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Teaching minority primary school pupils in Greece about the cell

Abstract

The present study investigates the effectiveness of a novel didactic approach concerning the concept of cell and relevant biological concepts on minority Greek primary pupils' knowledge. Participants were 353 pupils of the two higher grades of primary education, (5^{th} and 6^{th}) aged 10/11 and 11/12 respectively. A number of 150 of them comprised the experimental group, where the didactic intervention took place, whereas the rest formed the control group. The intervention was designed in the context of constructivism and used cooperative learning methods, multiple representations and of visual aids. For both groups, students' knowledge was examined during two measurements: one pre- and on post- intervention. The results show that intervention was effective even in the case of minority education followed by a significant improvement of the pupils' knowledge in the experimental group. Despite the difficulties concerning the peculiarities of minority schools, pupils' responses of the experimental group were overall more accurate than those given by pupils of the control group.

Key words: Cell, Biological concepts, Minority Education, teaching methods, multiple representations, constructivism.

Introduction

One of the main objectives of Biological Education is the introduction of the fundamental concept of the cell. Dori, Yeroslavski and Lazarowitz (1995) underline, that learning about the cell is a vital presupposition for understanding the structure and functions of all living organisms.

An attempt to introduce the concept of the cell has, first of all, to take into consideration pre-existing alternative ideas of the pupils on this concept. According to Driver, Learch, Millar and Scott (1996), the understanding of children's alternative ideas could help us to better determine the process of children's learning and thus, to achieve more efficient teaching of science. Chi and Roscoe (2002) state that pupils' initial knowledge has two characteristic attributes: it can be inaccurate, and it can often inhibit the process of acquiring generally accepted scientific knowledge. They note that many times, pupils' misconceptions appear to be robust and very resistant to change, especially when they are not supported by observations. Research on alternative ideas about the cell, although still limited (Flores, Tovar and Gallegos 2003, Pfund and Duit 1999) reveals a wide variety of pupil misconceptions and demonstrates the need for further research on this field. Most of the studies on the subject are usually oriented to the secondary education, mainly because of the complexity of the cell itself and its relation to other concepts. Even in secondary education, pupils retain a number of misconceptions, which inhibit the understanding of what a cell really is. Lewis and Wood-Robinson (2000) suggest that many pupils 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 pupils aged 14-15 years old, confuse the concept of the cell with the molecule or/and the atom. In that research the majority of a sample of 249 pupils believes that proteins consist of molecules and cells. Only one half of the sample thought that a biscuit is made of molecules, whereas a percentage 30% of them believes that it is made only of cells.

Arnold (1983) provided additional evidence indicating that pupils tend to confuse these two concepts, i.e. the cell and the molecule. When Arnold asked 14-15 year-old pupils to draw molecules, drawings represented rather cells than molecules – they were characterized by the author as *"molecells"*. A vast majority of those pupils (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. As Chantzis, Pramas and Lialiaris reported (2006), primary school pupils tend to either think of cells as inorganic particles or confuse them with blood or body parts. Tregidgo and Ratcliffe (2000) suggest that some pupils believe that cells are parts only of the human body. Dreyfus and Jungwirth (1988) found that a number of 15-16 year-old pupils 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 pupils to often obediently memorize relevant information about the cell without having understood this concept.

The relation of the cell to its parts and other parts of an organism seems to be an even bigger problem. Pupils' understanding of the relation between the components of the cell and their functions seems to be very difficult (Zamora and Guerra, 1993). Pupils 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 and 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.

In contrast to other Greek primary schools, the concept of the cell has been subject of teaching in public primary schools of the muslim minority during the last decades. The fact that minority Greek schools have been taught about the cell at such a young age, in combination with research evidence suggesting that pupils' alternative ideas appear to be resistant to change even during secondary education (Chi and Roscoe, 2002), becomes a challenge for further investigation. To what extent do pupils' pre-existing ideas still remain unchanged, after the traditional teaching implemented in Greek minority schools? What are the characteristics of these ideas? Could these ideas be changed after a novel didactic approach?

Minority education in Greece

[N.B.: The information provided here is an attempt to permit the reader to understand (a) the complicated peculiarities of minority education in Greece and (b) the specificity of the design of a constructivistic teaching intervention on the concept of the cell which could be appropriate for such minority pupils.]

