



ISSN:1306-3111

e-Journal of New World Sciences Academy
2010, Volume: 5, Number: 1, Article Number: 1C0132

EDUCATION SCIENCES

Received: June 2009
Accepted: January 2010
Series : 1C
ISSN : 1308-7274
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**A QUALITATIVE STUDY ON STUDENT' UNDERSTANDING AND MISCONCEPTIONS
REGARDING THE LIVING CELL**

ABSTRACT

This paper presents findings from a qualitative study that investigates students' understanding and misconceptions regarding a living cell, its processes and structure. Data was collected through semi-structured interviews from 11 sixth-grade students (4 females and 7 males) attending two schools located in Izmir, Turkey. The data was thematically analyzed within the framework of sixth grade science curriculum. The results of this study revealed that students: (a) have problems to organize their prior knowledge; (b) cannot detach the differences about concepts related to cell and tissue, (c) suffer from recalling and remembering of some their knowledge; and d) explain the concepts better when the teachers used analogies and visual materials in their courses. The study also determined that students held eleven misconceptions regarding living cells. The paper concluded with the implications for teachers concerning teaching of living cell and tissue concept and removal of misconceptions.

Keywords: Living Cell, Tissue, Misconception, Prior Knowledge

**ÖĞRENCİLERİN HÜCRE İLE İLGİLİ ANLAMLANDIRMALARI VE KAVRAM YANILGILARI
ÜZERİNE NİTEL BİR ÇALIŞMA**

ÖZET

Bu çalışma hücrenin yapı ve işlevleri ile ilgili öğrencilerin anlamlandırmaları ve kavram yanlışları ile ilgili nitel çalışmadan bulgular sunmaktadır. Veriler İzmir, Türkiye'deki iki okulda öğrenim görmekte olan 11 tane 6.sınıf öğrencisinden (4 kız ve 7 erkek) yarı yapılandırılmış görüşmeler yoluyla toplanmıştır. Veriler 6.sınıf fen bilgisi dersi öğretim programı göz önünde bulundurularak ve tematik yolla analiz edilmiştir. Bu çalışmanın sonuçları öğrencilerin (a) ön bilgilerini organize etmelerinde sorunlar yaşadıklarını; (b) hücre ve doku kavramları ile ilgili farklılıkları ayıramadıklarını; (c) bazı bilgileri geri çağırma ve hatırlama güçlükler çektiklerini; (d) öğretmenlerin derslerinde analogiler ve görsel materyaller kullandıklarında kavramları daha iyi açıkladıklarını ortaya koymuştur. Çalışma aynı zamanda öğrencilerin sahip olduğu onbir kavram yanlışını belirlemiştir. Çalışma, hücre ve doku kavramlarının öğretimine ve kavram yanlışlarının ortadan kaldırılmasına yönelik önerilere sunar.

Anahtar Kelimeler: Hücre, Doku, Kavram Yanılgısı, Ön Bilgi

1. INTRODUCTION (GİRİŞ)

Many studies in biological education indicate that it is an imperative that further research takes place on how students learn and understand biological concepts at different educational levels (Flores & Tovar, 2003; Lewis, Leach, Wood-Robinson, 2000; Wood-Robinson, 1994; Turney, 1995). Since Robert Hooke's studies during 1665, living cells have been one of the attractive fields of investigation for scientists. In many scientific fields, it has been defined as the smallest structural and functional unit of all living organisms. Recent literatures suggest that, living cells are known as "essential aspects of many biological molecular processes" (Koyama et al., 2005) and dynamic micro-environments, complete with microtubule transport networks and protein motors (Haury, 2002).

