JOURNAL OF BALTIC SCIENCE EDUCATION

ISSN 1648-3898

DETERMINING PROSPECTIVE BIOLOGY TEACHERS' COGNITIVE STRUCTURE IN TERMS OF "BIOTECHNOLOGY"

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Abstract. *Knowledge concerning continuously improving branches of science such as biotechnology in particular is difficult to be understood properly by students, or they learn it incorrectly. One of the most important reasons for this is that students cannot associate in their mind the relevant concepts. The aim of this research is to determine prospective biology teachers' conceptual framework of biotechnology, and thus determining their cognitive structure. The data were collected from 34 prospective biology teachers. Considering the fact that these prospective biology teachers had taken biotechnology course previously, they were selected on the basis of volunteering. Word association test and draw-and-write technique were used in collecting the data. The data obtained were organised on the basis of qualitative content analysis. Then the data were grouped into 7 categories (methods/techniques, biotechnology applications, genetics, other branches of science, organisms, meaning attributed to biotechnology, laboratory) according to word association test, and into 4 categories (methods/techniques, biotechnology applications, genetics, organisms) according to draw-and-write technique. According to the research findings, almost half of the prospective teachers had correct and appropriate associations for biotechnology, whereas a considerable part of them did not have adequate conceptual associations. Also, it was found that prospective teachers had misconceptions about biotechnology.*

Key words: *teaching of biotechnology, cognitive structure, draw-and-write technique, word association test.*

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Introduction

The concept of biotechnology, which was first used by Karl Ershy in 1919, was derived from the words biology and technology and was defined in various ways. Broadly speaking, biotechnology is a branch of science containing all methods used in reproducing a new organism, which naturally does not exist by using the whole or a part of organisms with the help of DNA technology, or in making desired modifications in the genetic structure of an existing organism. Although it is known that traditional practices of biotechnology activities such as making wine or cheese, selecting and reproducing farm animals date back to hundreds of years ago; great progress was made in biotechnology applications especially in recent years. Today biotechnology applications are actively used in many fields such as agriculture, pharmacy, industry, and solution of environmental problems. Struggle with global hunger, producing energy, purification of water, and recycling the waste are among the most widely known applications of biotechnology.

The rapid advances in biotechnology and its applications have caused serious controversy in cultural, social, political, economic, ethical and educational fields (Pardo et al., 2002; Qin & Brown, 2007; Kidman, 2010; Lamanauskas & Makarskaité- Petkevičienė, 2008; Lysaght et al., 2006; Massarani & Moreira, 2005; Prokop et al., 2007; Sürmeli & Şahin, 2010). Individuals in a society need to have certain level of knowledge concerning biotechnology so that they can put forward views or make correct evaluations in relevant arguments. However, research concerning high school and university students point to the inadequacy of these students' level of knowledge concerning biotechnology (Chen & Raffan, 1999; Dawson & Schibeci, 2003; Lamanauskas & Makarskaitė-Petkevičienė, 2008; Prokop et al., 2007; Temelli, 2006; Turkmen & Darcin, 2007). Several pieces of news on biotechnology appear in the press. Some of the information presented there can cause individuals to learn incorrectly or to develop wrong attitudes. Therefore, biology teachers have the biggest responsibility to make sure that the young have access to correct information. The subjects related to biotechnology have been in the biology curriculum in Turkish secondary education since 1998 (MEB, 1998). The head council of education and discipline of the Ministry of National Education included the subject of biotechnology in the biology curriculum of 2013

under the title of Modern Genetic Applications" for 10th graders and under the title of "Genetic Codes and Protein Synthesis" for 12th graders. The curriculum aimed to ensure that students learn the operation fields /methods of biotechnology and that they can discuss its effects on the environment, economy and human health (MEB, 2013). Content of the biotechnology course at university is usually as follows: Definition of concepts of biotechnology and modern biotechnology, significance and application areas of biotechnology, fundamentals and methods of gene technology, cloning and transgenic organisms, recent developments in biotechnology, gene technology in application of agriculture and farming, medical-pharmaceutical, environment, ecology, criminalistics and forensic medicine, ethics, economic, social, legal and religious aspects of biotechnology and gene technology.