The term "minority education in Greece" refers to the education of the Muslim minority of Thrace, Greece, as declared by the International Treaty of

Lausanne 1923 (Democritus University of Thrace, 1993). The Treaty of Lausanne was signed by the United Kingdom, France, Italy, Japan, Greece, Romania, Serbia-Croatia-Slovenia, U.S.A., Turkey and Bulgaria. Among others, it declared the rights and the protection of non-muslim minorities in Turkey, and correspondingly of the Muslim minority in Greece (Treaty of Lausanne 1923, Articles 37-45). The access to education, being directly related to the protection of human rights concerning language, was an important issue for the Treaty. Thus, the two countries (Greece and Turkey), in a framework of mutuality, undertook the commitment to properly facilitate public education for minority pupils, in the minority's native language (Treaty of Lausanne, 1923, Articles 41 and 45).

Apart from the Treaty of Lausanne, two educational Protocols have been signed between Greece and Turkey in 1951 and 1968 (Panagiotides, 1996). There are also two Laws, namely the 694 and the 695 of 1977 (Panagiotides, 1995) which determine the general framework of the educational policy concerning the Muslim minority in Greece. As a result, minority education in Greece is quite a particularity, concerning its institutional character, the structure of the curriculum and the educators (Tsitselikis, 1996). The institutional framework of minority education is rather complicate and changeable, as many matters are settled by decrees and regulations; it allows central and local education administrating bodies to fully control minority education (Askouni, 2006).

Mostly male pupils attend minority schools, while girls often quit school at the Sixth grade of Primary School (at the age of 11-12). This phenomenon is mostly observed in rural areas where geographical isolation and traditional social structure provide limited access to education and social activity for women. In most recent years, the tendency is for all pupils (male and female) to complete primary education (Askouni, 2006). However, there is a number of children who do not complete even the six years of obligatory education.

Minority schools employ as many teachers as needed to cover the needs of the bilingual curriculum, even if the school has a limited number of pupils. Especially in small villages, where normally only one teacher would be enough for the school, in minority schools there are usually two or three: one Christian and at least one Muslim. The Muslim teacher can either be (a) graduate of the Special Pedagogical Academy of Thessaloniki (Greece) or graduate of Turkish Pedagogical Academy (which nowadays is the most common case), (b) graduate of Turkish second-grade religious schools of the 60s or (c) Turkish teacher employed by the Turkish government who are working in Greece in the framework of mutuality (equal, small amount of Greek teachers serve in Christian orthodox minority schools in Turkey) [Askouni, 2006]. Most of the teachers in minority schools are men, and usually elderly (especially in the highlands).

Minority education curriculum is divided in two equal parts (in terms of duration): one is conducted in Greek language and the other in Turkish. The Greek part of the curriculum includes the following courses: Greek language, History, Geography, Social and Civil Education and Environmental Education. The Turkish part of the curriculum includes the following courses: Turkish language, Mathematics, Natural Sciences, Religion, Arts and Physical Education (Tressou, 1997). The books that cover the needs of the Greek-language curriculum are issued by the Greek authorities, while the books for the Turkish-language curriculum come from Turkey according to the Educational Protocol of 1968; a corresponding procedure is valid for the Christian orthodox minority schools in Istanbul (Panagiotides, 1996).

Recently, a new curriculum was developed and applied in Turkish primary schools and consequently in minority schools in Greece Natural Science are now implemented by a course called “Science and Technology” (Özden M., 2007). However, problems of Turkish education concerning the course of “Science and Technology” have been recorded as follows (Esme, 2004):
1. The course is very intensive (95% of all science education program) but the time planned for the instructions is insufficient (87 hours per year).
2. The instructions are built on an information-only level. Pupils remain passive; they just listen and take notes, while only the teacher is active, writing on the board and teaching in a traditional way.
3. Evaluation is carried out again on an information level, with the use of multiple choice elements.
4. The opportunities to use science laboratories are limited.

Additionally, relevant research carried out by of Özden (2007) suggests the following:
- the informational education applied is orienting pupils to memorizing and only exam achievement,
- the link with other lessons of natural sciences is broken,
- the classes are overpopulated with pupils,
- teachers need in-service training.

