

## High School Students' Cognitive Structures and Views: What is a Genetically Modified Organism?

Lise Öğrencilerinin Bilişsel Yapıları ve Görüşleri: Genetiği Değiştirilmiş Organizma Nedir?

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**Abstract.** This research aims to demonstrate high school students' cognitive structures and views about GMOs. This research employs Phenomenology- one of the qualitative research methods. The research group was composed of 205 students attending various high schools chosen through purposeful sampling. A 3-part form was used as the data collection tool. Part one contained a word association test while part two contained views and part three contained a section for drawings. The data were evaluated with content analysis. Consequently, it was found that the participating students' 1024 concepts about GMOs were divided into 5 categories and their 156 drawings were divided into 5 categories. It was found that conceptual framework in relation to GMO had not been formed completely in the participants. On examining the drawings, it was found that students made drawings about the harm of GMOs to health most.

**Keywords:** Genetically modified organisms, high school students, cognitive structure, word association test

**Öz.** Bu araştırmada lise öğrencilerinin GDO'ya ilişkin bilişsel yapıları ve görüşlerinin belirlenmesi amaçlanmıştır. Araştırma nitel desende tarama modelindedir. Araştırmanın çalışma grubunu amaçlı örneklem tekniği ile seçilen ve farklı liselerde okuyan 205 öğrenci oluşturmaktadır. Veri toplama aracı olarak 3 bölümde oluşan bir form kullanılmıştır. Formun ilk bölümünde kelime ilişkilendirme testi, ikinci bölümde görüşler ve üçüncü bölümde ise çizimlerin yapılacağı kısım bulunmaktadır. Veriler içerik analizi yapılarak değerlendirilmiştir. Sonuç olarak araştırmaya katılan öğrencilerin GDO ile ilgili 1024 kavramın 5, 156 çizimin ise 5 kategoride toplandığı görülmüştür. Araştırmaya katılan öğrencilerde GDO ile ilgili kavramsal çatının tam oluşmadığı gözlenmiştir. Yapılan çizimler incelendiğinde ise en çok GDO'nun sağlığa zararları ile ilgili çizimlerin yapıldığı belirlenmiştir.

**Anahtar Kelimeler:** Genetiği değiştirilmiş organizma, lise öğrencisi, bilişsel yapı, kelime ilişkilendirme testi

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## Introduction

It is difficult to learn concepts in biology education. The reason for this is that most of the concepts are abstract and that the students' prior knowledge is inadequate (Byrne and Grace, 2010; Maskill, Cachapuz, and Koulaidis, 1997). Using such approaches such as the constructivist approach is important in disciplines such as biology where abstract concepts are abundant. Fact is not denied in constructivist approach, nor is the role of social interactions and the one of society ignored (von Glaserfeld, 1991). Misconceptions always occur and are unavoidable in biology (Knipples, Waarlo and Boersma, 2005; Kostova, and Radoynovska, 2010). This is caused by the students' perception of abstract concepts- that is to say, their trying to configure the abstract concepts by concretising them (Ozata-Yucel and Ozkan, 2015). In this process, students can have many misconceptions (Tripto, Assaraf, and Amit, 2013). Studies to increase concept acquisition have been conducted in constructivist approach (Harrison, Grayson, and Treagust, 1999; Tao and Gunstone, 1999). One of those studies determines students' cognitive structures through word association test and assures that concepts are taught meaningfully as a whole (Kostova, and Radoynovska, 2010). Some difficult to each subjects difficult to teach are transferred to students through constructivist approach. The subject of the urinary system is a good example for this. Concept maps, v-diagrams and word association methods and techniques are used today in teaching such subjects (Posner, Strike, Hewson, and Gertzog, 1982; Wagner, Valencia, and Elejabarrieta, 1996). In this way, it is easier for students to understand the concepts, interpret them correctly and to form conceptual frameworks (Hovardas, and Korfiatis, 2006).