Biology is a course students have difficulty in learning (Bahar et al., 1999; Çimer, 2012). Knowledge concerning continuously improving branches of science such as biotechnology in particular is difficult to be understood properly by students, or they learn it incorrectly. One of the most important reasons for this is that students cannot associate in their mind the relevant concepts. A mental configuration about biotechnology should occur in learners' mind and meaningful learning should occur so that they can have correct accumulation of knowledge related with the subject. Meaningful learning occurs by bringing the newly learnt and the previously learnt concepts together in a conscious and organised way and combining them tightly (Güneş et al., 2006). At this point, the "constructivist" approach, which describes how individuals discover knowledge and how learning occurs, comes to the fore (Colburn, 2000). According to this approach, knowledge is configured in individuals' mind by associating it actively with their prior knowledge and prior experiences (Anderson, 1992). In order for students to learn meaningfully, firstly their prior knowledge should be uncovered (Pines & West, 1986; Tsai & Huang, 2002). Thus, exhibiting the associations that individuals set up between concepts they have and their cognitive structure about the subject would be the most influential way in determining whether or not meaningful learning occurs. Many techniques such as structured grids, word association tests, tree diagrams, concept maps, and analogy are used for this purpose (Bahar, 2013).

It was found that there are studies concerning biotechnology in the literature in Turkey, too. These studies centred mostly on the evaluation of people's knowledge and attitudes regarding biotechnology (Erdoğan et al., 2009; Erdoğan et al., 2012; Özel et al., 2009; Uşak et al., 2009); but detailed research on cognitive structures about biotechnology is missing. This research aims to investigate prospective biology teachers' conceptual framework about biotechnology and thus to determine their cognitive structure. It is thought that an assessment of the situation will provide important clues for teacher training. It is also thought that finding out the cognitive structure of prospective teachers- who are the teachers of the future- in relation to biotechnology activities would be important in preparing programmes to determine their inadequacies/incorrect knowledge of biotechnology, and to increase their knowledge of the topic and to correct their incorrect knowledge. Prospective teachers' graduation from university with a correct mental structure developed will ensure that they communicate the subject to their future students correctly, and thus they help to increase the number of individuals with developed consciousness in this respect in society.

Within the scope of the research, prospective biology teachers' conceptual framework about biotechnology was examined by using draw-and-write technique and word association test, and as such, following questions were tried to be answered:

1. How is the cognitive structure of prospective biology teachers in relation to biotechnology? How do prospective biology teachers configure concept of biotechnology in their mind?
   (a) Which words evoke concept of biotechnology to prospective biology teachers?
   (b) Which visuals evoke concept of biotechnology to prospective biology teachers?

Main limitation of this research is the assumption that participants have enough ability and desire to explain their conceptual framework related to biotechnology concept through drawings.

Methodology of Research

General Characteristics of Research

This research is a qualitative one, and was conducted during the 2015-2016 academic year. The word association test and the draw-and-write technique were used as data collection instruments. The collected data were subjected to content analysis. Based on the categories, frequency was provided.

Sample of Research

The research group of the research was composed of 34 (29 female and 5 male) fourth and fifth year prospective biology teachers studying in the biology teaching department of the Educational Faculty of Hacettepe University. Considering the fact that these prospective biology teachers had taken a course in biotechnology previously, they were selected on the basis of volunteering. Before the main application, a test application is made to 5 prospective biology teachers. Thus, appropriateness of the form and the time given to answer are tested.

Data Collection and Instrument

Word association tests (Howards & Korfiatis, 2006) and draw-and-write technique (Backet-Milburn & Mickie, 1999; Patrick & Tunnicliffe, 2010) were employed in this research.

