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Are the Genetic Materials of Gametes and Somatic Cells Different? The Conceptions of Pre-Service Teachers

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Biology that is a branch of science examining organisms in every aspect has a very wide content. Besides this wide content, there are abstract concepts in some subjects. Various alternative conceptions are determined in different education levels especially in abstract and microscopic biology subjects. The aim of this study is to determine the alternative conceptions of pre-service teachers related with the genetic material in gametes and somatic cells. 97 pre-service teachers that are freshmen at university participated in the research. In order to determine the alternative conceptions about the subject, open-ended questions are asked to the pre-service teachers. Also, 12 pre-service teachers amongst 97 pre-service teachers are selected for semi-structured interviews and interviews are performed. Analysing the data obtained from the open-ended questions and interviews, it is determined that pre-service teachers have many alternative conceptions about the genetic materials in gametes and somatic cells. These alternative conceptions are introduced in categories and discussed.

Keywords: alternative conceptions, autosome, gonosomes, pre-service teachers

INTRODUCTION

There are serious difficulties for biology subjects that include many concepts both abstract and concrete to be meaningfully learnt and comprehended by both students and teachers, as well as individuals with different ages and status. According to researches, there are difficulties for many biology subjects especially abstract subjects to be taught by teachers and learnt by students (Wood-Robinson, Lewis and Leach, 2000; Yip, 1998; Turney, 1995; Songer and Mintzes, 1994; Kindfield, 1994; Lazarowitz and Penso, 1992; Westbrook and Marek, 1991). It is stated in various researches that a great number of abstract biology subjects such as cell divisions (Dikmenli, 2010; Lewis, and Wood-Robinson, 2000; Smith, 1991), photosynthesis (*Lonergan*, 2000; Hazel and Prosser, 1994) and protein synthesis (Johnstone and Mahmoud, 1980; Fisher, 1985) particularly are learnt insufficiently and inaccurate by students of all ages and at every instructional level. In the studies performed about which subjects are hardly comprehended by the students it is indicated that concepts especially related with genetics are hardly comprehended and that there are difficulties in learning them (Bahar, 2002; Bahar, Johnstone, and

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Hansell, 1999). These concepts that cause difficulty for students to learn and for teachers to teach have generally prerequisites for complicated biology subjects. Insufficiencies about teaching and learning these concepts that are perceived as difficult cause students develop scientifically inaccurate thoughts about the subject (Mak, Yip, and Chung 1999). In other words the difficulties and uncertainties about learning the same biology concepts may cause the formation of alternative conceptions in students' minds.

Studies made about biology education show that students, pre-service teachers at every instructional level and even teachers have alternative conceptions about the concepts that constitute the foundation of biology knowledge (Soyibo, 1993). Moreover, researches made about comprehension of science concepts by students show that they have many alternative conceptions, different from scientific knowledge, even after formal education (Sanders, 1993; Wandersee, Mintzes and Novak, 1994). Scientifically inaccurate thoughts of students in their prior knowledge negatively affect them to understand and learn complicated concepts in their following instructional levels (Tsai, 1999). Therefore Pashley (1994) states that the primary and most important mission to change alternative conceptions students have with scientific facts and to increase the number of students who manage this change is determining the students' alternative conceptions. Also, studies made with teachers and pre-service teachers show that they do not have enough knowledge to teach biology subjects significantly and sufficiently, moreover they have alternative conceptions related with many biology concepts (Mak, et.al., 1999; Öztaş, Özay and Öztaş, 2003) and that they transfer these alternative conceptions to their students during teaching life (Soyibo, 1993). The purpose of this study is to determine pre-service biology teachers' alternative conceptions about genetic material of gametes and somatic cells.

