JOURNAL OF BALTIC SCIENCE EDUCATION

ISSN 1648-3898

THE ALTERNATIVE CONCEPTIONS OF PRE-SERVICE TEACHERS CONCERNING THE STATUS OF ORGANELLES DURING CELL DIVISION

Mehmet Yakışan

Abstract. *The aim of this study was to identify pre-service teachers' alternative conceptions concerning the status of organelles during cell division. A total of 212 pre-service teachers participated in the study. Data were collected by asking open-ended questions of all pre-service teachers, and semi-structured interviews were conducted with 12 participants. Data were analyzed by coding data segments within 11 categories. Categories were tabulated and interpreted by including sample data sections about the codes.*

The results indicated that there were some students who explained that no organelle dissolved or disappeared and no change occurred in any organelles during cell division besides pre-service teachers who said that all organelles dissolved and disappeared during cell division. In addition, a few pre-service teachers thought that while some organelles dissolved and disappeared, others did not. It was understood that those pre-service teachers were confused about which structures and organelles disappeared and which ones continued their existence, and they had various alternative conceptions. Moreover, pre-service teachers had alternative conceptions regarding the status of organelles particularly about structures such as chromosome, centrosome, DNA, and RNA.

Key words: *alternative conceptions, cell division, organelles, pre-service teachers.*

Mehmet Yakışan
Ondokuz Mayıs University, Turkey

Introduction

Science educators conduct research to determine methods pre-service teachers to learn science concepts and concepts more easily and comprehensively. However, certain difficulties and ambiguities are experienced in many complex scientific subjects (Bahar, Johnstone, & Hansell, 1999), often leading to alternative conceptions in the minds of students (Öztaş, Özay, & Öztaş, 2003). Previous research has demonstrated that students and pre-service teachers at different grade levels have various alternative conceptions concerning basic biology concepts (Soyibo, 1993). Alternative conceptions are common in abstract, micro-level biology concepts besides concrete biology concepts including growth and development of plants (Barman, Stein, McNair, & Barman, 2006), diversity of living things (Mak, Yip, & Chung, 1999), human organs and systems (Reiss & Tunnicliffe, 2001), and ecological concepts (Leach, Driver, Scott, & Wood-Robinson, 1996). A variety of alternative conceptions have also been found in biology concepts involving microscopic level abstract concepts such as osmosis and diffusion (Odom, 1995), photosynthesis (Amir & Tamir 1994), cell structure (Storey, 1990; Zamora and & Guerra, 1993), genetics (Stewart & Van Kirk, 1990; Cavello & Schafer, 1994; Temelli, 2006), and protein synthesis (Sinan, Yıldırım, Kocakülah, & Aydın, 2006). Cell division, appears to be one of the primary topics students have the most difficulty in learning (Smith, 1991). In other words, students have a high number of alternative conceptions with regard to cell division. Dikmenli (2010) found that students were confused on basic concepts about cell division such as the phases and events taking place. Alternative conceptions regarding cell division, specifically meiosis (Brown, 1990; Stewart, Hafner, & Dale, 1990; Kindfield, 1994), the number and structure of chromosomes (Kindfield, 1991), and the behaviors of chromosomes and genes during meiosis (Stewart & Dale, 1989) have all been studied. However, previous research has mostly focused on cell division in terms of events related to genetic concepts such as DNA, chromosomes, and genes. To put

it in another way, previous research has centered upon the content of cell and cell division, which has been reduced to nuclear division. Therefore, an attempt has been made to determine the alternative conceptions of pre-service teachers about the relationship between DNA and chromosomes as well as the action, number, structure, and behaviors of chromosomes during cell division phases. The present study covered pre-service teacher views regarding behaviors and status of organelles during cell division. In other words, this study aimed at identifying pre-service teachers' alternative conceptions concerning probable changes of organelles and what happens to the organelles during cell division.

Methodology of Research

Participants

A total of 212 pre-service science and mathematics teachers from Turkey participated in the present study. 77 of them studied in the field of biology education, 47 studied in the field of physics education, 42 studied in the field of chemistry education, and 46 studied in the field of mathematics education. In addition, 12 pre-service teachers were selected randomly from among the above-mentioned 212 pre-service teachers (3 from each field) for interview.

Instrument and Procedures

Pre-service teachers were asked open-ended questions for data collection. In addition, semi-structured interviews were conducted with 12 pre-service teachers. Within the scope of preparation, a pilot study was carried out with 32 pre-service teachers who had similar characteristics to the pre-service teachers participating in the present study. The question, "What happens to organelles during cell division?" was asked in the pilot study. The obtained data were examined, and additional questions were developed based on the answers provided by pre-service teachers participated in the pilot study. The prepared open-ended questions were presented to two scientists who specialized in the field and determined to be valid. Those open-ended questions were asked to the study group. Pre-service teachers were requested to explain the reasons underlying their answers to the open-ended questions. The same questions were asked of the 12 pre-service teachers who were randomly selected from the study group for interviewing. New questions were also posed according to their answers.

Data Analysis

The data acquired via open-ended questions and interviews were analyzed in stages through qualitative data evaluation methods. The opinions of two scientists who specialized in cells and genetics were requested in order to verify scientific truth of the obtained data. Data were understood to be valid. At the next stage, data were revised via qualitative data evaluation program several times to be divided into data sections. Then, codes indicating data sections were assigned and the data were combined in categories based on similarities. The opinions of the experts were taken in regard as to whether the data sections and codes were accurate. Those codes on which no consensus was reached were removed, while codes considered similar were combined under a common code. The finalized categories and related codes are presented in tables below.

Results of Research

After the analysis of data we have results that pre-service teachers were confused and had alternative conceptions concerning the status of organelles during cell division. The codes obtained based on pre-service teacher data are presented in categories below along with sample pre-service teacher data sections.

One major category of pre-service teachers' conceptual understanding emerged from data was the idea that all organelles dissolve and disappear during the cell division. Pre-service teachers' alterna-

tive conceptions relevant to this category can be seen in Table 1. Some samples of data excerpts are provided below Table 1.

Table 1. Alternative conceptions of pre-service teachers on the disappearance and dissolution of organelles.