It is quite difficult to describe individuals' cognitive structure about a topic. Only key words of the topic can be determined and comments can be made for this. One of the techniques most commonly used in determining the associations that individuals set up between concepts – and thus in determining their cognitive structures- is word association test. Word association tests are frequently used especially in the field of science education (Aydın & Taşar, 2010; Bahar, Johnstone & Sutcliffe, 1999; Bahar & Özatlı, 2003; Ercan et al., 2010; Köseoğlu & Bayır, 2011; Kurt, 2013; Kurt et al., 2013; Timur & Taşar, 2011; Torkar & Bajd, 2006), and there are also examples in recent years for their use in different fields (Bahar & Kılıçlı, 2001; Işıklı et al., 2011). The technique of word association test is based on the assumption that the ideas coming to one's mind in relation to a stimulant word given are listed (Bahar et al., 1999; Sato & James, 1999). Individuals are given a stimulant (key) word to determine their cognitive structure. In this research, individuals were given the concept of "biotechnology" as the key word. The test administered was composed of two stages. At the first stage, the word "biotechnology" was written ten times one under another, and the participants were asked to write the word it reminds them next to it each time. The participants were given 40 seconds for this. The reason for writing the words in the form of a list one under another was to hinder the risk of chain answers; because if students do not turn back to the key concept each time, they can write the words reminded by the words they write instead of the words reminded by the key concept- which can damage the purpose of the test. In this application made at the first stage, there may be products of association which do not have meaningful relations with the key concept and which are at the level of remembering. In order to be able to determine this, at the second stage, the participants were asked to write sentences related with the key concept in 20 seconds. Thus, the purpose was to obtain statements more complex than a word and upper level statements, and attempts were made to assess the statements in more details on the basis of whether or not they were scientific or they contained misconceptions.

Draw-and-write technique is a technique aiming to obtain data on individuals' hidden thoughts about concepts and on their making sense as well as their attitudes (Backett-Milburn & Mckie, 1999; White & Gunstone, 2000), and it has been successfully used in many research studies in the field of science (Cetin et al, 2013; Kurt & Ekici, 2013; Nyachwayaa, et al., 2011; Stafstrom et al., 2002). The participants were, accordingly, asked to describe in 5 seconds what they knew about biotechnology with figures. They were not imposed a restriction, thus it was made sure that they stated their thoughts freely. Hence, in-depth analysis of the thoughts about the concept was aimed.

Data Analysis

Responses obtained from the word association test were analysed through qualitative content analysis by using the content analysis programme MAXqda. In qualitative content analysis, the material of the data is divided into pieces according to certain category systems (Mayring, 2002). Summative content analysis method, which was an inductive approach, was employed in this research. The words of response were categorised on the criterion of semantic relations. For the reliability of the research, the data were encoded separately by two experts, and the final shape was given on the basis of agreement between the two experts. Tables were prepared for the frequencies about the responses which were grouped under different headings. The words considered to be unrelated and repeated only once were not included in the table. A model describing prospective teachers' cognitive structure about biotechnology was established based on the categories and on the frequencies of the responses in the categories. Moreover, each of the sentences written for biotechnology was analysed one by one, and thus, an attempt was made to determine the misconceptions related. In the draw-and-write technique also the data

coming from this technique in relation to the concept of biotechnology were analysed through summative content analysis. Participants' drawings in relation to the concept of biotechnology were brought together under certain main categories/sub-categories and thus a model was formed. Besides, interesting data obtained through word association test and through draw-and write technique were given as they were by stating the participant number in the text and by citing from participants' drawings and written works.

Results of Research

Findings are presented in two categories as the findings obtained through word association test and as the findings obtained through draw-and-write technique according to the instruments of measurement. Misconceptions are also included in the presentation of findings.

Findings Obtained through the Word Association Test

In consequence of the analysis of the data concerning prospective teachers' cognitive structure for the concept of biotechnology, 7 categories were distinguished with the words stated. The categories were: 1) *methods/techniques* employed in biotechnology, 2) biotechnology *applications*, 3) concepts related with *genetics* reminded by biotechnology, 4) *other branches of science* reminded by biotechnology, 5) *organisms* used in biotechnology activities, 6) *meanings attributed* to biotechnology, and 7) concepts related with *laboratory* which are reminded by biotechnology. 57 different words used in response to these categories and their frequencies are shown in Table 1.

Table 1. The distribution of prospective biology teachers' cognitive structure in terms of "biotechnology" according to the categories.