Another type of misconception is the formation of alternative conceptions. Students configure the concepts that they cannot perceive and thus form alternative conceptions (Dykstra, Boyle, vand Monarch, 1992). It is quite difficult to change and to re-configure those conceptions. New strategies have been developed to correct the alternative conceptions created. They are the misconception change strategies which are based on Piaget's theory of cognitive development. According to Piaget, misconceptions are the structures stemming from lack of knowledge and added one upon another. These structures are randomly shaped by unqualified teaching, students' existing knowledge and by experiences. These structures emerge as misconceptions (Rowell, Dawson and Harry, 1990). According to Piaget (1964), teaching cognitive structures is possible by changing the schemata present in the students' minds, by interpreting them and by organising them. The concept called organising means putting knowledge into organisation, coordinating it, combining and integrating it. When considered from the aspect of biology concepts, flow maps are thought to be associated with organising the schema in students' minds. Word association tests are also used in this context.

Another cause for misconceptions is the effects of the environment (Dascolia, Dimos and Kampylis, 2012). This is because students are sensitive to environmental stimuli and because they are easily influenced by them. Unless students can configure the concepts they cannot fully understand, they have incorrect perceptions due to environmental stimuli. In consequence, either the concept is incorrectly configured and misconceptions are created, or students create alternative conceptions under the influence of the environment, and thus, misconception are created. This is an undesired situation for teachers because it is quite difficult to change those learnt alternative conceptions or misconceptions (Schonborn and Anderson, 2008). Many tests and structures such as word association tests, drawing-writing technique and two-tier tests are

used to reduce the environmental effects (Bahar, Johnstone and Sutcliffe, 1999; Cebesoy and Taşdere, 2016; Nyachwayaa et al. 2011).

Word association tests are an important instrument to uncover the associations between concepts. With them, it is also possible with them to organise the associations between concepts and to correct misconceptions if there are any. Studies conducted include not only primary, secondary and high school students but also university students (Brotman, Mensah, and Lesko, 2010; Daskolia, Dimos and Kamylyis, 2012; Lee and Liu, 2010). The methods and techniques used in all those studies aim to raise the level of cognitive structures in the field of biology. One of the important techniques in this respect is word association technique, and it yields positive results in teaching (Kostova, and Radoynovska, 2008).

On reviewing high school biology course books (MONE, 2013), it was found that there were no units on genetically modified organisms (GMOs) in the 9<sup>th</sup> and 11<sup>th</sup> grade course books. It was found, on the other hand, that the unit of “the general principles of genetics” (a sub-topic of modern genetics applications) was included in the 10<sup>th</sup> grade biology course book and the unit “from genes to proteins” (the sub-topic of Genetics Engineering, Aras of Work, the Contributions of Genetics Engineering and Biotechnology Applications to Health and Economy) was included in the 12<sup>th</sup> grade biology course book. The number of learning outcomes for the unit included in the 10<sup>th</sup> grade course book was 6 and the number of class hours was 42. The unit goals were to assure that students “*understand the concepts and processes related with genetics and Mendel’s principles, exemplify genetic diseases occurring in humans, and understand the genetic bases of biological diversity*” (MONE, 2013). The learning included the following:

- The areas use of such technologies such as gene technologies, DNA finger print, stem cell technologies are researched.
- Traditional and modern biotechnology applications are analysed.
- Plant and animal breeding in the world and in our country is researched and its effects on life are discussed.
- Discussions are made through examples given for the basic topics (applications such as genetic engineering, in vitro fertilisation, stem cell therapy and their importance of them from the social aspect) (MONE, 2013).

The unit of “from genes to proteins” was available in the 12<sup>th</sup> grade biology course book. The number of learning outcomes for the unit was 7 and the number of class hours was 42. The unit goals were to assure that students “*are informed of DNA and RNA, their structure and importance, genetic code, are informed of protein synthesis and central dogma activities, exemplify bioinformatics studies, make estimations about the probable effects of human genome project and genetic counselling on living creatures*” (MONE, 2013). The learning outcomes for the unit included the following:

- The areas of work of genetic engineering and biotechnology (proteomics, genomic, bioinformatics, etc.) are researched.
- The differences between genetic engineering and biotechnology are discussed.
- The production of vaccine, antibiotics, insulin and interferon and applications of cancer treatment are researched.
- Gene therapy is researched.