Topic		Alternative Conceptions	
1	All organelles dissolve and disappear during cell division.	1.1.	All organelles dissolve and disappear.
		1.2.	Organelles disappear during cell division, but reemerge at the end of division.
		1.3.	During cell division, the membranes of organelles dissolve, and their ingredients are scattered in the cytoplasm.

Pre-service teachers stated that all organelles dissolved and disappeared during the division of a eukaryotic cell, but they reemerged in the new cells coming out at the end of division. A series of sample pre-service teacher views are as follows:

Researcher (R): What happens to organelles in the cell during cell division? Why?

Pre-service teacher (S): They dissolve and disappear.

R: Why?

S: Because, when chromatids and chromosomes withdraw to the poles during division, the existence of organelles is somewhat… All in all, they have performed their tasks. They disappear because they are not needed anymore.

Another pre-service teacher has a similar alternative conception as follows:

R: Do you agree with the statement, "All organelles dissolve and disappear during cell division."?

S: I am not sure about the accuracy of this statement, but at least I know that organelles do not exist during cell division.

The same question was answered by another pre-service teacher: "*While new cells are being formed, the organelles in the old cell give their codes and disappear. They leave their models, but disappear and dissolve themselves.*" Another pre-service teacher provided his idea as follows:

S: DNA and chromosomes do not dissolve and disappear. Other organelles dissolve and disappear.

R: Why do not DNA and chromosomes dissolve and disappear?

S: When organelles dissolve and disappear, there needs to be an organelle to create and synthesize them. (DNA and chromosomes are referred to as an organelle by the pre-service teacher)

R: Why do other organelles dissolve and disappear?

S: To minimize energy loss in the cell.

Likewise, a pre-service teacher holding the thought, "*Organelles are digested and broken into pieces.*" said, "*Because the cell concentrated on division.*" when he was asked about the reason for his thought.

Another pre-service teacher expressed her opinion as follows: "*Organelles disappear during cell division, but they reemerge after the division. For example, when an organelle is found during cell division, it must be an organelle coming from the old cell. It does not represent the new cell. A new organelle will emerge if there is a new cell.*" The statement of this pre-service teacher indicates that all organelles disappeared during cell division, and new organelles were formed in the new cell.

Some pre-service teachers stated that organelles did not completely disappear physically during cell division, but their membranes dissolved and their ingredients dissipated into the cytoplasm. In other words, dissolution in the cell did not eliminate organelles completely, and a break-up took place in the membrane of the organelle. In this respect, one pre-service teacher observed:

- *Organelles do not disappear. Their membranes dissolve. Their ingredients flow into cytoplasm. When cell division comes to an end, dissolved membranes revert back.*

Another explained:

- *No organelle disappears. We assume so when we see their membranes dissolving. They flow into cytoplasm because their membranes dissolve. This is because they do not have any task during division. Nuclear membrane dissolves, and reemerges later on. Only nucleus is emphasized during the teaching of cell division. Other organelles are similar to nucleus, too.*

In contrast to the above pre-service teacher views, another group of pre-service teachers believed that no organelles dissolved and disappeared during division.

Table 2. Alternative conceptions of pre-service teachers against the disappearance and dissolution of organelles.

Topic		Alternative Conceptions	
2	No organelle dissolves or disappears	2.1.	No organelle disappears during division.
		2.2.	Organelles are innate.
		2.3.	Not all organelles can disappear.
		2.4.	No cell can exist without organelle.
		2.5.	Since cell division is not about organelles, they are not affected by division.

In regard to what happens to the organelles during cell division, some pre-service teachers thought that no organelle disappeared during division. In this regard, one pre-service teacher said, "*Chromosomes that are in the cell during division are demonstrated. This is because division takes place in the DNA of the cell. However, Golgi apparatus or endoplasmic reticulum meets the membrane needs of organelles.*" The pre-service teacher indicated that no change occurred during division in organelles such as the nucleus, endoplasmic reticulum, and Golgi complex, whose membranes were broken down during cell division.

Additional views of pre-service teachers included:

- *No organelle disappears. It is not possible for such organelles as mitochondria, chloroplast, and nucleus to disappear*.
- *Since all organelles must exist in the new cell, no organelle disappears during cell division. On the contrary, they double. They pass to the new cell during division.*
- *Organelles do not disappear during cell division. They cannot function if they disappear. Functions belonging to a living thing are not fulfilled. When such functions are not fulfilled, vital actions come to an end.*

Some pre-service teachers stated that organelles never disappeared, and existing organelles had been innate. One pre-service teacher stated, "*Organelles are given to a living thing when they are born. So, if they disappeared, there would not be vitality at all.*" Another pre-service teacher indicated, "*The organelles observed during cell formation are innate.*"

Likewise, pre-service teachers who thought that organelles could not disappear or that there could not be a cell without organelles stated that even temporary changes could not take place in organelles during cell division. One pre-service teacher explained, "*Organelles do not disappear. This is because; the organelles of living things reproduce by division during cell division. At cell division stage, organelles are distributed to the cells divided into other cells. Since organelles are the structures ensuring the functional integrity of living things, they cannot disappear.*" Pre-service teachers were worried that organelles would disappear completely and that the cells that emerged later would not have any organelles. A pre-service teacher clearly expressed his concern as follows: "*Organelles have important tasks in the cell. It means that organelles may be needed for division to take place. I think so because I do not have any idea about the following: If organelles disappear during division, how can the new cells developed at the end of division re-emerge when they need such organelles?*"

Some pre-service teachers felt that cell division had nothing to do with organelles, so organelles would not be affected by division by any means. When asked, "If organelles do not disappear during cell division, why are organelles not included in figures about division?" one pre-service teacher said,

"*They are not included because cell division is not very related to other organelles than nucleus.*" Similarly, another pre-service teacher described the irrelevance of organelles saying, "*Division takes place in nucleus. Organelles function upon the instruction of nucleus, which orders only centrosome to form spindle apparatus during division.*" Another pre-service teacher had the same alternative conception, stating, "*Organelles are outside the cell, thus they do not disappear during cell division*."

In general, pre-service teachers thought that cell metabolism continued as it was during cell division and all organelles had to be the same. They clearly expressed this thought by saying, "*If organelles disappear, their functions cannot be fulfilled by another organelle.*"

Table 3. Alternative conceptions of pre-service teachers holding views, "While some organelles dissolve and disappear, others do not dissolve".