Categories	Concepts and Frequencies in the Categories	Total Frequencies
Methods/techniques employed in biotechnology	Cloning (18)	72
	PCR (18)	
	Gene technology (10)	
	Gene transfer (5)	
	DNA purification (5)	
	Gene therapy (3)	
	Genome project (3)	
	Gene maps (3)	
	Gene treatment (2)	
	Gene bank (2)	
	DNA analysis (2)	
	DNA manipulation (2)	
2. Biotechnology applications	GMO (18)	59
	Treatment of illnesses (7)	
	Making yoghurt (7)	
	Cheese (6)	
	Corn (6)	
	Mutant (3)	
	Milk (3)	
	Medications (3)	
	Agricultural product (2)	
	Forming different organisms (2)	
	Hybrid animals (2)	

Categories	Concepts and Frequencies in the Categories	Total Frequencies
3. Concepts related with genetics reminded by biotechnology	DNA (12)	57
	Recombinant DNA (11)	
	Gene (9)	
	Vector (6)	
	Enzyme (6)	
	Plasmid (4)	
	Gene isolation (3)	
	Protein (2)	
	Replication (2)	
	Change of chromosomes (2)	
4. Other branches of science reminded by biotechnology	Biology (12)	36
	Molecular biology (8)	
	Molecular genetics (5)	
	Genetics (5)	
	Microbiology (3)	
	Genetic engineering (3)	
5. Organisms used in biotechnology activities	Bacteria (9)	27
	Virus (5)	
	Cell culture (4)	
	Plant (3)	
	Microorganism (3)	
	Bacteriophage (2)	
	M13 phage (2)	
6. Meanings attributed to biotechnology	Technology (4)	12
	Innovation (2)	
	Technique (2)	
	Development (2)	
	Curing (2)	
7. Concepts related with laboratory reminded by biotechnology	Laboratory (2)	10
	Test tube (2)	
	Incubator (2)	
	Microscope (2)	
	Computer (2)	
Total	57 words	275 words

An examination of Table 1 shows that methods/techniques used in biotechnology ranks the first with 12 different concepts and 72 frequencies. The concepts of "cloning", "PCR", "gene technology" are the most frequently given responses.

In the category of "biotechnology applications" ranking the second and having 59 frequencies are 11 different responses. The most frequently focused responses are "GMO", "treatment of illnesses", "making yoghurt", and "cheese".

"Concepts related with genetics" reminded by biotechnology is the third category. The most frequently used answers among the 10 different answers are "DNA", "recombinant DNA", "gene", "vector", and "enzyme".

"Other branches of science" reminded by biotechnology was distinguished as the fourth category. Accordingly,

participants' associations of this category are mostly with the concepts of "biology", molecular biology", "molecular genetics", and "genetics".

In the fifth category called "organisms used in biotechnology activities", the responses of "bacteria" and "virus" are the responses with the highest frequencies.

"Meanings attributed to biology" is the sixth category. Here, it was found that the concept of biotechnology reminded participants more of "technology".

"Concepts related with laboratory reminded by biotechnology" is the seventh category distinguished. Accordingly, it was found that a small portion of participants wrote the words of "laboratory", "test tube", "incubator", "microscope" and "computer".

Prospective biology teachers' explanations in relation to the concept of biotechnology are as in the following (F= Female students; M= Male students):

Examples for the category of "methods/techniques employed in biotechnology" are:

The gene map of the M13 phage was made during DNA cloning activity, and it was used in activities with vectors (M1).

Biotechnology is the procedures made for instance in such ways as deriving pure culture, isolating the genes, DNA cloning, DNA recombination and purification by using technology (F4).

PCR (polymerase chain reaction) is a name given to the reactions which take place within DNA and which are applied in order to increase the original zone between two segments whose sequence is known (F32).

Examples for the category of "biotechnology applications" are:

People's illnesses and genetic ties can be detected by looking at their gene maps (F25).

GMOs affect people's health in a negative way (F26).

The long-term effects of GMOs are not known (F11).

Biotechnology is a science of producing new and different types of organisms by making gene modifications at molecular level with the development of biology (F29).

Although treatment methods found for illnesses and medications are positive for our health, GMOs are a threat to human health (F3).

It is a commonly used technology in meeting the food needs which are increasing due to the increase in population (F8).

Examples for the category of "the concepts related with genetics reminded by biotechnology" are:

Recombinant DNA technology means cutting and destroying with gene technology the DNA molecules which cannot occur on their own in nature and which are mostly derived from different biological species (F2).

There are intron and exon zones in recombinant DNA (F13).

Examples for the category of "other branches of science reminded by biotechnology" are:

Fields such as molecular biology, genetics and biology help biotechnology (F5).

Biotechnology works in parallel to genetic engineering (F15).

Molecular genetics is a sister science to biotechnology (F18).