- Probable consequences of cloning activities and genetically modified organisms are evaluated.
- The issues of biosafety and bioethics are researched and discussed (MONE, 2013).

GMOs are the products whose genetic structures are modified by using biotechnological techniques and methods. GMOs are performed by using two methods: addition and deletion. The purpose of GMOs is to obtain living organisms resistant to drought, frost, insects, viruses, soil salinity acidity, extreme weather, etc. In consequence, increase in crops will be yielded, and labour and use of chemical fertilisers will be economised. GMOs have entered into our life and we have been using them intentionally or unintentionally. It is also a commonly known fact that they are harmful as well as useful. Although their production is not dangerous, they can cause formation of dangerous compounds. The level of knowledge and consciousness is important for the users of GMOs. Unavailability of studies in the literature demonstrating high school students' cognitive structures and views about GMOs indicates the importance of this study.

### **Purpose of the Study**

This study aims to identify high school students' cognitive structures and views on genetically modified organisms (GMOs). Within the scope of this study, answers are sought to the following questions:

1. How are students' cognitive structures about the GMOs?
2. What are students' views on GMOs?
3. How are students' drawings about the GMOs?

### **Method**

Survey model one of the qualitative research designs was used in this study. Survey models are the research models aiming to describe a situation which existed in the past or which currently exists as it is (Creswell, 2013).

### **Study Group**

The study group was composed of 205 high school students in the 2016-2017 academic year. The study group was formed through purposeful sampling. The group consisted of participants in the 17-19 age range. Of the participants, 120 are male whereas 85 are female.

### **Data Collection Tool**

The research data were collected with a word association test. The test contained 3 parts. In part one, the key phrase "Genetically Modified Organisms" was written 10 times one under another, and the students were asked to write a word the or phrase which reminded them of the key phrase next to it the phrase in the time allowed. In part two, the participants were asked to write a sentence about the "Genetically Modified Organisms". Time allowed for both parts was 55 seconds (40 seconds for writing ten key words, 15 seconds for writing a sentence about the key

concept). In part three, the students were asked to state their ideas about the concept of “Genetically Modified Organisms”. The time allowed for part three was 5 minutes.

### **Data Analysis**

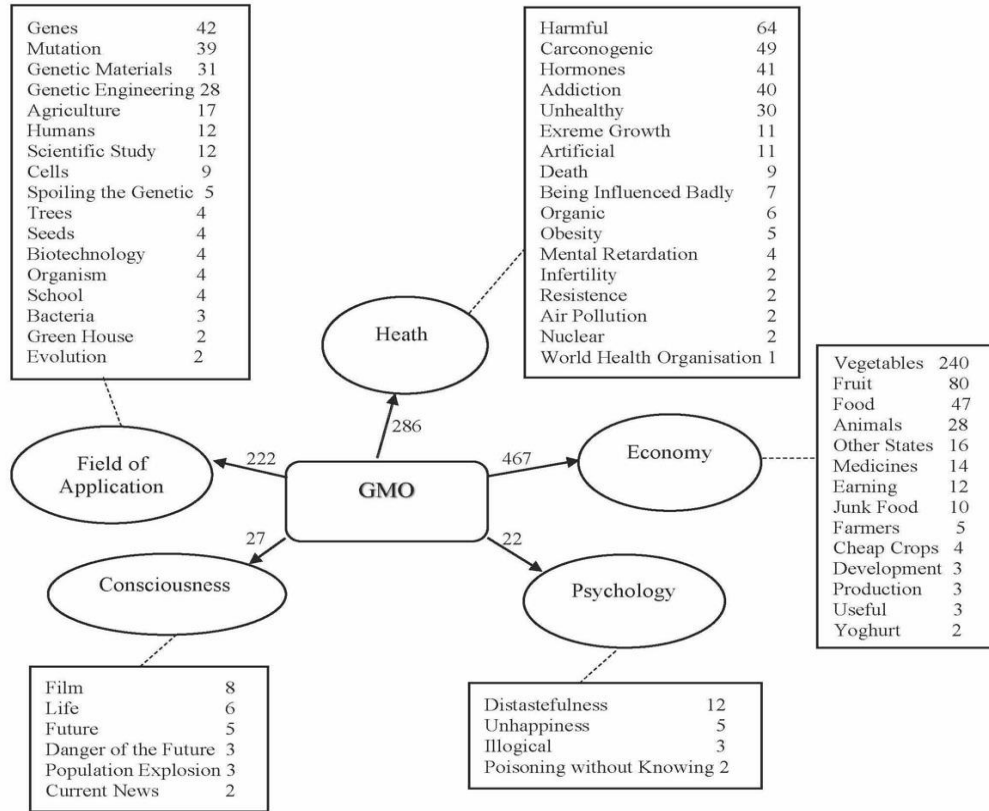
The data coming from the writing and the drawing processes asked in the word association test were put to content analysis. The concepts were divided into categories by experts working independent of each other, according to their relevance. After that, agreement between coders was checked. The frequencies for the words in the categories distinguished were found.