Methodology

Aims of the study
Focusing on the concept of cell, the above provide stimulus for a research on the pupils’ relevant ideas and introduction of the concept of the cell, focusing on the importance of more effective teaching approaches. According to the literature along with our own experience (Chantzis, Kogianni, Tripsianis, Constantinidis, and Lialiaris 2010), it is not only possible to effectively teach primary school pupils about the cell, but it is further vital for the pupils to get familiarized with the concept of the cell at young ages. Along with the investigation of pupils’ relevant ideas that remain unchanged through the traditional context of teaching, the main objective of the present study was to investigate the effectiveness of a non-traditional introduction of the concept of the cell; the introduction would be based on constructivism, cooperating learning and the use multiple representations, taking into consideration the characteristics of the minority primary pupils like those described above.

Procedure
We conducted a research with pre- and post- assessments, on both experimental and control groups (Campbell and Stanley, 1974; Vasilopoulou, 1998). The sample consisted of a total of 353 pupils of minority primary schools (MPS), which is correspondingly the 28.2% of the total number of 5th and 6th grade minority primary school pupils of the research area (prefecture of Evros and Rhodopi, Northeastern Greece). A number of 150 MPS pupils formed the MPS Experimental Group (MPS EG) and 203 of them formed the MPS Control Group (MPS CG). The research plan included 36 out of the 72 Minority Public schools of the area (correspondingly 50%). Our initial goal was to have a sample of 424 MPS pupils, but 71 MPS pupils were absent and missed either the pre- or the post-test process.

We defined the sample according to the methodology of analogous distribution in layers, in order to be representative and accurate (Grawitz, Brimo and Jahoda 1996). Our initial distribution of the total pupil population in groups followed the administrative structure of local "education offices". Then we distinguished urban, suburban and rural schools (Zafiriades, 2002) applying a definition by the Greek National Statistical Service (1994), according to which: " an area is defined as urban when it has over 10.000 inhabitants, suburban when it has a population between 2.000 and 9.999 people and rural when it has up to 2000 inhabitants". Finally, we randomly chose the schools that would take part in the research, following two basic criteria: (a) analogous representation of every "education office" relatively to the total number of pupils and (b) analogous representation of urban, suburban and rural schools within the boundaries of each "education office".

Further to the actual research, we conducted a preliminary assessment on 85 pupils (45 pupils of the 5th and 40 pupils of the 6th Grade). Thus, we were able to trace any difficulty, vagueness or other problems, and consequently improve the research process. At the same time we could note initial ideas of the pupils.

Pupils of Minority Public Schools get usually two or three sessions on the concept of the cell and its structure at the beginning of the 6th grade in the context of the 6th grade "Science of Technology" ("İlkokul Fen Bilgisi 6" in Turkish, Yalçın, et all, 2000) early in September; the teaching model in these sessions is the traditional one ("frontal teaching"). The pupils of both research Groups took part in our 1st assessment in October, so that we could assess their knowledge three weeks after they had attended their traditional sessions on the cell ("pre-intervention", during a period from October 1st to October 10th). Then, in March, the Experimental Group received an one-hour instruction on "The Cell and its Structure". The Control Group received no such didactic intervention. Three weeks later we repeated the same assessment on the pupils of both Groups, in order to assess the impact and the effect of the intervention on the pupils' knowledge (2rd assessment, "post-intervention"). Then, conducted statistical processing and analysis of the results using SPSS. The comparison between the answers of pupils of the Experimental and the Control Group helped us draw conclusions on the basic objectives of the research.

Admissions and Restrictions

In order to make sure that the assessments would take place under the same circumstances in all cases (a) we avoided informing the teachers of the classes about the content of the evaluation procedure or the objectives of the research and (b) all instructions were implemented by the 1st author. In order to adjust our research to the special conditions prevailing in minority schools, as stated above, we carried out the evaluation process in both Greek and Turkish languages. In addition, the teacher of the class was present throughout the evaluation process and also during our instruction to the experimental group pupils.

We also make the admission that there was no information flow between the Experimental and the Control Group of every school.

Evaluation tool

The evaluation tool we applied for the assessments, consisted of two parts. In the first part, pupils were asked to write a text about the cell –to explain what a cell is, as well as to describe it in details and in relation to other relevant concepts/ things they knew.

In the second part pupils were asked to draw a cell and every of its components explaining everything they draw. Both parts were written in Greek and in Turkish. The time available for both parts was 45 min.