Topic		Alternative Conceptions	
3	While some organelles dissolve and disappear, others do not dissolve.	3.1.	During cell division, some organelles dissolve, break up, disappear, but some others do not.
		3.2.	Those organelles which do not have any duty in division dissolve and disappear, but those organelles which have things to do in division do not disappear.
		3.3.	Those organelles which do not have any duty in division are broken up and are used for generation of energy.
		3.4.	The organelles which complete their tasks disappear.
		3.5.	Some organelles are harmful. These organelles disappear during division.
		3.6.	Spindle apparatus disappears.
		3.7.	Centrosome disappears.
		3.8.	Ribosome remains while other organelles disappear.
		3.9.	Organelles about protein synthesis do not disappear during division.
		3.10.	Endoplasmic reticulum and Golgi complex do not disappear.
		3.11.	Mitochondria does not disappear. Events take place in mitochondria.
		3.12.	Mitochondria functions more during division.
		3.13.	Only nucleus disappears. Others do not disappear.
		3.14.	Nucleolus may disappear. Other organelles do not disappear.

Pre-service teachers stated that some organelles dissolved, broke up, or disappeared during cell division while some others did not. These pre-service teachers were asked, "Which organelles disappear? Which organelles do not disappear? Why?" Some pre-service teacher answers follows:

- *Those organelles which do not take charge during division disappear. Others do not disappear.*
- *Not all organelles are needed during cell division. For that reason, while some organelles disappear, those organelles which help cell division do not disappear. All in all, cell division is an event that requires energy, and there is a need for organelles that generate energy.*
- *Those organelles which are unnecessary may be broken up and used for generation of energy. Some of these organelles are converted into energy at interphase.*
- *At prophase, centrosomes are used for meeting the energy need.*
- *Those organelles which play an active role in the continuance of metabolism must not disappear. However, harmful organelles must disappear.*
- *Lysosome disappears. Organelles such as ribosome, mitochondria, and Golgi complex do not disappear.*
- *Lysosome disappears. It has a specific task. After it completes its work, it may disappear. Ribosome does not disappear. It must be in the cell continuously because it always has a task to fulfill.*
- *Nucleus and nucleolus disappear. Mitochondria, Golgi apparatus, and endoplasmic reticulum do*

not disappear. They conduct important activities for other cells to remain alive during division.

- *Nucleus and endoplasmic reticulum disappear. DNA, mitochondria and Golgi complex do not disappear.*
- *Nucleus does not disappear, but other organelles disappear.*
- *Nucleus and mitochondria do not disappear. Because mitochondrion is the energy source of cell.*
- *Ribosome and nucleus do not disappear, but other organelles disappear.*
- *While nucleus and nucleolus disappear, other organelles do not disappear.*
- *Nucleus disappears, but others do not disappear. This is because; nuclear membrane dissolves the structures in it double, and a new cell is formed.*
- *Spindle fibers and nucleolus disappear.*
- *Centrosome which exists in animal disappears during cell division. There is no centrosome in plant cell. Thus, it does not appear in the plant cell.*
- *Ribosome does not disappear. Centrosome dissolves.*
- *Division occurs thanks to spindle apparatus since there will be no centrosome after a while.*
- *Centrosome disappears. Nuclear membrane dissolves.*
- *Nuclear membrane disappears as the cell is divided into two parts.*
- *Cell wall disappears, but mitochondria do not disappear.*
- *Ribosome, DNA, and RNA do not disappear. These organelles are used for synthesizing new organelles.*
- *Since energy is needed only during division, mitochondria functions more.*
- *Mitochondria do not disappear. These events take place thanks to mitochondria.*
- *Ribosome, mitochondria, and centrosome do not disappear. Other organelles disappear. Ribosome is used for generating amino acid while mitochondria are used for generating energy. Centrosome is used for division to take place.*
- *Centrosomes disappear after they fulfill their tasks. Others do not disappear.*

A great majority of pre-service teachers in this category stated that those organelles which do not have a duty during division or which fulfilled their tasks during division dissolved and disappeared, while those which in charge of completing a task did not disappear. However, it was understood that they were confused and had alternative conceptions in regard to which organelles dissolved and disappeared and which organelles did not disappear.

Table 4. Alternative conceptions of pre-service teachers holding views "Organelles replicate themselves during division".

	Topic		Alternative Conceptions
4	Organelles replicate themselves during the division	4.1.	Organelles replicate themselves during division.
		4.2.	Organelles form new organelles by dividing into two during division.
		4.3.	As chromosomes are replicated in cell, other organelles are replicated, too.

Pre-service teachers had some alternative conceptions in regard to how the number of organelles in a cell increased (i.e. how new organelles came out). Although such organelles as mitochondria and chloroplast, which have unique genetic materials, reproduce by self-replication, a considerable number of pre-service teachers stated that all organelles increase in number by replicating themselves immediately before or after division. Pre-service teacher statements concerning this alternative conception are as follows:

R: What happens to organelles in the cell during cell division? Why?

S: Organelles replicate. In other words, they increase in number. They double. Two cells will be formed. For instance, in mitotic division, two new cells will be formed. Let's assume that there will be one ribosome in each cell. If there are 10 ribosomes in one cell, we will need 20 ribosomes so that there will be 10 ribosomes each cell. 10 more

will be synthesized to achieve 20 so that division into two cells becomes possible.

Similarly, some pre-service teachers said that the organelles in the cell replicated themselves and increased in number as follows:

- *I remember that organelles do not disappear, but replicate themselves during cell division.*
- *Since organelles replicate themselves during cell division, they bear all characteristics of the cell divided.*
- *A eukaryote cell is a cellular structure that has membranous organelles. During the division of a eukaryote cell, organelle replication and chromosome division occur*.

While some pre-service teachers stated that organelles increased through replication, some others said that organelles increased by dividing. In this regard, some examples of pre-service teacher views are as follows:

- *Cell division refers to the emergence of a new cell out of a cell where this new cell is the same as the one out of which it emerges. Organelles divide in the same manner, and there is an increase in amount.*
- *Nucleus disappears at one stage during division while some organelles divide into two parts in the middle.*
- *Organelles may divide and double in number during cell division.*
- *While some organelles divide into two parts, some others disappear during the division of cells*.