Examples for the category of "organisms used in biotechnology activities" are:

Viruses and bacteria are used in biotechnology (F11).

They play on the genes of plants, animals and microorganisms with DNA technology... They reproduce enzymes resistant to high temperature and present them for use in PCR. They derive these enzymes from bacteria (F21).

Examples for the category of "meanings attributed to biotechnology" are:

These are the activities performed so as to improve the genetic properties of organisms with biological arrangements and so as to re-arrange them (F16).

It means removability of defects in organisms or bettering them with the advances in technology (F7).

Examples for the category of "concepts related with laboratory reminded by biotechnology" are:

Modern biotechnology usually performs in vitro activities (F30).
Biotechnology studies the working of genes and DNA sequence in the laboratory (F23).
Computers are used in biotechnology for the transfer of data (F21).

On examining prospective teachers' explanations in relation to the concept of biotechnology, it was found that they were quite superficial, that they did not offer any explanations apart from the categories obtained through the word association test, and that they made sentences associated with the words of response.

A model was established for the prospective teachers' cognitive structures about biotechnology by analysing the data obtained from the word association test (see Figure 1).

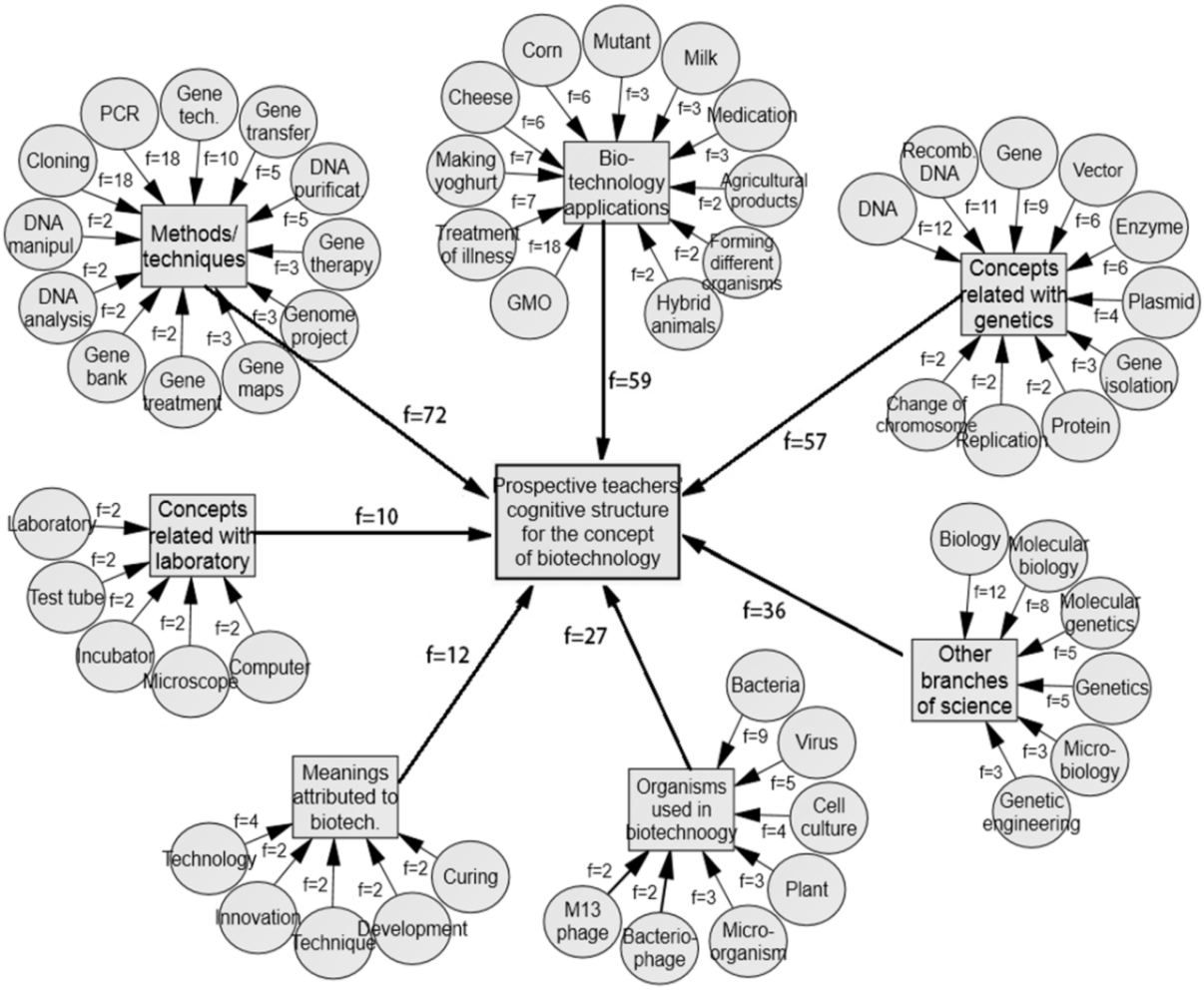

Figure 1: The model for prospective biology teachers' cognitive framework of biotechnology determined through word association test.

As can be seen from the model in Figure 1 prepared according to the measurement tools used in this research, prospective biology teachers' cognitive structures about the concept of biotechnology are divided into 7 categories.

Findings Obtained through Draw-and-Write Technique