It is pointed out that understanding of living cells' functions is important for students when they are to learn functioning of multi-cellular organisms. While it is evident that students find it difficult to develop a coherent understanding of cell as 'the basic unit of life' (Ariely, 2005). Flores & Tovar (2003) have indicated that:

Conceptual problems range from the understanding of the cell as an autonomous organism and the functions it performs to difficulties in its spatial and metrical representations, resulting in confusion between cells, atoms and molecules. In particular, the establishment of relationships between cell structures and their functions are especially complex for students who are not able to integrate them into an overall picture. The lack of such relationships does not allow them to understand such processes as respiration, reproduction, nutrition or genetic regulation mechanisms and organelle composition (p. 270)

Flores et al. (2003) also categorized the living cell studies such as:

- Animistic and anthropomorphic view of processes (Bartov 1978, Tamir and Zohar 1991);
- Confusion between like genes and alleles (Lewis et al. 2000);
- Photosynthesis and respiration (Stavy et al. 1987, Seymour and Lodgen 1991, Wood-Robinson 1991);
- Cells and atoms or molecules (Caballer and Gime'nez 1993);
- Cell membrane and cell wall (Zamora and Guerra 1993);
- Confusion between meiosis and mitosis (Lodgen 1982).

Within the last twenty-five years, practical and empirical researches have been carried out on the misconceptions regarding scientific phenomena. According to Hammer (1996) (a) misconceptions are strongly held, stable cognitive structures, (b) they differ from expert conceptions, (c) they affect in a fundamental sense how students understand natural phenomena and scientific explanations, and (d) misconceptions must be overcome, avoided, or eliminated for students to achieve expert understanding. A study by Smith, diSessa, & Roschelle (1993) reports that some researchers explain the term misconception in different ways, such as, preconceptions (Clement, 1982b; Glaser & Bassok, 1989; Wiser, 1989), alternative conceptions (Driver & Oldham, 1985; Pfund & Duit, 1991; Carmichael et al, 1991; Hewson & Hewson, 1984), naive beliefs (McCloskey, Caramazza, & Green, 1980), alternative beliefs (Wiser, 1989), alternative frameworks (Driver, 1983; Driver & Easley, 1978), and naive theories (McCloskey, 1983; Resnick, 1983). It is generally accepted that students come to courses with misconceptions which need to be identified by teachers

before any kind of instruction. Smith et al. (1993) indicate that students' prior learning at the classroom or physical and social world precede the misconceptions. They also emphasize the importance of documenting misconceptions for future researches as a major task. Teachers can be a good source of students' misconceptions as Boo and Ang (2004) argue that not only students but also teachers have misconceptions about some life science and physical science concepts drawing evidence from a pool of primary science assessment items. It is also revealed that textbooks, reference books, teachers, language, cultural beliefs and practices may cause students' misconceptions of many science concepts in biology (Friedler, Amir, & Tamir, 1987, Storey, 1992a, 1992b).

2. RESEARCH SIGNIFICANCE (ÇALIŞMANIN ÖNEMİ)

The present paper aims to provide new findings and insights for researchers and teachers on the students' understandings and misconceptions related to the cell. Students' understandings and misconceptions still appear to be a significant deficit in teaching and learning environments and teachers still ignore this situation to a greater extent. It can be based on a lack of awareness of the benefits of different practice for teaching and learning, lack of practical pedagogical skills, and possibly lack of time and incentives to develop practice. The paper also aims to provide the necessary information to teachers and researchers in terms of teaching facilities.

3. METHOD (METOT)

This study employs a qualitative research technique that is characterized by its sensitivity to the natural environment, the participant role of the researcher, its holistic approach, its ability to demonstrate perceptions, its flexibility in research pattern and its inductive nature of analysis (Yıldırım & Şimşek, 2004). In this sense, qualitative researches are sensitive to the social context within which a particular study is conducted (Kuş, 2003). A semi-structured interview (Bogdan & Knopp-Biklen, 1998) has been carried out to obtain data from 11 sixth-grade students (4 females and 7 males) attending two primary schools located during 2004-2005 teaching semester in Turkey. Students' participation to the study was voluntary. The selection of the participants was based on their overall performance in the science course. Each of the eleven face-to-face interviews lasted for approximately one and half hours. During the interviews, students were encouraged to use paper-and-pencil as needed. The interview protocol's driving questions were constructed based on a review of the literature, especially on living cell related issues. The researcher was conscious in making the environment more relaxed so the students are at ease to portray the relevant scenario. Information constitutes participants' background, their attitudes and beliefs about science and biology as well as their experiences from nature. The interviewer started by asking some general questions. All of the interviews were recorded and fully transcribed and analyzed. In order to protect identity of students they were given pseudonyms.