METHODOLOGY OF RESEARCH

Participants and procedures

97 pre-service teachers that were freshmen at the education faculty of a university in Turkey participated in the research. The selection of the pre-service teachers was based on convenience sampling. Convenience sampling was one of the non-random sampling methods. A convenience sample is any group of individuals that is conveniently available to be studied. 56 of the pre-service teachers were female and 41 of them were male. These pre-service teachers have not taken any undergraduate level course related to genetics before the study. Survey model was used in this study that has been carried out to determine alternative concepts they have and the comprehension of the pre-service teachers about the genetic material in gametes and somatic cells. Data were obtained by the participating 97 pre-service teachers via open-ended questions. In the study, 97 pre-service teachers were asked questions such as,

- *"Can you compare gametes and somatic cells in terms of genetic material?"*
- *"Do you think the chromosomes in liver, bone, nerve cells and gametes in our body are the same or different? Why?*
- *"Are there X and Y chromosomes in somatic cells of a male?"*

Answers given by the pre-service teachers to open-ended questions have been analyzed and the statements that include probable alternative concepts have been determined. In the research semi-structured interviews have been made to detail these answers more and to be able to ask additional questions according to the answers given. Thus, 12 pre-service teachers have been selected randomly. The pre-service teachers interviewed have been requested to answer primarily open-ended

questions orally. And then the statements that are determined in the answers given by other pre-service teachers to open-ended questions and that include alternative concepts have been introduced to 12 pre-service teachers during the interview and then they have been asked to state whether they agree or not to the statements introduced by explaining the reasons of their preferences. Examples of the statements were given below.

- *"Our chromosomes in different cells in our body have the same characteristics. Because our chromosomes are formed by the combination of 'X' chromosomes that come from the mother and 'X' or 'Y' chromosomes that come from the father."*
- *"While there are 'XY' or 'XX' chromosomes in gametes, there are '44' chromosomes in somatic cells."*
- *"Genes are found in gametes but not in somatic cells."*
- *"Because gametes shall have meiosis division they are '2n', and somatic cells have mitosis division they have 'n' chromosomes."*

Additional questions are asked according to the answers given during the interview. The data were recorded by a voice recording of the answers given.

Data analysis

The obtained data were analysed with qualitative data analysis. In the process of data analysis, the voice records obtained from the interview were primarily resolved and redacted. And then the answers given by pre-service teachers to the questions were analysed with the help of computer software by considering the alternative conceptions they have. The data were separated into data sections for the analysis with the help of qualitative data evaluation program and codes that would represent these data sections are formed and assigned to data sections. For similar codes categories were constituted and codes are combined with the data sections they represent in the form of categories. Codes that were assigned to these categories formed and whether the data sections were assigned accurately or not were discussed by various researchers and the codes that were not settled with were either changed or removed. Similar codes were combined under a common code. A table was formed for final categories and the related codes.

FINDINGS

Analysing the data obtained in the study, it is comprehended that pre-service teachers have uncertainties in their minds about gametes and somatic cells and have some alternative conceptions. The codes, sample data sections along with categories and interpretations related with alternative conceptions of the pre-service teachers are displayed below.

'X' and 'Y' chromosomes are not found in somatic cells.

The question 'Are 'X' and 'Y' chromosomes found in somatic cells of a male?' is asked to pre-service teachers and answers are received as follows;

… "In somatic cells? (in astonished manner..), there are 'X' and 'Y' chromosomes in gametes, but in somatic cells there are no 'X' and 'Y', these 'X' and 'Y' chromosomes are found only in gametes." (T.92)

…

… "No, these chromosomes are in gametes. They are not found in somatic cells, they are only in gametes." (T.15)

…

Table 1. Alternative conceptions of pre-service teachers about genetic material in gametes and somatic cells

Topics		Alternative Conceptions
1 Autosome and genosomes	**1.1**	X and Y chromosomes are not found in somatic cells.
	1.2	There are only 'X' and 'Y' chromosomes in gametes.
	1.3	A male is formed by the combination of only 'X' and 'Y', a female is formed by combination of only 'X' and 'X' chromosomes.
	1.4	While there are 'XY' or 'XX' chromosomes in gametes, there are 44 chromosomes in somatic cells.
	1.5	In gametes 'XX' or 'XY' chromosomes are found together with their homologous.
2 Chromosome and genetic diversity	**2.1**	Gonosomes (chromosomes related with gender) are in passive form in somatic cells.
	2.2	While there is genetic diversity in gametes, there is no genetic diversity in somatic cells.
	2.3	Genes are found in gametes, there are no genes in somatic cells.
	2.4	While homologous chromosomes are found only in gametes, they don't exist in somatic cells.
3 Haploid- Diploid concepts	**3.1**	Gametes are (2n) diploid, somatic cells are (n) haploid.
	3.2	Somatic cells may be both haploid (n) and diploid (2n).
	3.3	Gametes and somatic cells are (2n) diploid.
	3.4	Gametes form gametogonium and they may have meiosis division as they are diploid (2n).