### **Validity and Reliability**

Validity and reliability analyses were performed. Data analysis process was described for validity. For research reliability, whether or not the concepts represented the categories to which they belonged was assessed, and the concepts were categorised according to their relevance. The procedure was done by two experts in 5 weeks. At the end of the procedure, the agreement between coders was found to be 81%.

### **Findings**

This section presents the findings. In relation to the first research problem, the concepts written by students about the GMOs are shown in Figure 1 as a cognitive model. Accordingly, students reported 58 different concepts about the GMOs. The concepts were divided into 5 categories as 1024 concepts. 21 concepts were excluded from evaluation since they were found meaningless. 122 students wrote fewer than 10 concepts that they were supposed to write. According to Figure 1, the largest number of concepts (467 concepts) is in the category of economy while the smallest number of concepts (22 concepts) is in the category of psychology. The most frequently reported vegetables in the category of economy are cucumber, potatoes, peppers, carrots, corn, tomatoes, and the most frequently reported fruit include quince, bananas, water melon, apples, melon, strawberries, pears and grapes.



**Figure 1.** Model for cognitive structure

In relation to the second research problem, students' views concerning GMOs were determined. There were 4 participants who did not state any views. Selected samples from the views stated are quoted below:

*"Trying to get more products depending on population density"*

*"GMOs can be useful or harmful and they can also help development. They can also cause mutation"*

*"Genetically modified organisms, going through mutation by playing with DNA, desire to get more crops"*

*"Every useful product will become a harmful product in the future"*

*"Research has shown that using GMOs in fruit and vegetables gives harm to human health"*

*"Even though food with GMOs is an epoch scientifically, it can be harmful to human health. "They sell hormone-injected fruit and vegetables at the supermarket"*

*"There are genetically modified fruit and plants. They have a modified DNA. They look fresh and bright. For example, apples, water melons, carrots are delicious. But they are unhealthy. Humans are also influenced by them"*

*"Humans themselves are modified by GMOs"*



*“Farmers practicing agriculture are modifying the genetics of fruit and vegetables”*

*“Water melons in the shape of a cube are made by modifying their genetics so that they can pile and store them easily in China”*

*“We ourselves are shortening humans’ life in order for products to have longer shelf life”*

*“In my opinion, they are the cause of colourless lives and all disorders including behavioural disorders. GMOs spoil the naturalness of living things”*

*“there is so much cheating on the market that we are consuming unnatural fruit and vegetables with GMO and this is influencing our health greatly”*

*“Products with GMOs are usually harmful to our body”*

*“They are playing with human life to get more crops in a shorted time”*

*“There was a strawberry inside a tomato. They say GMO products cause cancer. Organic farming is about to finish. They say our life is being shortened because of the GMO products”*

*“It means modifying the genetics to produce more food”*

*“It is for making the shape and taste of fruit and vegetable better”*

*“Consuming unconsciously the organisms which are genetically modified without our knowledge”*

*“Giving pesticide so that fruit and vegetables can be ripe more quickly”*

*“A weapon that pharmaceutical industry makes in order to earn more money”*

*“it means modifying the DNA of a product but it causes cancer and they call these products hormone-injected products in daily language”*