4. FINDINGS (BULGULAR)

The results obtained in the research are presented on the basis of the responses to the questions. The analysis did not depart from any given presupposition or any theory; and because existing theories impose ready-made categories and thus pose the risk of determinism, the emphasis was as much as possible on the transcribed text obtained from the interviews. The meaning categories within the text occurred

spontaneously and in the inter-text relations at each step of the analysis. In this context, as a result of the data analysis, the factors affecting the understanding of living cells were represented under seven main categories: organization of prior knowledge; DNA and genes; atom and molecules; recalling information; analogical methods; the structure of living cells; the importance of drawings and pictures. The misconceptions obtained from the students during interview were also reported.

4.1. Organization of Prior Knowledge (Ön Bilgi Organizasyonu)

According to constructivist theory, prior knowledge does play an important role in the process of accumulating new information. Students find it difficult if the organizations of new information are not in concordance with their prior learning. Much data related to prior knowledge obtained during the interviews, some dialogues can be mentioned as an example:

I (Interviewer): What can the smallest part of living thing be?

S1 (Student 1): Living cell

I : What kind of things come to your mind when living cells is said?

S1: [thinking, and smiling] living cell, circle, I do not know... I can not remember easily..

I: What are the differences between animal and plant cell?

S11: ummm... chromosomes are stored up at the plants..

S7: Animals are active than the plants.. Plants are slow.. I think that animals are cleverer than the plants.

S3: The only thing I remember is that plants have chlorophyll in order to make photosynthesis. Animals have not chlorophyll.. I do not remember any other thing..

S4: Plants eats water and soil. Animals.. as a feed... use soil, grass, water... umm

S5: There is difference.. for example, vacuole are bigger at the plants.. Plant cells are developed because it makes its own feed..

4.2. DNA and Genes (DNA ve Genler)

In addition to "organization of prior knowledge" section, it was found that some interrelated concepts such as gene and DNA has not been constructed adequately by students and they had difficulties in explaining the differences. The dialogues include the prior background information from students:

I : What is DNA?

S2: ummm.. I used to know but I can not explain it right now, I can not imagine it, but I know what it is..

I: What is gene?

S1: gene is... umm... it is something which DNA carries it.. it can be opposite. I forgot it..

I: What are the differences between DNA and gene?

S2: There is difference... umm... I do not remember..

I: We look like mothers and fathers, how are these similarities are transferred to us?

S5: It causes from genes

I: What is gene?

S5: *It is something... it is thick*
I: **We look like mothers and fathers, how these similarities are transferred to us?**
S8: *from DNAs*
I: **What is DNA?**
S8: *DNA is human's character, color of eyes, complexion, and color of hair... umm, the size of ear...*
I: **We look like mothers and fathers, how these similarities are transferred to us?**
S9: *from genes*
I: **What is gene?**
S9: *Gene is... DNA includes it...*
I: **What are the differences between DNA and gene?**
S2: *There is exactly difference between DNA and gene. But I can not remember it...*

4.3. Atom and Molecules (Atom ve Moleküller)

Atom and molecules are one of the abstract concepts and so difficult to understand by primary students. Learning difficulties for atoms and molecules are described at the Benchmarks for Science Literacy which says;

When students first begin to understand atoms, they cannot confidently make the distinction between atoms and molecules. Students often get the idea that atoms somehow just fill matter up rather than the correct idea that the atoms are the matter. Middle-school students also have trouble with the idea that atoms are in continual motion. Coming to terms with these concepts is necessary for students to make sense of atomic theory and its explanatory power. (Benchmarks for Science Literacy, p. 75.)