The data in the draw-and-write technique were divided into 4 groups: methods/techniques used in biotechnology ($f_{drawing}$=39, $f_{writing}$=24), biotechnology applications ($f_{drawing}$=16, $f_{writing}$=5), concepts related with genetics reminded by biotechnology ($f_{drawing}$=15, $f_{writing}$=9), and organisms used in biotechnology ($f_{drawing}$=14, $f_{writing}$=8). Table 2 shows the frequencies for the writings that participants added to their drawings. The most dominant category for the data concerning both the drawings and the writings is genetics, accordingly.

Table 2. Findings for the concept of biotechnology obtained through draw-and-write technique.

Main Categories	Sub-categories	Draw (f)	Write (f)
1. Concepts related with genetics reminded by biotechnology	DNA	15	9
	Plasmid	7	3
	Vector	6	5
	Recombinant plasmid	5	5
	Nitrogenous organic base	4	2
	Chromosome	2	0
	Total	39	24
2. Biotechnology applications	GMO (corn, apple, strawberry)	12	2
	Stem cell technology	2	2
	Treatment of illnesses	2	1
	Total	16	5
3. Methods/ techniques employed in biotechnology	Gene cloning	7	4
	Bacteria division	5	3
	PCR	3	2
	Total	15	9
4. Organisms used in biotechnology activities	Bacteria	8	4
	Cell culture	2	2
	Total	10	6
	Total	80	44

It was found that 33 out of 34 prospective teachers made drawings for the concept of biotechnology, and that only 1 did not make a drawing. A detailed analysis of the data showed that the drawings made by prospective teachers for the concept of biotechnology were unsatisfactory. Only 11 of the participants (%32) were able to make drawings having the conceptual representation power. The prospective teachers dominantly used DNA helix and GMO production in their drawings, and they offered explanations in writing. Vectors, plasmids, gene cloning and bacteria were other drawings which were prominent.

Prospective teachers' cognitive structures obtained with the draw-and-write technique were also supportive of the model obtained with the word association test (see Figure 2).

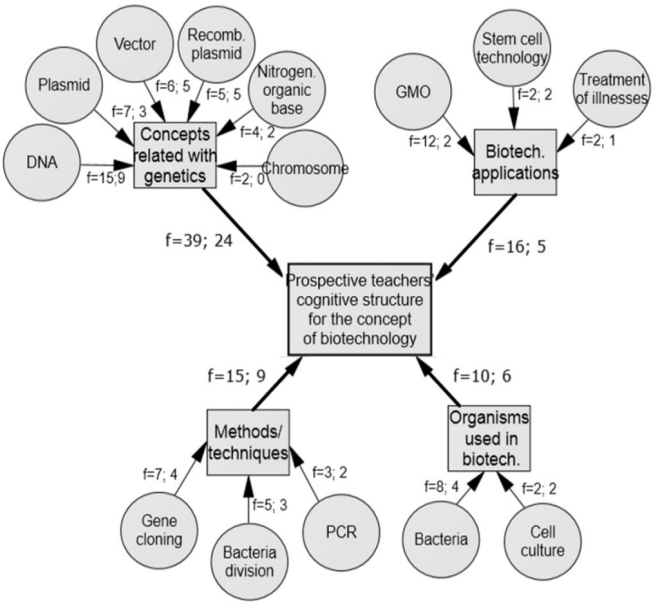

Figure 2: The model for prospective biology teachers' cognitive framework of biotechnology determined through the draw-and-write technique.