Some pre-service teachers regarded the chromosome as an organelle. Thus, they had a alternative conception that what took place in chromosomes would take place in other organelles, too. This alternative conception was clear from the following statement: "*As chromosomes replicate in cell, other organelles replicate, too.*"

Table 5. Alternative conceptions of pre-service teachers holding views "Some organelles metamorphose and change in form during division".

	Topic		Alternative Conceptions
5	During cell division, some organelles metamorphose and change in form.	5.1.	Some organelles metamorphose during cell division.
		5.2.	Organelles do not disappear during division. They just lose their functions.
		5.3.	Organelles just change in form, but they do not disappear.
		5.4.	Organelles separate into their constituents.
		5.5.	Organelles turn into chromatin fibers.

Some pre-service teachers thought that organelles metamorphosed, changed in form, lost their functions, separated into their constituents, or turned into other structures in the cell during cell division. In this matter, some pre-service teacher views are as follows:

- *Organelles just metamorphose, they do not disappear completely.*
- *No organelle disappears. They just change in form. The new organelle to emerge receives its root from the former one. If the former disappeared, the new organelle could not emerge and vitality might not continue*.
- *Some organelles that function during division metamorphose later on.*
- Some organelles shorten during division. They do not disappear.
- In my opinion, no organelle disappears. They just change in form and size.
- Organelles do not disappear completely. Organelles metamorphose. They change in form and size, and re-emerge.
- Some of the organelles do not disappear as they bear vital characteristics. Some of them divide, change, and vary.
- *Organelles lose their own characteristics, and turn into structures with different characteristics.*

Some pre-service teachers thought that organelles turned into different structures in the cell. For

example:

- *Centrosomes form chromosomes by shortening and thickening*.
- *Organelles turn into chromatin fibers.*

Table 6. Alternative conceptions of pre-service teachers about where cell division takes place.

	Topic		Alternative Conceptions
6	Where Cell Division Takes Place	6.1.	Cell division takes place in nucleus alone.
		6.2.	Cell division takes place in nucleus.
		6.3.	Organelles do not exist in the places where chromosomes replicate. Thus, they do not appear during cell division.

Some pre-service teachers thought that events during cell division took place in nucleus, rather than the cell. Some pre-service teacher views are as follows:

- *Because this cell division takes place in nucleus*
- *Division takes place in nucleus. Organelles function upon the instruction of nucleus, which orders only centrosome to form spindle apparatus during division.*

Pre-service teachers were asked why only chromosomes appear in figures about cell division in books, and why organelles except for centrosomes are not excluded, and they explained:

- The figures drawn refer to the division in the nucleus.
- Because this cell division takes place in nucleus
- They are not included because cell division is not very related to other organelles than nucleus.
- No organelle disappears. They may change in form for division to take place and finish. Organelles wait in cytoplasm, but pass to the other cell at division stage. Centrosomes are about nucleus. Therefore, only nucleus is demonstrated during division.

Pre-service teacher expressed that cell division is related to the nucleus alone and has nothing to do with other organelles. Moreover, almost all pre-service teachers stated that the nuclear membrane dissolved during cell division demonstrating their lack of awareness about many concepts and events. One pre-service teacher said, "*Organelles do not exist in the place where chromosomes replicate, thus they do not appear.*" This answer implies that it is in the nucleus where chromosomes replicate and cell division takes place and that organelles cannot be seen during cell division because they do not exist in the nucleus.

Table 7. Alternative conceptions of pre-service teachers about the location of organelles.

	Topic		Alternative Conceptions
7	The place of organelles	7.1.	Organelles are hidden in general.
		7.2.	During division, organelles are included in the chromosome and take charge there.
		7.3.	Organelles are in the nucleus.
		7.4.	Organelles are not in the cell.

The pre-service teachers also had alternative conceptions regarding the location of cell organelles. When asked why no organelles except for the centrosome were included in figures about cell division, one a pre-service teacher said, "*They may not be included because organelles are hidden in genes.*" Another pre-service teacher indicated, "*I think the organelle is included in the chromosome. It functions in the chromosome even if it does not perform the same task as the chromosome.*" Since cell division is taught to pre-service teachers based on the action of chromosomes alone, pre-service teachers have a tendency to think that organelles are hidden in genes or included in chromosomes during division.

When a pre-service teacher who believed no organelle would disappear, was asked why, the response was, "*During division, only nuclear membrane disappears, and organelles are scattered inside the cytoplasm.*" This answer clearly shows the belief that organelles exist in the nucleus. In reply to the same question, another pre-service teacher emphasized the point that organelles are not in the cell, saying, "*This is because; organelles are not in the cell. They are outside the cell, thus they do not disappear during cell division.*"

Table 8. Alternative conceptions of pre-service teachers about the chromosome during cell division.

Topic		Alternative Conceptions	
8	The concept of chromosome	8.1.	Chromosomes are in the forefront during cell division. Division is only about the events taking place in chromosomes.
		8.2.	Chromosome strands dissolve during division.
		8.3.	Chromosomes do not exist during division. They re-emerge out of chromatin fibers at the end of division.
		8.4.	Chromosomes turn into chromatids.
		8.5.	Chromosomes withdraw to poles and form spindle apparatus.
		8.6.	The number of chromosomes increased through cell division.

Pre-service teachers obviously had various alternative conceptions regarding the concept of chromosomes during cell division. A considerable number of pre-service teachers thought that chromosomes were in the forefront during cell division, that chromosomes ensured division, and that division was only related to the events taking place in chromosomes.

When asked why no organelles except for the centrosome were included in figures about cell division. Pre-service teachers answered as follows:

- *Cell division is already about the division of chromosomes.*
- *It is not organelles, but chromosomes that ensure cell division. It is DNA. Thus, others, organelles, may not be in the forefront.*
- *This is because; some organelles disappear during cell division. Chromosomes are in the forefront more during cell division.*
- *It is chromosomes and centrosomes that fulfill the main task during division.*
- *Organelles do not appear because cell division affects chromosomes.*

Pre-service teachers stated that division was related to and affected chromosomes alone, and organelles were not included in figures about division because division did not affect organelles.