The dialogue below might be used to be shown as evidence of difficulties to understand atom and molecules:

I : **What kind of things come to your mind when atom and molecules in living cells is said?**
S10: *Atom ummm.. the smallest part of matter, molecules are very small units... between atom and molecules... ummm... for atoms... I do not know...*
S7: *Atom... it is a kind of thing like flame ball..*
S9: *Atom...it is circle... like Saturn.. it has two hoop.. molecule.. ummm.. I do not remember...*
S6: *Atom hmm... Atom has molecules...*
S5: *Atom is smallest part of living cell.. It is a small.. like a marble.. circle... small circles... I can not explain it...*
S7: *I remember atom weapons when I think of atoms*
S11: *I think... neutron... yes... it is neutron...*

4.4. Recalling Information (Bilginin Geri Çağrılması)

Recalling is defined as conveying the information to short-term memory from the long-term memory (Arı, 2006). It is reported in many studies that students at the primary education level have memory problems (Education, 2008; Gathercole, 2003). Students who have difficulty with working memory often forget what they are doing while doing it. It is found that students have problems in recalling information related to living cells. The following dialogues reveal the difficulties of students when attempting to explain and express living cell's organelles.

I : What kind of things can be inside of a living cell?

S6: inside of living cell... ummm.. there are nucleus, and membrane and also a kind of liquid.. I do not remember right now..

S7:I think that we observed something last year but I am not sure.. I can not remember..

S7: umm... I know... but I can not tell it now... I cannot imagine it..

4.5. Analogical Definition (Analojik Tanımlama)

Analogy is a cognitive mechanism that people use to make inferences and learn new abstractions. Klein (2006) defined the analogy as a comparison in which the relationships among elements of a source are mapped onto relationships among elements of a target. It is generally accepted that analogies can help learners to understand abstract and complex concepts. However misunderstandings can occur if they are applied to broadly. During the interviews, students used analogies to explain the concepts which were difficult to express in a scientific way. Following dialogue can be taken into consideration in terms of use of analogies in defining concepts by students.

I : How does a cell perform liveness? What do you think?

S3: umm... central can be brain but the plants has not a brain...

S4: I looked it from microscope... It looks like a yellow wall... I looked it two years ago..

S8: It is something like mosaic... there is a big marble inside of it. Small small marbles..

S10: It is a knitted block

4.6. The Structure of Living Cell (Hücre Yapısı)

When two students were asked about structure of living cell, they generally explained that the living cell consisted of 3 parts which are cell membrane, cytoplasm and nucleus. Following dialogue can be shown as an example of students' understandings about the structure of living cell. In this part, in addition to interview, interviewer also asked to students to draw a living cell. A paper and a pencil were provided to students.

I : Can you draw a living cell?

S3: yes, I can.. for example, (she is drawing a circle) at centre there is a nucleus, there is also something to protect plant cell, I do not remember now, cell membrane to protect the cell.. There is also something inside of nucleus.. that's all..

I: What kind of things can be inside of a living cell?

S4: ummm... nucleus, membrane at the outside, cell membrane, and a liquid inside of cell... I do not remember...

S6: chromosome is stored at the plants...

4.7. The Importance of Pictures and Drawings (Resim ve Şekillerin Önemi)

It is known that well structured drawings and pictures increase the understanding of abstract concepts, and help students to recall information. Following dialogue can be given as evidence of the

importance of pictures and drawings in the text books or materials provided to students.

I : What kind of things come to your mind when atom and molecules in living cells is said?

S1: I remember from my text book... it is circle and it has two hoops... I also remember the drawings which my teacher drawn it...

S2: it was colorful things... I saw it in my text book...

4.8. The Misconceptions (Kavram Yanılgıları)

There are eleven misconceptions determined by researchers during interviews. They are indicated below:

1. Chromosomes are stored at the plants
2. Chromosome is an organelle to breath up
3. Plants are more ascendant things than the animals because of the photosynthesis
4. Atom is a matter that is consisted of molecules
5. Atoms integrate everything
6. Atom is a neutron
7. Cell membrane in charge of living cell
8. Animal cell has a cell wall
9. Atom is a flame ball
10. Cell consist of tissues
11. Genes are available inside of DNA

5. DISCUSSIONS (TARTIŞMA)

The main aim of this paper is to find evidence to affect students' understanding regarding living cell and to find misconceptions held by students. According to the first result related to prior knowledge, many studies stressed the ideas of students to construct new knowledge. Present study showed that students have not enough prior knowledge or ideas to remember easily the concepts or functions related to living cell. The main problem was also defined at the Flores and Tovar (2003) study that *the establishment of relationships between cell structures and functions are complex for students who are not able to integrate them into an overall picture.* And also lack important knowledge of various processes of multicellular organisms.