*“Growing crops faster by using GMOs brings profits but it is harmful to health. It means similar size for vegetables”*

*“Poisonous pesticides are being used while growing potatoes, corn, soybean and tomatoes and they are being made harmful to health, and this causes people to put on weight”*

*“Products with GMOs cause genetic disorders.”*

*“it means eating oranges in Summer.”*

*“it is a scientific procedure performed on agricultural products and animals so that they can become ripe earlier.”*

*“GMOs damage the general development of the body.”*

*“Because products with GMOs are used very often in Turkey, the physical and bodily health of children has been spoilt.”*

In relation to the third research problem, students’ drawings about GMOs were analysed. Accordingly, it was found that the students had 42 drawings for vegetables and 32 drawings for fruit. On sequencing the vegetables from the most to the least, the order was as in what follows: tomatoes, corn, cucumber, pumpkin. And the fruit was sequenced as in what follows: apples, water melons, bananas, pears, strawberries, plums. The students also made drawings in relation to health apart from fruit and vegetables. 40 drawings about health were about obesity, extreme forms of growing up, diseases and death. Apart from that, 21 drawings were about economic

value, 14 were about the living structures and the vital activities (DNA, chromosomes, and cellular division) and 5 were about growing crops. In addition to that, 51 drawings were meaningless or empty. A selection of samples from students' drawing is shown below (see Figure 2).