Some pre-service teachers stated that chromosomes dissolved during cell division or did not appear during cell division but re-emerged out of chromatin fibers at the end of division. Such alternative conceptions of pre-service teachers are clear from the comments below:

- Organelles do not disappear. However, we know that chromosome strands dissolve.
- No organelle dissolves or disappears during division.
- *This is because; no organelle disappears. Only some transformations may take place. For example, chromosomes do not appear during division. However, they have not disappeared. They have just turned into chromatin fibers. After division, chromatin fibers turn into chromosomes again.*

Some pre-service teachers stated that chromosomes turned into chromatids during cell division as follows: "*Chromosomes turn into chromatids. Spindle fibers and nucleolus disappear.*"

Some pre-service teachers said that chromosomes withdrew to poles and formed spindle apparatus as follows: "*As far as I remember, chromosomes withdrew to poles, formed spindle apparatus, and re-emerged.*"

In addition, pre-service teachers expressed alternative conceptions that the number of chromosomes increased: "*As a result of cell division, cell reproduces by division and renews itself. The number of chromosomes increases.*"

Table 9. Alternative conceptions of pre-service teachers about the concepts of DNA and RNA

Topic		Alternative Concepts	
9	The concepts of DNA and RNA	9.1.	DNA and RNA are organelles.
		9.2.	Some parts of DNA disappear while some others do not disappear.
		9.3.	During interphase, DNA dissolves and turns into fibers.

Some pre-service thought DNA and RNA were organelles. One pre-service teacher view is as follows:

S: During cell division, some organelles may undergo change or disappear completely so as to be used for different purposes. However, some of them do not change. DNA and RNA are among non-changing ones.

R: Which organelles disappear during division? Which organelles do not disappear? Why?

S: Nuclear membrane disappears as the cell divides into two parts Ribosome, DNA, and RNA do not disappear. These organelles are used for synthesizing new organelles.

Some pre-service teachers who regarded DNA as an organelle thought that some parts of DNA disappeared during division. When asked which organelles do or do not disappear during division and why? one pre-service teacher revealed this alternative conception by answering "*Some parts of DNA disappear. Some do not disappear. Those which are to replicate when they divide pass to another part.*"

Similarly, some pre-service teachers stated that DNA dissolved and turned into fibers at preparation stage: "*Cell division includes various phases including interphase, prophase, and anaphase. At these phases, various events take place. DNA dissolves and turns into fibers at interphase.*"

Table 10. Alternative conceptions of pre-service teachers about the concept of centrosomes.

Topic		Alternative Conceptions	
10	The concept of centrosome	10.1.	Division is ensured by centrosome.
		10.2.	Organelles other than centrosome do not play any role in division.
		10.3.	Centrosome is not needed during cell division.
		10.4.	Centrosome disappears during division.
		10.5.	Centrosome and chromosomes are the organelles ensuring the transfer of inheritance.
		10.6.	Centrosomes form chromosomes by shortening and thickening.

Various alternative conceptions were determined in regard to the concept of the centrosome. The most common alternative conception was that the centrosome ensures cell division:

- Centrosome exists in the animal cell. Centrosome ensures division.
- Only centrosomes are included in figures about cell division because it is centrosomes which enable cell division.

In addition, pre-service teachers stated that other organelles did not play any role in division. This alternative conception of pre-service teachers was clear in their following statements:

- *Since other organelles than centrosomes do not play any role in division, they are not included in figures.*
- *In fact, no organelle disappears here. Since other organelles than centrosome do not fulfill any task in cell division, they are not included in figures.*

In contrast to the thought that centrosome is the only organelle that plays an active role in division, some pre-service teachers thought that the centrosome was not needed during division, the centrosome disappeared during division, or the centrosome became evident during division and disappeared later:

- Centrosome disappears and nuclear membrane dissolves during division.

- When cell division is to take place, centrosome disappears or is not seen.
- Centrosome becomes evident during cell division. Then, it disappears.

Some pre-service teachers thought that the centrosome was related to chromosomes and took part in the transfer of inheritance. One pre-service teacher explained: "*Centrosome and chromosome that take charge during division enable inheritance to pass to other cells exactly as it is without losing anything. Other organelles are not related to inheritance, but are associated with other vital activities.*"

Some pre-service teachers thought that some organelles disappeared during division. Those pre-service teachers were asked, how those organelles that disappear re-emerge and which structures enable this formation. One pre-service teacher replied with the alternative conception, "*Centrosomes, spindle apparatus, and so on. Centrosomes constitute chromosomes by shortening and thickening.*"

Table 11. Alternative conceptions of pre-service teachers about structures that fulfill tasks of organelles thought to disappear.

Topic		Alternative Conceptions	
11	The structures that fulfill the tasks of those organelles which are thought to disappear during division	11.1.	The organelles which do not disappear fulfill the tasks of those organelles which disappear during division.
		11.2.	Nucleus fulfills the tasks of those organelles which disappear during division.
		11.3.	DNA fulfills the tasks of those organelles which disappear during division.
		11.4.	Chromosome fulfills the tasks of those organelles which disappear during division.
		11.5.	Enzymes fulfill the tasks of those organelles which disappear during division.
		11.6.	The cell contains auxiliary elements that can act as the substitutes of organelles.
		11.7.	The organelles of other cells fulfill the tasks of those organelles which disappear during division.

When asked which structures fulfill the tasks of those organelles which disappear during cell division, the pre-service teachers gave the following answers:

- *The organelles which do not disappear fulfill the tasks of those organelles which disappear during division*.
- *Other organelles in the cellular membrane or cytoplasm fulfill the tasks of those organelles which disappear during division.*
- *Nucleus fulfills the task. This is because; the nucleus contains DNA. All codes are held by DNA.*
- *Nucleus and DNA constitute the basis of a cell. Nucleus and DNA can fulfill the task.*
- *Ribosome, DNA, and RNA.*
- Enzymes fulfill the tasks.
- At that time (during cell division), cellular events take place through chromosome and thanks to ribosome.
- Not all organelles disappear. However, when they disappear, the organelles to take on their tasks can be determined by the nucleus.
- Intercellular liquid.
- It may be nucleus or cytoplasm.
- Not all organelles disappear. If they disappear, auxiliary elements may replace them.
- *When some organelles disappear, their tasks are fulfilled by ribosome, mitochondria, etc.*
- *Mitochondria may fulfill tasks.*
- *Organelles in another cell may fulfill tasks.*

The most common answer was that the organelles that did not disappear fulfilled the tasks of those organelles that did disappear during division. In addition, some pre-service teachers thought that the

nucleus or DNA took on the tasks of the missing organelles. Some pre-service teachers further thought that chromosomes, enzymes, or other cell organelles fulfilled the above-mentioned tasks.