Two important studies on the DNA and gene carried out by Wood-Robinson (1994) and Turney (1995) showed that understanding of genetics and inheritance is poorly understood by all age groups. In the present study, it is also revealed that there are difficulties to understand, explain and clarify the differences between DNA and gene. Furthermore Lewis (2000) reported that students are not able to explain the questions about its basic function, where it might be found and how it relates to other structures. Lewis also found that many students had difficulty in locating genes within the whole body. Metz (1998) also reported that one of the problematic situations for learning the genetics concept is that children are unable to think in abstract ways.

Understanding problems and confusions between cells and atoms or molecules have been indicated in many studies (Caballer and Gimenez, 1993; Flores and Tover, 2003). In addition to these studies, students' conceptual problems are similar to those given above. Present study also showed that students have difficulties in explaining atoms and molecules in living cell and defining its shape. Schwaner et al (1994) found that many students had difficulty in grasping even a rudimentary understanding of basic biological chemistry. Harrison and Treagust

(1998) reported that language is a major source of confusion for some students to understand atom and molecules. Nakhleh & Samarapungavon (2005) showed that middle school students were unable to consistently explain material properties based on their knowledge. Ariely (2005) also revealed that students tend to explain biological concepts at macro level.

Gathercole & Pickering (2000) investigated the relationship between students' assessments and working memory. They found that students have poor working memory function. The wide range study in England showed that students in particular at primary education level, suffered from poor working memory, which seriously impeded their learning. In the present study, it is also revealed that students have difficulties in recalling the knowledge related to the living cell. The previous studies above also support these findings.

According to study carried out by Di'az et al. (1996), students only identify square elements that remind them of a wall or of an undecipherable tangle of lines and dots after cell-related observation using the microscope. One of students in the present study also indicated that he remembered "yellow walls" from his microscope observation. And another one used "small marbles" to explain the nucleus. It means that students make a link among elements of a source which are mapped onto relationships among elements of a target (Lakoff & Johnson, 1999).

As it mentioned in the introduction of this study, students have difficulties to integrate connections between cell structures and their functions (Flores & Tovar, 2003). In the present study, when interviewer asked "Can you draw a living cell?" and "What kind of things can be inside a living cell?" students provided answers in three categories namely: cell membrane (one student mentioned it as to protect plant cell), cytoplasm (one student indicated it as liquid inside of cell), and nucleus. Knowing then structure of the living cell is particularly important when learning and understanding respiration, reproduction, nutrition or genetic regulation mechanisms and organelle composition (Flores & Tovar, 2003).

Some studies highlighted that poor educational materials can be a barrier for teaching and learning for both students and teachers (Abraham, Grzybowski, Renner, & Marek, 1992). On the other hand, well designed curriculum materials improve the quality of teaching and learning (Ball & Cohen, 1996; Schmidt, McKnight, & Raizen, 1997). In this study, students remember some abstract concepts such as atom and molecules from their textbooks. It shows the importance of textbooks and materials given to students.

In the study, eleven misconceptions were found which were held by students and presented above.

6. SUGGESTIONS (ÖNERİLER)

There are six main implications to be drawn from this study. They are:

- Turkish primary education curriculum is based on the constructivist theory therefore meaningful understanding and particularly cognitive processing should be taken into consideration and in this process, knowing students' prior knowledge and eliminating the misconceptions are essential before organizing of any kind of further instruction.
- The teachers are an important part of the teaching and learning process. Some studies highlighted that teachers can be the source of misconception(s). For this reason, in-service teacher training camps should be organized where they could easily

explore the new and innovative teaching and learning strategies to eliminate these misconceptions.

- It is also widely accepted that the use of analogies provides students to a better understanding specifically for abstract and complex concepts such as atom and molecules. It is also a necessity for teachers to include analogies in their instruction
- Minogue, Jones, Broadwell and Oppewall (2006) indicate that innovative technologies such as Virtual Reality and haptic devices can make contributions to the students learning. That is why teachers are encouraged to use innovative technologies in their courses. It will provide students with the link between difficult to understand concepts.
- Textbooks and educational materials should be examined and produced in constructivist and innovative ways so that teachers can rely on the textbooks when their area of expertise is other than biology.
- Bahar, Johnstone and Hansell (1999) highlighted the importance of time and they concluded that discussion and time for experiment were not clear for both teachers and students. For this reason, more time should be provided for discussions and practical applications in the teaching and learning environments.