Teaching instructions and methods

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 found it. Cellular structure of multicellular organisms was further discussed (nucleus, cytoplasm, cellular membrane for animal cells, cellular wall and chloroplasts for plant cells). Our instruction did not include over-detailed descriptions of specialized terms that would confuse the pupils; we tried to transmit the gist of the most basic structural and functional parts of the cell.

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 implemented within the context of constructivism, giving emphasis on cooperating learning and alternative pupils' ideas. Pupils in each class divided into groups of threes, working together. During lessons, teacher (one of the researchers) was trying to reveal and use pupils' pre-existing ideas in order to give the opportunity to pupils to construct more scientifically correct ideas. This took place through a discussion inside the groups and within the groups. In certain moments, pupils were asked to answer relevant questions on a worksheet and to make relevant drawings.

In order to be more effective, we used multiple representations in the context of our instructions (Tsui and Treagust, 2003, 2007). Thus, we showed a video in order to achieve 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. We held a PowerPoint presentation, 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, we displayed clay models of animal and plant cells (circa 12cm in diameter) in order to help for a 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, we presented the components of cell through colorful drawings.

Data analysis

Data were analyzed applying Content Analysis (Carley, 1990). Pupils' responses were classified by two independent researchers in categories according to the points they focus on, their correctness and their completeness. Taking into account the categories of pupils' responses, each pupil was categorized in one or more final categories. The percentage agreement between the two researchers reached to 100% after relevant discussions. After this procedure, a quantitative statistical analysis took place. For both quantitative and qualitative content analyses we took into account a number of relevant studies (Palmquist 1990, Weber 1990, Grawitz 1981, Stemler 2001, Klippendorf 2004).

Results and discussion

On the basis of the analysis described above, a number of categories for pupils' responses resulted from both the text and the drawings of the pupils. These final categories were found to be similar to those of a recent study carried out in Greek public schools (Chantzis et al, 2010) so we followed a similar categorization, which is presented in Table 1a:

Table 1a. Categorization of pupils' responses

Categories	**Description**
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".
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…."
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
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".
5. *Components of the cell*	Responses with reference to the components and the structure of the cell, for example its membranes, nucleus, etc (e.g. "the cell has nucleus, cytoplasm, membrane and particles").
6. *Differences between cells*	Responses that focus on the differences between kinds of cells are categorized here, like plant cells vs animal cells, blood cells vs nerve cells, etc
7. *The cell as an organism*	Responses, which consider a cell autonomous as an organism, e.g. "a cell is an amoeba" or "cell is a microorganism in our body".
8. *Relation to upper systems or organs*	Responses like "many of the cells make up an organ"

9. *Use of biology terms*	Responses, which include terms and expressions of biology related to other lessons that pupils had attended, and could not be classified in any other category. It is usually about phrases that pupils had memorized 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".
10. No answer	Absence of any answer or the presence of few words making no sense

Pupils' distribution into the categories of Tale 1a for both experimental and control groups, pre- and post- intervention, is presented in Table 1b, whereas Table 2 presents some interesting statistical data concerning the same categories for the experimental group, pre- and post- intervention. As one can see, 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, and 7th). In categories 6 and 8 the improvement was notable in the experimental group, although not statistically significant. At the same time, we noted an impressive decrease in category 10- "no answer" especially in the experimental group; a corresponding decrease in the control group, although not as impressive, could be contributed to the gradual familiarization of the pupils to the research procedures, who were thus encouraged to give answers even if not sure for their correctness.

Among the categories of Tables 1 and 2, the 1st and the 2nd refer to the external characteristics of the cell. Although these characteristics are not connected to the contribution of the cell in life, they are significant because they help pupils to draw a picture in their mind for the cell. Zamora and Guerra (1993) as well as Dreyfus and Jungwirth (1988) reported that, although of great importance, it is difficult for pupils to picture the cell. The percentage of pupils of the experimental group who fall in these categories over doubled after the intervention.

The key point in category 4 is the tracing 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 from the first assessment, the majority of the pupils of both experimental and control groups believed that the cells could be found only in humans, while the second most popular answer was "humans and animals". That was about a limited view of the cell existence. However, the number of these views presented a significant decrease for the pupils of the experimental group, post intervention. Still, the initial ideas of the pupils showed a tendency to be resistant to change. Table 3 shows in details the pupils' distribution into the total of the responses for this category (4), pre and post intervention for both groups.