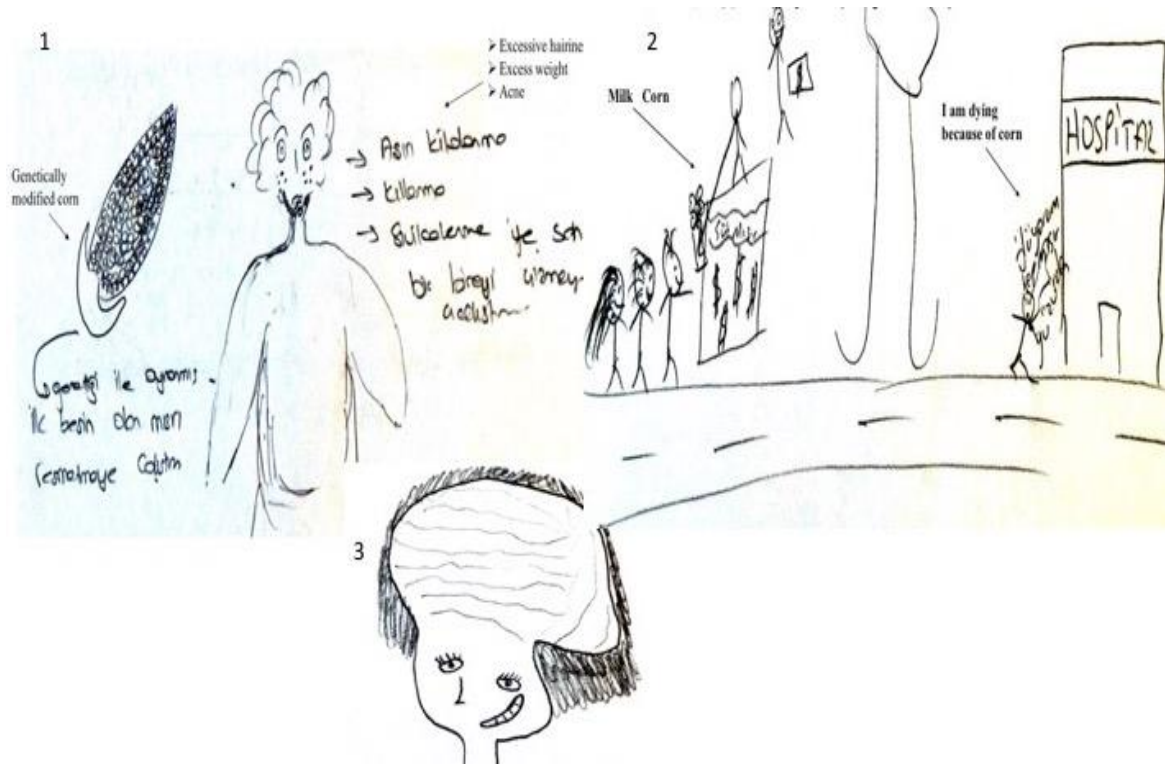


Figure 2. Sample student drawings in relation to GMOs

## Conclusion and Discussion

Processing knowledge is the basis of cognitive learning. The fact that students have differing perceptions although the teacher teaches the same subject to the students in the same classroom is related with their configuring of the knowledge. On examining high school biology course books, it was found that subjects and concepts related with GMOs were available in the 10<sup>th</sup> and 12<sup>th</sup> grade course books (MONE, 2013). 1024 concepts written by 205 students who had been included in the research were divided into the categories of economy, health, field of application, psychology and consciousness. It was remarkable that the number and frequency of concepts in the category of consciousness was smaller than in the other three categories. According to Wilson et al. (2006), interrelated subjects such as biological systems should be considered from a holistic perspective in teaching biology. Otherwise, students confuse similar or related concepts, acquire incomplete or incorrect knowledge, fail to associate their learning with daily life or forget what they learn. It was observed in this research that there was not great variation



in concepts. It was also important that the concepts presented were not about the scientific concepts related with the subject. This indicated that conceptual framework had not been completely formed.

On examining students' views about GMOs in relation to the second research problem, it was found that all students except for 4 stated their views about the subject. 23 of the views were positive whereas 167 were negative and 11 were neutral. On analysing the content of the views, it was found that they were not associated with all of the GMO subjects included in the 10<sup>th</sup> and 12<sup>th</sup> grade course books (MONE, 2013). Students' statements about GMOs indicated that students were knowledgeable about the subjects but that they had incomplete knowledge and that they could not analyse and synthesise because of this. This was indicative of the fact that one learning outcomes in the 10<sup>th</sup> grade course book (the effects of animal and plant breeding on life are discussed) and two learning outcomes in the 12<sup>th</sup> grade course book (the probable consequences of GMOS are evaluated and biosafety-bioethics issues are discussed) were not obtained. According to Piaget (1964), cognitive development is influenced by some factors which we interact with. The factors are maturation, experience, cultural transfer, balancing and organising. Students' learning is also influenced by their experience gained previously in their life. Students' statements such as "useful products will become harmful in the future", "They sell hormone-injected fruit and vegetables at the supermarket", "Farmers practicing agriculture are modifying the genetic of fruit and vegetables", "They say our life is being shortened because of GMO products" and "they say they cause cancer" show that students are influenced by their environment. Students who learn by doing and by experiencing play more active roles in cognitive activities and they reduce environmental effects. This in turn influences their learning in positive ways.

Visuals are also important in learning a subject (Ainsworth, Prain, and Tytler, 2011; Patrick, and Tunnicliffe, 2010). It was found in relation to the third research problem that 154 student drawings about GMOs were related with fruit and vegetables, economy, health, living structures and vital activities. 51 drawings were meaningless and they were excluded from the evaluation. On analysing the drawings, it was found that most of them were about the harms of GMOs to health. It was important that the shapes and concepts were incomplete in drawings about living structures and vital activities. This situation shows us think that the visuals about GMOS were inadequate in learning. It is pointed out in studies that learning and recalling what has been learnt is easier with the use of visuals (Canham and Hegarty, 2010; Cook, 2006; Mason, Pluchino and Tornatora, 2013; Medina-Jerez, Kyndra, and Orihuela-Rabaza, 2011).

### **Implications**

Students with accurate and strong cognitive structures, meaningful and complete learning are among the basic goals of teaching. Therefore, conceptual concrete conceptual learning in relation to GMOs included in biology curriculum should be considered important. In this context, students' levels of knowledge and their misconceptions before and after classes can be determined and teaching can be performed accordingly. Here, concept maps which enables one to set up ties between concepts can be used. In addition, students' learning the GMO subjects by doing and by experiencing is also considered important in associating them with daily life and is a part of environmental effects. Apart from that, it is also important that further studies are performed in relation to the effects of the visuals about GMOs included in biology curriculum.

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