Pre-service teacher (T.81): It is more accurate to say that there are both 'X' and 'Y' chromosomes in gametogoniums instead of saying there are 'X' and 'Y' chromosomes in somatic cells.

Researcher (R): So you mean that they are found in gametogoniums but not in somatic cells?

T.81: Yes.

Pre-service teachers state that 'X' and 'Y' chromosomes that are gonosomes found only in gametes and that these chromosomes don't exist in somatic cells. It is seen that they are surprised by the question about whether 'X' and 'Y' chromosomes are exist in somatic cells and that they state confidently that they are found only in gametes.

A situation similar to this alternative conception pre-service teachers have is that in gametes there are only 'X' and 'Y' chromosomes but there are no autosomes.

There are only 'X' and 'Y' chromosomes in gametes.

T.94: 'X' and 'Y' chromosomes are gender chromosomes, if there are only 'XX' or 'XY' they are diploid, only 'X' or only 'Y' chromosome they are haploid.

R: What will you say for other chromosomes?

T.94: What do you mean by other chromosomes?

R: Are there any chromosomes than 'X' and 'Y' chromosomes?

T.94: Yes but in gametes only these chromosomes are found.

Similar to the alternative conception of the previous item, pre-service teachers think that in gametes there are only 'X' and 'Y' chromosomes but no other chromosomes. Another alternative conception showing that pre-service teachers think there are only 'X' and 'Y' chromosomes in gametes is the thought that 'an individual is formed by combination of only 'X' and 'Y' (for male) or 'X' and 'X' (for female) chromosomes' as in the code that follows.

A male is formed by combination of only 'X' and 'Y', a female is formed by combination of only 'X' and 'X' chromosomes.

R: "Our chromosomes in different cells in our body have the same characteristics. Because our chromosomes are formed by the combination of 'X' chromosomes that come from the mother and 'X' or 'Y' chromosomes that come from the father." Is this statement true?

T.67: The second phrase is true. The first phrase is… oh, it is the same. Yes, it is right.

R: For instance, are my chromosomes formed by the combination of X chromosomes that come from the mother and Y chromosomes that come from the father?

T.67: Yes, right.

…

… "Male is formed by 'X' and 'Y' chromosomes anyway." (T.67)

…

R: Are we formed by the combination of 'X' chromosomes that come from the mother and 'X' or 'Y' chromosomes that come from the father?

T.45: Right. (Self-assured)

R: Let me ask this. If we are formed by the combination of 'X' and 'Y' chromosomes, how does the number of chromosomes become 46?

T.45: I don't know how.

The pre-service teachers have an alternative conception about that in gametes there is only 'X' or 'Y' chromosomes. Pre-service teachers state that in the sperm there is only either X or Y chromosome and in the egg there is X chromosome. Therefore, they think that the fertilization of egg by sperm that carries Y chromosome forms a male and the fertilization of egg by sperm that carries 'X' chromosome forms a female. However pre-service teachers generally cannot answer the question '*If there are only 'X' and 'Y' chromosomes in gametes, then how do 46 chromosomes appear in human beings?*'

While there are 'XY' or 'XX' chromosomes in gametes, there are '44' chromosomes in somatic cells.

R:"While there are 'XY' or 'XX' chromosomes in gametes, there are '44' chromosomes in somatic cells." Is this statement true?

T.81: It is true. '44' of '44+XX' are autosomes, 'XX' are gonosomes.