Finally, the number of pupils of the experimental group who fall into the category 9 (use of biological terms) was relatively low in the first assessment for both groups, but it did not show significant decrease in EG answers post intervention. It seems that, despite the intervention, some pupils tended to use terms without understanding their meaning. This could be a sign of confusion between different science subjects being taught in the school and could thus have a relation to the "missing link" with other lessons, as it was reported by Özden (2007).

Table 1b: Pupils' contribution into the final categories for both experimental and control groups, pre- and post- intervention – Number of pupils (and percentages)

	Number of pupils (percentage)			
Pupils' categories	**Experimental group**		**Control group**	
	Pre-intervention	**Post-intervention**	**Pre-intervention**	**Post-intervention**
1. Size of the cell	75 (50.0)	96 (64.0)	89 (43.8)	104 (51.2)
2. Shape of the cell	3 (2.0)	10 (6.7)	8 (3.9)	7 (3.4)
3. Division of the cell	6 (4.0)	26 (17.3)	9 (4.4)	14 (6.9)
4. Where the cell is found	31 (20.7)	68 (45.3)	34 (16.7)	38 (18.7)
5. Components of the cell	13 (8.7)	103 (68.7)	13 (6.4)	6 (3.0)
6. Differences between cells	6 (4.0)	26 (17.3)	9 (4.4)	14 (6.9)
7. The cell as an organism	41 (27.3)	76 (50.7)	43 (21.2)	69 (34.0)
8. Relation to upper systems	6 (4.0)	18 (12.0)	6 (3.0)	8 (3.9)
9. Use of biology terms	2 (1.3)	3 (2.0)	13 (6.4)	2 (1.0)
10. No answer	30 (20.5)	2 (1.3)	54 (26.6)	28 (13.8)

Table 2. Statistical analysis concerning the final categories for the experimental group, pre-intervention and post experimental intervention.

	Mean rank				
	Pre-intervention	**Post-intervention**	X^2	***Df***	***P***
1. Size of the cell	1.43	1.57	9	1	0.003
2. Shape of the cell	1.48	1.52	3,769	1	0.052
3. Division of the cell	1.48	1.52	3,6	1	0.058
4. Where the cell is found	1.38	1.62	23,203	1	<0.001
5. Components of the cell	1.20	1.80	82,653	1	<0.001
6. Differences between cells	1.43	1.57	12,5	1	0.001
7. Cell as an organism	1.38	1.62	23,113	1	<0.001
8. Relation to upper systems	1.46	1.54	6,545	1	0.011
9. Use of biology terms	1.50	1.50	0.200	1	0.655
10. No answer	1.59	1.41	26,133	1	<0.001

Table 3: Pupils' responses of the category 4 for both experimental and control groups pre- and post- intervention. – Number of pupils and percentages.

Pupils' categories	Number of pupils (percentage)			
	Experimental group		Control group	
	Pre-intervention	post-intervention	Pre-intervention	post-intervention

1. All living organisms	31 (20.7)	68 (45.3)	34 (16.7)	38 (18.7)
2. Humans and animals	8 (5.3)	5 (3.3)	12 (5.9)	11 (5.4)
3. Humans and plants	1 (0.7)	2 (1.3)	3 (1.5)	2 (1.0)
4. Plants and animals	5 (3.3)	0 (0.0)	3 (1.5)	0 (0.0)
5. Humans only	33 (22.0)	44 (29.3)	62 (30.5)	79 (38.9)
6. Animals only	1 (0.7)	0 (0.0)	2 (1.0)	1 (0.5)
7. Plants only	1 (0.7)	1 (0.7)	0 (0.0)	1 (0.5)
8. Living organisms and inorganic material	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

It is important to notice that, the number of scientifically acceptable answers given by pupils of the experimental group after our research instruction (2rd assessment, "post-intervention") was considerably higher than those of the control group correspondingly (note especially Category 5, *components of the cell*). This fact shows not only the effectiveness of our planned instruction, but also its prevalence, compared to the traditional teaching methods. It is also quite indicative, that we got the best results in pre-intervention assessment only in two classes where the teachers had used computers in their traditional instruction. Still, the outcome was not as satisfactory as the result of our intervention. Apparently, it is not just the use of visual aids that improves learning; these should be applied in the context of an integrated and carefully structured approach. Our intervention used multiple representations, not just one form of visual aid, it incorporated an attempt to replace existing alternative ideas, it had a careful structure of presentation concerning the cell (simpler concepts and then more complex ones) and it was built on a cooperative basis, thus enabling maximum active participation of the pupils. Only considering the whole context, one can evaluate its prevalence over traditional methods, shown by the results above.