REFERENCES (KAYNAKLAR)

- Abraham, M.R., Grzybowski, E.B., Renner, J.W., and Marek, E.A., (1992). Understanding and misunderstandings of eighth graders of five chemistry concepts found in textbooks. *Journal of Research in Science Teaching*, 29, 105-120.
- Arı, A., (2006). Level of Recalling and Forgetting Mathematical Knowledge in the Fourth Grades in Primary Schools. *Sosyal Bilimler Dergisi*, 16, 109-119.
- Ariely, M.S., (2005). Characterization of the living cell conceptions and aspects of macro-micro thinking of Junior-High school graduates in Israel. Unpublished Master Thesis. [http://stwww.weizmann.ac.il/menu/dissertations/Moriah_Sharon_Ariely_e_MSc.htm].
- Bahar, M., Johnstone, A.H., and Hansell, M.H., (1999). Revisiting learning difficulties in biology *Journal of Biological Education*. 33(2) 84-87.
- Ball, D.L. and Cohen, D.K., (1996). Reform by the book: What is—or might be—the role of curriculum materials in teacher learning and instructional reform? *Educational Researcher*, 25, 8-14.
- Bartov, H., (1978). Can students be taught to distinguish between teleological and causal explanations? *Journal of Research in Science Teaching*, 15, 567-572.
- Bogdan, R.C. and Biklen, S.K., (1998). *Qualitative research in education: An introduction to theory and methods*, (3rd ed.) Needham Heights, MA: Allyn & Bacon.
- Boo, H.K. and Ang, K.C., (2004). Teachers' misconceptions of science as revealed in science examination papers. Annual Conference of the Educational Research Association, 2004, Singapore.
- Caballer, M. and Giménez, I., (1993). Las ideas del alumnado sobre el concepto de célula al finalizar la educación general básica. *Enseñanza de las Ciencias*, 11, 63-68. In Flores, F., Tovar, M.E. (2003). "Representation of the cell and its

- processes in high school students: an integrated view"
International Journal of Science Education, 25, 2, 269-286.
- Carmichael, P., Driver, R., Holding, B., Phillips, I., Twigger, D., and Watts, M., (1991). Research on Students' Conceptions in Science: A Bibliography. Children's Learning in Science Research Group, University of Leeds.
 - DI´az de Bustamante, J. and JimE´nez, A.M.P., (1996). Ves lo que dibujas? Observando ce´lulas con el microscopio. Ense˜anza de las Ciencias, 14, 183-194. In Flores, F., Tovar, M.E. (2003) "Representation of the cell and its processes in high school students: an integrated view" International Journal of Science Education, Vol. 25, 2, 269-286.
 - Driver, R. and Oldham, V., (1985). A constructivist approach to curriculum development in science. Studies in Science Education, 13, 105-122.
 - Education, (2008). Poor working memory holds back one in ten schoolchildren. Issue 302, p2-2, 1/5p;
 - Flores, F. and Tovar, M.E., (2003). "Representation of the cell and its processes in high school students: an integrated view" International Journal of Science Education, Vol. 25, 2, 269-286
 - Friedler, Y., Amir, R., and Tamir, P., (1987). High school students' difficulties in understanding osmosis. International Journal of Science Education, 9(5), 541-551.
 - Gathercole, S.E. and Pickering, S.J., (2000). Working memory deficits in children with low achievements in the national curriculum at seven years of age. British Journal of Educational Psychology, 70, 177-194.
 - Gathercole, S., (2003) Working memory skills and educational attainment: evidence from national curriculum assessments at 7 and 14 years of age. Applied cognitive psychology. 18 (1).
 - Hammer, D., (1996). 'Misconceptions or P-Prims: How May Alternative Perspectives of Cognitive Structure Influence Instructional Perceptions and Intentions? Journal of the Learning Sciences, 5, 2, 97-127.
 - Harrison, A.G., Treagust, D.F., (1998). Secondary students' mental models of atoms and molecules: Implications for teaching chemistry. Science Education. 80, 5, Pages 509 - 534.
 - Haury, D., (2002). "Teaching about the Life and Health of Cells" ERIC Educational Reports.
 - http://findarticles.com/p/articles/mi_pric/is_200210/ai_38092080
12.
 - Koyama, I., Ritchie, K., Fujiwara, T., and Lino, R., (2005). "Fluorescence Imaging for Monitoring the Colocalization of Two Single Molecules in Living Cells" Biophysical Journal, March 1.
 - Kuş, E. (2003). Nicel-nitel araştırma teknikleri. Ankara: Anı Yayıncılık.
 - Lakoff, G. and Johnson, M., (1999). Philosophy in the flesh: The embodied mind and its challenge to Western thought Basic Books, New York
 - Lewis, J., Leach, J., and Wood-Robinson, C., (2000). All in the genes?--young people's understanding of the nature of genes. Journal of Biological Education, 34(2).
 - Longden, B., (1982). Genetics--are there inherent learning difficulties? Journal of Biological Education, 16, 135-140.