As a result; the examination of pre-service teacher views reveals that pre-service teachers are confused and have alternative conceptions of events that take place in cellular structures and organelles during cell division as well as what happens to organelles during the process. Some pre-service teachers thought that all organelles dissolved and disappeared during cell division, some thought that no organelles dissolved or disappeared, and some thought that while some organelles dissolved, other organelles remained exactly as they were and did not undergo any change.

Some pre-service teachers indicated that organelles do not have any task to fulfill or they fulfill their tasks before division or all organelles dissolve and disappear during cell division in order to ensure energy saving, and they re-emerge at the end of division. In addition, pre-service teachers stated that since division was an event related to chromosomes alone, chromosomes played an active role during division and took part at all phases of division while organelles were not related to division and there would be no organelle during division.

Those pre-service teachers who believed that no organelle dissolved or disappeared said that although organelles did not disappear, they metamorphosed, or turned into other structures during cell division.

The pre-service teachers stating that some organelles dissolved, while some others remained exactly as they were without undergoing any change put forward different ideas. A considerable number of these pre-service teachers said that while the organelles taking charge in division did not disappear, those organelles which did not have any task to fulfill or which completed their tasks would disappear. Pre-service teachers especially thought that mitochondria and ribosome did not disappear, but functioned more. While some pre-service teachers thought that organelles other than nucleus would not disappear, some other pre-service teachers felt the centrosome or organelles other than ribosome would disappear. Based on the fact that pre-service teachers gave a great variety of answers, it can be said that they do not know what kinds of changes occur in which organelles during division, and they have alternative conceptions in this matter.

Based on the result from these three groups, it is understood that pre-service teachers do not know that the membranes of endomembrane system elements including the nucleus, endoplasmic reticulum, and Golgi complex break up during division, and their integrity is disrupted for a short time.

Moreover, pre-service teachers have alternative conceptions about the location of organelles, the environment where division takes place and other structures in the cell.

Pre-service teachers also had alternative conceptions in regard to how the number of organelles in the cell increased (i.e. how new organelles emerged). Although such organelles as mitochondria and chloroplast, which have unique genetic materials, reproduce by self-replication, a considerable number of pre-service teachers stated that all organelles increased in number by replicating themselves and dividing immediately before or after cell division.

Some pre-service teachers thought that organelles metamorphosed, changed in form, lost their functions, separated into their constituents, or turned into other structures during cell division.

The examination of pre-service teacher views shows that they thought division occurred in the nucleus but not in the cell. Almost all pre-service teachers stated that the nuclear membrane dissolved during cell division. The belief that division occurs in the nucleus was an indicator of the poor awareness of pre-service teachers about many concepts.

While some pre-service teachers thought that organelles were in the nucleus, others argued that there was no organelle in the nucleus, which is where they thought cell division took place, thus organelles were not included in figures and pictures about cell division. Moreover, some pre-service teachers had the alternative conception that organelles were hidden in genes or included in chromosomes, fulfilled tasks of the chromosome.

Various alternative conceptions were found concerning the concept of the chromosome. A considerable number of the pre-service teachers thought that chromosomes were in the forefront during cell division, that chromosomes ensured division, that division was only related to events taking place in the chromosome, and that division only affected chromosomes. These pre-service teachers thought stated

that organelles would not be included in and appear in figures related to division. On the contrary, some pre-service teachers stated that chromosomes dissolved during cell division, while yet others believed that while chromosomes did not appear during cell division, they re-emerged out of chromatin fibers or turned into spindle apparatus at the end of division.

While some pre-service teachers regarded DNA and RNA as organelles, others thought that parts of DNA disappeared during division or DNA dissolved and turned into fibers at interphase.

The most common alternative conception about centrosomes among pre-service teachers was found to be that the centrosome was the structure ensuring cell division and other organelles did not play any role. Some pre-service teachers thought that centrosomes took part in the transfer of inheritance along with chromosomes, and centrosomes formed chromosomes by shortening and thickening. Some pre-service teachers stated that the centrosome disappeared or was not needed during division.

Discussion

The research findings revealed that the pre-service teachers did not have necessary knowledge to teach cell division subjects meaningfully and sufficiently, and had some alternative conceptions on the above-mentioned subjects. The previous research reports that pre-service teachers and students from different grades have alternative conceptions about cell division (Wright & Newman, 2011; Quinn, Pegg, & Panizzon, 2009; Chattopadhyay, 2005; Wood-Robinson, Lewis, & Leach, 2000). As distinct from the alternative conceptions about cell division found in the related literature, the present study demonstrated the alternative conceptions held by the pre-service teachers concerning the statuses of cellular organelles and structures during cell division. The related literature contains just a limited number of studies on the statuses of cellular organelles and the changes likely to occur in the cellular structures during division.

Some of the pre-service teachers included in the present study stated that no change occurred in the organelles, while some others told that the number of the organelles doubled during cell division. This opinion of the pre-service teachers stems from their thought that cellular metabolism runs normally without slowing down and halting even in special conditions like cell division, and thus there must be no change in organelles.

A considerable amount of the pre-service teachers thought that all organelles disappeared through dissolution, while some of the pre-service teachers were of the opinion that organelles had nothing to do with division and thus there was no organelle in the environment where division took place. The cell division figures in course books or other sources and the teaching activities created by using such figures have a big effect on the formation of these kinds of alternative conceptions. As a matter of fact, the pre-service teachers stated their reason for this thought as follows: no organelle is included in the pictures or figures about cell division, and microscopic images about cell division do not contain any structure other than chromosomes. In search of the causes of misconceptions, it can be said that the deficiencies and conceptual problems in source books and in the learning activities created by using such books lead to ambiguity among students, and such ambiguity causes alternative conceptions among students (Dikmenli, Çardak and Öztaş, 2009; Soyibo, 1993). Another cause of the above-mentioned alternative conceptions is that cell division and organelle are micro-level concepts. The previous research on the comprehension of concepts at different organizational levels in science generally indicates that micro-level concepts (cellular and molecular concepts) are understood more difficultly in comparison to macro-level concepts (Marbach-Ad and Stavy, 2000; Lazarowitz and Penso, 1992).