Regarding now some sociological factors, it seems that there is to be an interesting relation between the family background (father and mother's occupation and education level) and the score of the pupil, as well as the difference of scores between the two sexes. In most categories, and sometimes in all of them, the most significant increase in correct EG pupil answers ($p<0.001$, x^2 =7.400 to 133.976) was presented by pupils whose:

- mothers and fathers had only completed primary school education,
- mothers were occupied at home as housewives,
- fathers were workers or farmers

The significance of the improvement could be partly attributed to the low initial scores of the pupils with the above mentioned family background.
As far as the sex is concerned, female pupils generally scored higher than male in all categories (1-9), at a percentage that reached 20% in some cases. This seems to contradict Ozden's outcome (2007) according to which, female pupils did not tend to like science; however the score is not directly connected to preferences, but it can be attributed to the fact that girls appeared to be more concentrated in the classroom and more eager to learn.

Pupils' alternative ideas
Apart from the categorization of Tables 1 and 2, pupils' responses were also analyzed on the basis of their alternative ideas. As a result, many alternative ideas had been found in each one of the categories of Tables 1 and 2. Moreover, as already discussed, category 7 of Tables 1 and 2 (the cell as an organism) consisted an alternative idea itself. Apart from the latter, some other interesting alternative ideas could be further classified in the seven categories of Table 4a.

Table 4a. *Categorization of pupils' alternative ideas*

Category	Description
1. Cell is an (unspecified) organ	The cell is thought to be an organ or something like an organ inside the human body. Examples: *"the cell is a vital organ of humans", "the cell is an organ in our body", etc.*
2. Cell is something inside a particular organ (of the human body)	This category includes 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".*
3. Cell is a part of the genetic system	There is confusion of the cell with 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"*
4. Cell is a part of the blood circulation system	The cell is thought to be part of blood circulation system, e.g. "*cells are veins".*
5. Cells are blood components	Cells are considered to be blood components, e.g. *"the cell is the smallest part in our blood" or "the cell is what helps us heal wounds or fight microbes"*
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".*

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).*

Table 4b presents the distribution of pupils' answers into the above seven categories of alternative ideas for both experimental and control groups, pre- and post-intervention. Table 5 presents some interesting statistical data concerning the same categories for the experimental group, pre- and post- intervention.

Table 4b: *Categories of pupils' alternative ideas: Both groups, pre- and post-intervention - Number of pupils and percentages.*

	Number of pupils (percentage)			
Pupils' alternative ideas	**Experimental group**		**Control group**	
	Pre-	**Post-**	**Pre-**	**Post-**
1. Cell is an (unspecified) organ	5 (3.3)	1 (0.7)	8 (3.9)	3 (1.5)
2. Cell is something inside a particular organ	9 (6.0)	0 (0.0)	10 (4.9)	11 (5.4)
3. Cell is a part of the genetic system	2 (1.3)	0 (0.0)	3 (1.5)	1 (0.5)
4. Cell is a part of the blood circulation system	2 (1.3)	0 (0.0)	2 (1.0)	2 (1.0)
5. Cells are blood components.	2 (1.3)	0 (0.0)	8 (3.9)	18 (8.9)
6. Cell is a plant system	1 (0.7)	0 (0.0)	1 (0.5)	0 (0.0)
7. Cell is a kind of inorganic material	2 (1.3)	1 (0.7)	3 (1.5)	2 (1.0)

Table 5a. *Statistical analysis concerning alternative ideas for the experimental group, pre- and post- intervention.*

	Mean Rank		X^2	*Df*	*P*
1. Cell is an (unspecified) organ	1.52	1.48	5	1	0.025

2. Cell is something inside a particular organ	1.53	1.47	9	1	0.003
3. Cell is a part of the genetic system	1.51	1.49	2	1	0.157
4. Cell is a part of the blood circulation system	1.51	1.49	2	1	0.157
5. Cells are blood components.	1.51	1.49	2	1	0.157
6. Cell is a plant system	1.50	1.50	1	1	0.317
7. Cell is a kind of inorganic material	1.50	1.50	0.333	1	0.564

Table 5b. Overall presentation of pupils' alternative ideas throughout the research (comparatively in the three assessmentes).