- Metz, K.E., (1998). Scientific inquiry within reach of young children. In B.J. Fraser & K.G. Tobin (Eds.), *International handbook of science education* (pp. 81-96). London: Kluwer.
- Minogue, J., Jones, G., Broadwell, B., and Oppewall, T., (2006). The impact of haptic augmentation on middle school students' conceptions of the animal cell. *Virtual Reality* 10, 293-305.
- Nakhleh, M.B. and Samarapungavan, A., (2005). Middle school students' beliefs about matter. *Journal of Research in Science Teaching*, 42, 581-612.
- Perry, D., Klein a, *The Challenges of Scientific Literacy: From the viewpoint of second-generation cognitive science*, *International Journal of Science Education*, 28(2), 143-178.
- Pfundt, H. and Duit, R., (1991). *Bibliography: Students' Alternative Frameworks and Science Education*. 3rd ed. Kiel, Institute for Science Education, University of Kiel.
- Schwaner, T.D., Petty, J.T., and Schwaner, L.A., (1994). Modeling Atoms & Molecules: A New Lesson for Upper Elementary & Middle School Students. *The American Biology Teacher*, 56, 8, 488-491.
- Seymour, J. and Longden, B., (1991). Respiration - that's breathing isn't it? *Journal of Biological Education*, 25, 177-183.
- Smith, J.P., diSessa, A.A., and Roschelle, J., (1993). Misconceptions reconceived: A constructivist analysis of knowledge in transition. *Journal of the Learning Sciences*, 3(2).
- Stavy, R., Eisen, Y., and Yaakobi, D., (1987). How students aged 13-15 understand photosynthesis. *International Journal of Science Education*, 9, 105-115.
- Storey, R.D., (1992a, March). Textbook errors and misconceptions in biology: Cell energetics. *American Biology Teacher*, 54 (3), 161-166.
- Storey, R.D., (1992b, April). Textbook errors and misconceptions in biology: Cell physiology. *American Biology Teacher*, 54 (4), 200-203). [EJ 473 427].
- Tamir, P. and Zohar, A., (1991). Anthropomorphism and teleology in reasoning about biological phenomena. *Science Education* 75, 57-67.
- Turney, J., (1995). The public understanding of genetics - where next? *European Journal of Genetics Society*, 1, 5 - 20.
- Yıldırım, A. ve Şimşek, H., (2004). *Sosyal Bilimlerde Nitel Araştırma Yöntemleri*. Ankara.
- Wood-Robinson, C., (1994). Young people's ideas about inheritance and evolution, *Studies in Science Education*, 24, 29-47.
- Zamora, S. and Guerra, M., (1993). Misconceptions about cells. Technical Report, *Universum*, Universidad Nacional Autónoma de México, México. In Flores, F., Tovar, M.E. (2003) "Representation of the cell and its processes in high school students: an integrated view" *International Journal of Science Education*, 25, 2, 269-286.