The most important reason for the emergence of alternative conceptions found in the present study is that cell division is reduced to nuclear division in books and scientific studies due to its importance, and cytokinesis and how the organelles in the cytoplasm are affected by division are ignored or neglected. The results of the previous research confirm this inference. As a matter of fact, the studies involving activities aimed at determining the alternative conceptions of students and teachers in cell divisions generally deal with cell division within the framework of genetic materials, and make observations about the structures, amounts, and actions of chromosomes (Chattopadhyay, 2012; Wynne, Stewart, & Possmore, 2001; Lewis, Leach, & Wood-Robinson, 2000; Lewis & Wood-Robinson, 2000; Smith

& Kindfield, 1999; Hernandez & Caraballo, 1993; Mertens & Walker, 1992).

It is normal that topics such as genetic materials and the behaviors of chromosomes, genes, and allele genes are widely covered in scientific studies because they are essential for cell division. However, some problems emerge as cell divisions are taught only in terms of nuclear division, scientific research on cell division determines only the alternative conceptions about genetic materials, and organelles and other cellular structures are ignored in scientific studies. As a result, students get confused and have alternative conceptions concerning changes in organelles during cell division and how organelles act during the process. In parallel with the findings of the present study, Flores, Tovar and Gallegos (2003) determined that students had difficulty establishing a relationship among cellular structures and functions; they also state that although students know that the cell is the fundamental unit of an organism, they experience difficulties understanding its internal structure. They especially, emphasized how students know cell organelles by name but do not know their functions. In addition, Zamora and Guerra (1993) asked students to draw a picture of cell and concluded that the nucleus was the most frequently identified component while cytoplasm (liquid) and cell membranes were additionally included in some cases. The results of these studies demonstrate that students have cognitive problems with cellular structures and organelles parallel with the results of the present study.

More specifically, the results of the present study show that students consider cell division within the framework of the nucleus; the genetic materials contained by it, and associated concepts. The fact that the role of cell divisions related to nuclear division is overemphasized, cytoplasm division is rarely covered, and no organelles other than nucleus and centrosome are included in pictures about division cause the alternative conception that organelles have nothing to do with cell division, that there are no organelles in places where cell division occurs, that organelles do not take part in cell division, or that organelles dissolve and disappear during division.

Organelles may not be seen through microscopes during cell division phases due to the fact that refraction indices of some organelles are close to cytoplasm or the chemicals used to see chromosomes clearly may disrupt other organelles. However, the manifestation of the true status of organelles through figures in books and scientific papers will enable pre-service teachers to learn more accurately cells and cell divisions in all aspects.

Conclusion

The present study is one of the pioneering studies focusing on cytokinesis and thus the statuses of organelles and cellular structures during cell division, Being different from the studies determining the alternative conceptions concerning cell divisions, The previous studies found in the related literature mostly address the subject of cell division from the perspective of nucleus and karyokinesis alone. In parallel with that, the books and activities aimed at teaching the subjects about cell give more weight to nuclear division, but cover cytokinesis superficially and deficiently. To fill this deficiency, the present study determined the alternative conceptions regarding the statuses of the organelles in cytoplasm during cell division. Pashley (1994) emphasizes the importance of determining alternative conceptions to replace them with scientifically correct knowledge and to increase the number of students achieving this replacement. The determination of alternative conceptions may make important contributions to the realization of conceptual awareness and thus conceptual change. In this regard, the present study's detection of new alternative conceptions concerning the statuses of organelles and other structures regarding cell division is important in that it may allow the subject of cell divisions to be taught in all aspects.

The present study was conducted on pre-service teachers. This is because; teachers may transfer their misconceptions as well as deficient and incomplete knowledge to their students during teaching activities (Yip, 1998). The determination of new alternative conceptions among pre-service teachers is important in that it enables pre-service teachers to become aware of and eliminate their misconceptions before starting the teaching profession. Therefore, the alternative conceptions that may be held by pre-service teachers should be determined through various studies. Based on the research results, the teaching of pre-service teachers should be shaped accordingly, and necessary conceptual change should be achieved.

The alternative conceptions determined in the present study should be taken into account, and

possible changes in organelles besides chromosomes should be included in both the figures in books and the teaching activities to be conducted. In this way, better and more scientific learning may be achieved on this subject.

Various materials and strategies including animations, models, analogues, etc. should be used in order to remove the alternative conceptions of pre-service teachers.

References

Amir, R., & Tamir, P. (1994). In-depth analysis of misconceptions as a basis for developing research-based remedial instruction: the case of photosynthesis. *The American Biology Teacher,* 56, 94-100.

Bahar, M., Johnstone, H. A., & Hansell, M. (1999). Revisiting learning difficulties in biology. *Journal of Biological Education*, *33* (2), 84-87.

Barman, C., Stein, M., McNair, S., & Barman, N. (2006). Students' Ideas about plants and plant growth. *The American Biology Teacher,* 68(2), 73-79.

Brown, C. R. (1990). Some misconceptions in meiosis shown by students responding to an advanced level practical examination question in biology. *Journal of Biological Education, 24* (3), 182-185.

Cavello, A. M. L., & Schafer, L. E. (1994). Relationship between students' meaningful learning orientation and their understanding of genetic topics. *Journal of Research in Science Teaching, 31* (4), 393-418.

Chattopadhyay, A. (2005). Understanding of genetic information in higher secondary students in northeast India and the implications for genetics education. *Cell Biology Education*, *4* (1), 97-104.

Chattopadhyay, A. (2012). Understanding of mitosis and meiosis in higher secondary students of northeast India and the implications for genetics education. *Education*, *2* (3), 41-47.

Dikmenli, M. (2010). Misconceptions of cell division held by student teachers in biology: A drawing analysis. *Scientific Research and Essay, 5* (2), 235-247.