…

… "Let us consider it this way. There are 46 chromosomes in our body. We call it '44+XX' for the female. Starting from this point we call '44' of them somatic cells that are found in the body and 'XX' gonosomes that are found in gametes." (T.81)

Most of the pre-service teachers' state that there are only 'XX' or 'XY' chromosomes in gametes, and the remaining '44 chromosomes' are found in somatic cells. In the basis of this alternative conception lies the naming of 'X' and 'Y' chromosomes as gender chromosomes (gonosomes) and the thought that they appear only in gametes. Also, different from the former two alternative conceptions, in this alternative conception pre-service teachers state that 'XX' or 'XY' chromosomes are found together in gametes. Similar alternative conception takes place in the following code.

In gametes 'XX' or 'XY' chromosomes are found together with their homologous.

T.47: Our chromosomes are the same in liver, bone and nerve cells but different in gametes.

R: How different?

T.47: You know, we say '44+XX' or '44+XY'. '44' of them are somatic cells, 'XX' or 'XY' are gametes.

...

R: "While 'XY' or 'XX' chromosomes are found in gametes, there are '44 chromosomes' in somatic cells" Is this statement true?

T.45: Okay, this 'XY' and 'XX' chromosomes come from the mother and father and different in female and male.

As seen from the statement above the pre-service teachers think that in gametes both 'X' and 'Y' chromosomes or both 'X' and 'X' chromosomes are found together. When the pre-service teachers are asked which cells are gametes, almost all of them state that sperm and egg cells are gametes. However they think that in gametes that they state as sperm and egg cells 'XX' or 'XY' chromosomes are found together with their homologous.

Gonosomes (chromosomes related with gender) are in passive form in somatic cells.

R: Is there a difference between gametes and somatic cells such as liver, bone, nerve cells in terms of chromosomes?

T.94: Chromosomes are the same. In liver, bone etc. cells there are autosomes, in gametes there are gonosomes.

R: Then, are there gonosomes in gametes and autosomes in somatic cells?

T.94: There all exist but in gametes gonosomes are active and in somatic cells autosomes are active. They include all chromosomes but their activeness is different. 'X' and 'Y' chromosomes determine the gender. 'X' and 'Y' are gonosomes, the other chromosomes are autosomes.

Pre-service teachers generally describe 'X' and 'Y' chromosomes as gonosomes, and other 44 chromosomes as autosomes. In addition to this, in the questions asked some pre-service teachers state that there are all chromosomes in gametes and somatic cells however while 'X' and 'Y' chromosomes are active in gametes, in somatic cells the other '44 autosomes' are active. Also, it is possible to say that pre-service teachers think that 'X' and 'Y' chromosomes only determine gender and that they do not have another function.

While there is genetic diversity in gametes, there is no genetic diversity in somatic cells.

Pre-service teachers were asked the question *'Do you think the chromosomes in liver, bone, nerve cells and gametes in our body are the same or different? Why?'* and some of the data sections obtained were given below.

T.67: These are autosomes (in liver, bone, nerve etc. cells) and these are gonosomes (sperm and egg). There is genetic diversity in gametes but in liver, bone, nerve cells there is no hereditary variety. Somatic cells have continuously mitosis division; gametes can have meiosis division as well.

R:For instance, what do you mean by saying there is no genetic diversity in liver cell?

T.67: I mean, like, brown eye, black eye.

R: So do you think there is a characteristic as such in liver cell?

T.67: There is none in liver cell.

R: There is only in gametes?

T.67: Yes, there is in gametes. I mean, they occur in different type.

R: Thus, you say that somatic cells are different than gametes as they do not have hereditary variety?

T.67: Yes.

The pre-service teacher states that there is genetic diversity in gametes and there is no genetic diversity in somatic cells. And they exemplify genetic diversity as '*brown eye, black eye*'. It is remarkable that pre-service teacher states that the structure which controls the characteristics that occur in somatic cells such as eye colour do not exist in somatic cells and indicates that they exist only in gametes. Similarly, another pre-service teacher states that;

... "Chromosomes are the same in liver, bone and nerve cells but different in gametes. They are different because there is meiosis division in gametes. While there is mitosis division in somatic cells, there happens meiosis division, crossing-over, synapses etc. in gametes and the diversity is maintained." (T.45)

Evaluating all of the statements of pre-service teachers it is comprehended that they think the structures that provide the characteristics that qualify as genetic diversity and in other words genes and allele genes do not exist in somatic cells. The alternative conception supporting this is given below.

