pre-existing pupils' ideas could be successfully replaced and their misconceptions could be significantly minimized. As indicated by our intervention, taking pre-existing ideas into consideration while introducing new concepts (or maybe even noting the ideas beforehand) could facilitate a better understanding by the students.

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