Dikmenli, M., Çardak, O., & Öztaş, F. (2009). Conceptual problems in biology-related topics in primary science and technology textbooks in Turkey. *International Journal of Environmental & Science Education, 4* (4), 429-440.

Flores, F., Tovar, M. E., & Gallegos, L (2003). Representation of the cell and its processes in high school students: An integrated view. *International Journal of Science Education, 25* (2), 269-286.

Hernández, V., & Caraballo, J. N. (1993). Development of a diagnostic test to detect misconceptions in Mendelian genetics and meiosis. In J. D. Novak (Ed.), *In 3rd International Seminar on Misconceptions and Educational Strategies in Science and Mathematics*. Ithaca, New York: Cornell University.

Kindfield, A. C. H. (1991). Confusing chromosome number and structure: A common student error. *Journal of Biological Education, 25* (3), 193-200.

Kindfield, A. C. H. (1994). Understanding a basic biological process: expert and novice models of meiosis. *Science Education, 78* (3), 255-283.

Lazarowitz, R., & Penso, P. (1992). High school students' difficulties in learning biology concepts. *Journal of Biological Education, 26* (3), 215-223.

Leach, J., Driver, R., Scott, P., & Wood-Robinson, C. (1996). Children's ideas about ecology: Three ideas found in children aged 5-16 about the interdependency of organisms. *International Journal of Science Education, 18* (2), 129-141.

Lewis, J., & Wood-Robinson, C. (2000). Genes, chromosomes, cell division and inheritance: Do students see any relationship? *International Journal of Science Education, 22*, 177 – 197.

Lewis, J., Leach J., & Wood-Robinson, C. (2000). Chromosomes: The missing link-young person's understanding of mitosis, meiosis, and fertilization. *Journal of Biological Education, 34* (4), 189-199.

Mak, S. Y., Yip, D. Y., & Chung, C. M. (1999). Alternative conceptions in biology-related topics of integrated science teachers and implications for teacher. *Education Journal of Science Education and Technology, 8* (2), 161-170.

Marbach-Ad, G., & Stavy, R. (2000). Students' cellular and molecular explanations of genetic phenomena. *Journal of Biological Education*, *34* (4), 200-206.

Mertens, T. R., & Walker, J. O. (1992). Paper and pencil strategy for teaching mitosis and meiosis, diagnosing learning problems and predicting examination performance. *The American Biology Teacher, 54* (8), 470-474.

Odom, A. L. (1995). Secondary and college biology student's misconceptions about diffusion and osmosis. *The American Biology Teacher, 57*, 409- 415.

Öztas, H., Özay, E., & Öztas, F. (2003). Teaching cell division to secondary school students: an investigation of difficulties experienced by Turkish teachers. *Journal of Biological Education, 38* (1), 13-15.

Pashley, M. (1994). A-level students: their problems with gene and allele. *Journal of Biological Education, 28* (2), 120-126.

Quinn, F., Pegg, J., & Panizzon, D. (2009). First-year biology students' understandings of meiosis: An investigation using a structural theoretical framework. *International Journal of Science Education, 31* (10), 1279-1305.

Reiss, M. J., & Tunnicliffe, S. D. (2001). Students' understandings of human organs and organ systems. *Research in Science Education, 31*, 383–399.

Sinan, O., Yıldırım, O., Kocakülah, M. S., & Aydın, H. (2006). Pre-service primary science teachers' misconceptions about proteins, enzymes and protein synthesis. *G.Ü. Journal of Gazi Education Faculty, 26* (1), 1-16.

Smith, M. U. (1991). Teaching cell division: Students' difficulties and teaching recommendations. *Journal of College Science Teaching, 21*, 28– 33.

Smith, M. U., & Kindfield, A. C. H. (1999). Teaching cell division: Basics and recommendations. *The American Biology Teacher, 61* (5), 366-371.

Soyibo, K. (1993). Some sources of student's misconceptions in biology: A review. In J. D. Novak (Ed.), *In 3rd International Seminar on Misconceptions and Educational Strategies in Science and Mathematics.* Ithaca, New York: Cornell University.

Stewart, J., & Dale, M. (1989). High school students' understanding of chromosome/gene behavior during meiosis. *Science Education, 73* (4), 501-522.

Stewart, J., Hafner, B., & Dale, M. (1990). Students' alternate views of meiosis. *The American Biology Teacher, 52* (4), 228-232.

Stewart, J., & Van Kirk, J. (1990). Understanding and problem solving in classical genetics. *International Journal of Science Education, 12*, 575-588.

Storey, R. (1990). Textbook errors and misconceptions in biology: cell structure. *The American Biology Teacher, 52*, 213-218.

Temelli, A. (2006). Determination of misconceptions concerning genetic subjects of high school students. *Kastamonu Education Journal, 14* (1), 73-82.

Wood-Robinson, C., Lewis, J., & Leach, J. (2000). Young people's understanding of the nature of genetic information in the cells of an organism. *Journal of Biological Education, 35* (1), 29-36.

Wright, L. K., & Newman, D. L. (2011). An interactive modeling lesson increases students' understanding of ploidy during meiosis. *Biochemistry and Molecular Biology Education, 39* (5), 344-351.

Wynne, C. F., Stewart, J., & Passmore, C.(2001). High school students' use of meiosis when solving genetics problems. *International Journal of Science Education, 23* (5), 501-515.

Yip, D. Y. (1998). Teachers' Misconceptions of the circulatory system. *Journal of Biological Education, 32* (3), 207-215.

Zamora, S. E., & Guerra, M. (1993). Misconceptions about cells. *In 3rd International Seminar on Misconceptions and Educational Strategies in Science and Mathematics.* Ithaca, New York: Cornell University.

Received: *August 05, 2013* Accepted: *November 18, 2013*

Mehmet Yakışan Ph.D., Assistant Professor, Ondokuz Mayıs University, Education Faculty, Department of Secondary Science and Mathematics Education, Biology Education, 55200, Samsun, Turkey.
Phone: +90 362 312 19 19-5917.
E-mail: yakisanm@gmail.com.tr, yakisan@omu.edu.tr
Website: http://www2.omu.edu.tr/akademikper.asp?id=1403