Genes are found in gametes, there are no genes in somatic cells.

R: Do you think that the chromosomes in liver, bone, nerve cells and gametes in our body the same or different?

T.81: Genes are found in gametes. So we can think that chromosomes that form genes are not found in liver, bone and nerve.

...

... "The other three (liver, bone, nerve cell) are somatic cells. And that is different. For example genes are found in gametes but not in somatic cells." (T.72)

...

R: "Genes are found in gametes but not in somatic cells." Is this statement true?

T.72: Yes, genes are found in gametes.

R: Therefore, genes are not found in every cell?

T.72: Yes.

Analysing the answers given to the question about whether the chromosomes in the cells of different parts of the body are different or not, it comes out that pre-service teachers think that genes are found only in gametes.

Differently, another pre-service teacher states that genes are found in somatic cells too but these cells do not have a role in diversity. A statement of pre-service teachers regarding this is as follows.

R: "Genes are found in gametes but not in somatic cells." Is this statement true?

T.45: They are found in somatic cells but they do not provide diversity. In somatic cells there are genes but since they are subject to mitosis division, there is no difference. They do not provide heredity; do not play a role in diversity.

The pre-service teacher states that genes shall replace certainly with crossing-over and cause diversity and that this can happen in meiosis division and genes are useless in cells that are subject to mitosis division. Another alternative conception regarding this alternative conception is as follows.

While homologous chromosomes are found only in gametes, they do not exist in somatic cells.

R: What do you understand from homologous chromosome concept?

T.1: Homologous chromosomes are chromosomes that come from both mother and father and effect on the same characteristic.

R: Do all of our chromosomes have homologous?

T.1: No, only gametes do.

R: Do only gametes have pairs as such?

T.1: Our homologous chromosomes are found only in gametes and effect on the same characteristics. And they are found as pairs.

R: Are there homologous chromosomes in our somatic cells?

T.1: No, these are found only in gametes.

The pre-service teacher who provides this statement defines the homologous chromosome concept correctly as other pre-service teachers however he states that homologous chromosomes are found only in gametes but not in somatic cells. And another pre-service teacher that has the same alternative conception states that in somatic cells there are no homologous chromosomes and homologous chromosomes are found in gametes with his statement;

R: Are there homologous chromosomes in our somatic cells? Or not?

T.8: In fact, there are. It seems like there are. But in order for them to exist, meiosis division is required. Then there must be '2n'. But somatic cells are not '2n'. Therefore in somatic cells there are no homologous chromosomes.

The pre-service teacher that thinks that there must be meiosis division and thus 2n to have homologous chromosomes has the alternative conception that somatic cells are 'n' instead of '2n'. Because of this alternative conception he thinks that there cannot be homologous chromosomes in somatic cells.

Gametes are (2n) diploid, somatic cells are (n) haploid.

... "Cells with '2n' chromosomes are called diploid. Diploid cell is for example the types seen in gametes and haploid cell is the one used in mitosis division in somatic cells." (T.92)

...

... "Gametes do not work if not '2n'; they must be '2n'." (T.47)

...

T.42: Gametes have '2n', somatic cells have 'n' chromosome. According to this in somatic cells it shall be '22+X' or '22+Y'. This changes according to female or male.

R: Why are gametes '2n'?

T.42: During division it shall be '2n', 'n' and 'n'. Also, it is required for the genetic diversity to increase.

...

R: "Because gametes shall have meiosis division they are '2n', and somatic cells have mitosis division they have 'n' chromosomes." Is this statement true?

T.45: True

R: Can gametes have 'n' chromosomes?

T.45: No. Because they shall have meiosis division, so how will they decrease in half, shall they be 'n/2'?