Pupils' alternative ideas	Group Number of pupils (percentage)				
	Experimental group	Control group	X^2	Df	p
1st assessment	24 (16.0)	35 (17.2)	0.095	1	0.757
2nd assessment	2 (1.3)	37 (18.2)	25,049	1	<0.001

The analysis of the results, as demonstrated in the Tables above, provides us with some interesting points. As far as the pupils' alternative ideas are concerned, the first impression is that the pupils hold the idea that the cell is something located in a certain place or system, inside a particular organ, in the genetic system, in the blood, etc. 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 characteristics 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 pupils see the cells as separate units hosted in the human body and do not realize their importance for life.

Another interesting point concerns the lack of distinction between living and non-living stuff. 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 pupils.

In general terms, alternative ideas, although present in both groups, are significantly less frequent and in most cases they are completely absent 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) seem to be reinforced. It is remarkable that traditional teaching did not seem to have equally positive effect. In most cases, traditional teaching does not manage to lead to a decrease of alternative ideas (see Table 4b) while in Category 5 (cells are blood components) there is a notable increase of alternative ideas after the traditional intervention. This stresses the importance of the appropriate design of the didactic approach, especially in concepts that are not tangible and tend to confuse students.

Conclusions

Focusing on the main purpose of this work, which is related to the teaching approaches that could be used in order to introduce pupils to the concept of the cell, we could argue that our intervention had indeed a positive effect on the pupils of the experimental group. The pupils who attended our intervention, in contrast to those who attended only traditional instruction, appeared to have a better understanding of the concept of the cell, not only descriptively but also functionally; they could relate it to more complex concepts; their alternative ideas, although persistent after the traditional instruction, seemed to be reviewed after our intervention; and finally, long-term knowledge was more effectively achieved.

This prevalence could be attributed to the methodology of teaching and the content of the instructions. Pupils had the chance to get an integrated view of the cell, not separately from other relevant things, but in relation to them and to its importance for life, and that, avoiding confusion with unnecessary details. On the other hand, it is also important that the whole teaching procedure took place in the context of the collaborated method. Pupils had an active role in learning, and their participation kept their interest high, while teacher could explore and combat their alternative ideas. Vivid and multiple representations drastically captivated pupils' attention and enhanced their perceptive abilities.

Pupils' alternative ideas are also strongly related to another critical question about introducing the cell; that is, the optimum timing of this introduction. Since the understanding of the cell is a prerequisite for the teaching/learning process of other more complex biology concepts, the timing of its introduction to the educational curricula is a crucial question. Dori et al. (1995), reporting that the concept of the cell is a subject matter of the first classes of Israeli secondary schools, suggest that teaching about cells in primary education is possibly a way to avoid further misconceptions later on. Our intervention support this suggestion, showing that it is possible to effectively teach pupils of that age about the cell; and the results are very promising, provided that we implement an appropriately structured didactic approach.

However, while evaluating our results, we have to take into consideration (a) that our intervention was only a single one-hour instruction, and more importantly, (b) the peculiarities of the conditions prevailing in minority schools. With respect to the first point, we could suggest that a more systematic sequence of interventions with a progressive introduction of simpler and more complex concepts, would give more time for consolidation and facilitate better learning. As for the peculiarities of minority education, it should be stressed that in some cases the pupils actually received our instruction in two foreign languages (Greek and Turkish), as their curriculum does not include instructions in their native language. Language is an important tool in order to enhance knowledge and it can either improve or hinder understanding. The fact that our instruction gave better results than the traditional approach, indicates that a well structured intervention which includes multiple representations, although in a foreign language, can be more effective than a traditional instruction in the pupils' native language. Thus a well-planned approach can overcome the boundaries of language and achieve better learning. We can imagine that the results would be even better if the native language can be used.

Sociological aspects can also play a role, as the social background (educational level of parents, life in rural or urban areas) can affect the stimulus received by the pupils, the formation of alternative ideas and the process of understanding new concepts. It is important, especially when teaching minority pupils, to communicate with them in a language they understand, and to use their familiar frame of reference while trying to explain a new concept. As Ozden concluded in 2007, it would be important to aid the teachers in their effort, by providing in-service training, encouraging a link between different subjects through the curriculum and establishing better conditions in the schools (limited number of pupils per classroom, use of laboratories and teaching materials, etc).

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