...

... "Somatic cells are 'n', gametes are '2n'." (T.1)

Pre-service teachers define diploid (2n) cells are the ones that have meiosis division, and haploid (n) cells are the ones used in mitosis division. Thus, pre-service teachers think that the gametes they define as sperm and egg should be '2n' in order to have meiosis division. Pre-service teachers state that somatic cells have mitosis division, in other words somatic cells are the one that are used in mitosis and therefore they are haploid (n) cells.

In addition to this alternative conception some pre-service teachers have alternative conceptions such as;

"Somatic cells can be both haploid (n) and diploid (2n)."

"Gametes and somatic cells (2n) are diploid."

"Gametes form gametogoniums, and they can have meiosis since they are also diploid 2n."

These alternative conceptions show that pre-service teachers could not yet learn the concepts of diploid (2n) and haploid (n) completely and make comments about the question asked or according to the current situation. Shortly, it can be said that pre-service teachers are so confused about these concepts.

CONCLUSION AND DISCUSSION

Pre-service teachers are asked to compare gametes and somatic cells in terms of genetic material and it is determined that they have various alternative conceptions. Most of the pre-service teachers' state that in gametes there are only 'X' and 'Y' chromosomes, the remaining '44' chromosomes are in somatic cells and that in somatic cells there aren't absolutely found 'X' or 'Y' chromosomes. Even so, it is determined that many pre-service teachers find the question odd about whether or not there are 'X' and 'Y' chromosomes in somatic cells, they are surprised and self-assuredly they state that there cannot be 'X' and 'Y' chromosomes in somatic cells. Besides pre-service teachers suggest different opinions about that in gametes such as sperm and egg 'X' and 'Y' chromosomes can be found one by one as well as together with homologous in the form of 'XX' or 'XY'. Despite these differences in opinions, the common opinion of pre-service teachers is that in gametes there aren't found other chromosomes they think to be in somatic cells except 'X' and 'Y' chromosomes. When the pre-service teachers are asked if there are only 'X' and 'Y' chromosomes in sperm and egg and in a human being that is formed with the combination of these, how 44 of the 46 chromosomes excluding 'X' and 'Y' chromosomes are formed, it is determined that they could not answer. In response to this question some pre-service teachers state that in fact in all cells there are all chromosomes but in somatic cells 'X' and 'Y' chromosomes are passive, and in gametes chromosomes that are characterized as autosomes are passive. This conclusion corresponds to the alternative conception 'because cells have different functions they require different genetic information and thus in different cells there is different genetic information' determined in students by Lewis and Wood Robinson (2000); Lewis, Leach and Wood-Robinson (2000) in their studies.

Showing chromosomes in the form of '44+XX' or '44+XY' in lessons and books and labelling '44' of them as autosomes, 'XX' or 'XY' as gonosomes lie on the basis of commonly seeing pre-service teachers to have this type of alternative conceptions. Yet, showing chromosomes in the form of '44+XY' and stating that 'X' and 'Y' chromosomes are gonosomes are interpreted wrongly by pre-service teachers and make them think that these chromosomes are only in gametes thus not in somatic cells. Also, during the instruction of these subjects, emphasizing that 'X' and 'Y' chromosomes determine gender causes pre-service teachers to have the perception that these chromosomes determine only gender and they do not have any relations with other properties. And this perception causes pre-service teachers to think chromosomes are in two types, and thus to have the alternative conception that gonosomes that determine gender such as 'X' and 'Y' chromosomes aren't found in somatic cells such as eye, liver etc.

When the same pre-service teachers and students are asked, apart from this study, diseases such as haemophilia, Daltonism are related with which chromosome, almost all of them say that they are related with 'X' chromosome. However, while it is known by pre-service teachers that the genes controlling these diseases that are

associated with somatic cells such as blood and eye are related with 'X' chromosome, it is remarkable that in a different time they state, even become surprised by the question that 'X' and 'Y' chromosomes aren't found in somatic cells. Although pre-service teachers have memorization knowledge related with the concepts they learnt and stated when asked separately, it is comprehended that their awareness is insufficient and that they cannot transfer their knowledge related with these concepts to other situations. Pashley (1994) emphasizes in his study that insufficiency of the awareness about the contradictions students reveal about the relations between concepts shall affect their learning subsequent concepts about the subject negatively. And in this study pre-service teachers give contradictory answers about relations between concepts and it is comprehended that their relevant awareness is quite insufficient. This insufficiency about awareness causes the formation of alternative conceptions that pre-service teachers have.

Pre-service teachers that associate gametes with meiosis division state that homologous chromosomes that mention frequently in meiosis division are only in gametes and not in somatic cells. Hereby, it is comprehended that pre-service teachers have problems related with basic concepts and have knowledge structures based on superficial associations. Pre-service teachers that give sperm and egg as an example of gametes, emphasize that in order for the meiosis division to realize that they think to happen in these cells, gametes should be '2n' (diploid), and mitosis division realizes in somatic cells so they should 'n' (haploid). However, some pre-service teachers think that somatic cells may be 'n' (haploid) as well as '2n' (diploid). But, all pre-service teachers participating in the research emphasize that in order to for sperm and egg cells they call gametes to have meiosis division, they should be '2n' (diploid). Pre-service teachers confuse gametes with gametogoniums. They think that cells that have meiosis are sperm and egg cells, instead of gametogoniums, that are formed by these cells and are haploid. Moreover, although most of the pre-service teachers' label gametes as sperm and egg, they state that 'X' and 'Y' chromosomes are found in sperm as 'XY' and in egg as 'XX' along with their homologous. While in gametogoniums just like other chromosomes 'X' and 'Y' chromosomes are also found with their homologous in the form of 'XX' or 'XY', in normal haploid cells like sperm and egg cells there are no homologous of chromosomes. Therefore, even if the alternative conception about the existence of only 'X' or 'Y' chromosomes in gametes but no autosomal chromosomes is ignored, stating that chromosomes are found in sperm and egg as 'XY' or 'XX' with their homologous is another alternative conception. These alternative conceptions determined show that pre-service teachers could not meaningfully learn homologous chromosome and diploid-haploid concepts and that they comment according to question asked or current situation and have different alternative conceptions. When the literature is analyzed, in many studies, similar to this study, it is observed that students have alternative conceptions about homologous chromosome and haploid-diploid cell concepts (Chattopadhyay, 2012; Wright, and Newman, 2011; Quinn, Pegg and Panizzon, 2009; Wynne, Stewart, and Passmore, 2001; Kindfield, 1991; Brown; 1990).

Also, the continuous emphasis of 'gene' and 'crossing-over' that mention frequently in meiosis division that realizes in gametogoniums causes pre-service teachers to have the perception that 'gene' concept is only related with gametes. Yet, in mitosis division there is no crossing-over and gene concept is mentioned less than in meiosis division. Pre-service teachers associate mitosis division with somatic cells and meiosis division with gametes. And this contributes to pre-service teachers in forming alternative conceptions such as 'genes are found in gametes, there are no genes in somatic cells'. Pre-service teachers that focus on genetic diversity emphasize that genetic diversity is a concept related with gametes and that in

somatic cells there are no structures such as gene, allele gene that provide genetic diversity based on there is no genetic diversity in somatic cells. Moreover some of the pre-service teachers reveal that they have various alternative conceptions about the relation between gene and chromosome as well with the statement *'... chromosomes that form genes'*. The pre-service teachers who mention chromosomes of gametes or somatic cells and think that there are no genes in somatic cells are believed to have alternative conceptions about the relation between gene and chromosome. This result corresponds to the study of Venville, Gribble and Donovan (2005) in which it is determined that even though students are familiar with concepts such as gene and DNA, they do not have a conceptual understanding about what gene is, where it is, what its task is and what its relation with DNA is.

In conclusion, pre-service teachers know many concepts about the subject as definitions however they have difficulties in organizing the knowledge by relating it to other concepts and transfer to other situations. Instruction should be planned considering especially these problems of students and pre-service teachers.

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