Figure 2 shows that prospective biology teachers' conceptual structures about the concept of biotechnology were connected with the four categories mentioned: 1) concepts related with genetics reminded by biotechnology, 2) biotechnology applications, 3) methods/techniques employed in biotechnology, 4) organisms used in biotechnology activities.

Discussion

Biotechnology is a discipline which requires comprehensive knowledge of biology and whose benefits and harms are often argued. Therefore, prospective biology teachers in particular, who are supposed to have biology literacy, need to have accurate and adequate knowledge of biotechnology. It was found that studies concerning biotechnology in the relevant literature mostly centred on the evaluation of people's attitudes towards, views of and knowledge of the risks, benefits and acceptability of biotechnology applications (Erdoğan et al., 2009; Erdoğan et al., 2012; Özel et al., 2009; Uşak et al., 2009). Researchers calling attention to the importance of understanding and evaluating the attitudes displayed by the youth- the adults of the future- towards biotechnology and genetic engineering performed studies to determine students' knowledge and attitudes (Chen & Raffan, 1999; Dawson, 2007; Dawson & Schibeci, 2003; Prokop et al., 2007). This research, on the other hand, aimed to uncover prospective teachers' cognitive structures about biotechnology and thus to determine their views and thoughts of the issue in more details. In consequence of the word association test, their cognitive structures were described in a model composed of 7 categories - namely; methods/techniques employed in biotechnology, biotechnology applications, concepts related with genetics reminded by biotechnology, other branches of science reminded by biotechnology, organisms used in biotechnology activities, meanings attributed to biotechnology, and concepts related with laboratory reminded by biotechnology. According to the draw-and-write technique, however, four categories were obtained: methods/techniques employed in biotechnology, biotechnology applications, concepts related with genetics reminded by biotechnology, and organisms used in biotechnology activities. The categories obtained with both measurement instruments were supportive of each other. This case shows that detailed data can be collected on the conceptual structure about the same topic by using different measurement tools. Thus, it was exhibited in this research that rich data can be obtained supporting one another by employing different measurement tools. In both measurement tools methods/techniques employed in biotechnology, biotechnology applications, and concepts related with genetics reminded by biotechnology appeared to be common and dominant categories.

On examining the data obtained through both methods, it was found that the concepts that biotechnology most frequently reminded prospective teachers were cloning, PCR, GMO, DNA, recombinant DNA, biology, molecular biology, genes, gene cloning, bacteria, gene technology, treatment of illnesses, plasmid, vectors, yoghurt making, cheese, and corn. While it was observed that drawings were mostly about DNA helix, gene cloning, bacteria and GMOs; it was remarkable that prospective teachers stressed the harms of especially GMOs in their drawings. This was a finding parallel to the ones obtained in the literature. Hence, it was found in studies concerning the knowledge and attitudes of students who were against the use of biotechnology that the participants thought that foods containing genetically modified organisms were risky (Başaran et al., 2004; Sürmeli & Şahin, 2010). Sürmeli and Şahin (2010) found in their research with the students of science teaching, biology department and medical school that the group with the lowest attitude scores was the students of science teaching; and that the students of biology department were more supportive of biotechnology activities than the students of science teaching and of medical school. Prospective teachers, who had concerns about the use of biotechnology for the production of GMOs, also reflected their views in this research with their drawings and writings, Sürmeli and Şahin (2010) found that prospective teachers had positive approaches towards biotechnology in terms of producing medications and treatment of illnesses. In a similar vein, prospective teachers also displayed positive attitudes through their explanations and drawings in relation to the treatment of illnesses ($f_{\text{word association test}}=7$; $f_{\text{draw-and-write technique}}=2$) and the production of medications ($f_{\text{word association test}}=3$).

There are studies indicating the inadequacy of prospective teachers' associating what they have learnt with daily life and their inadequacy of comprehending the relations of scientific and unscientific concepts (Özmen, 2003; Kurt & Ekici, 2013). This was also a finding in this current research. Prospective teachers' words, their drawings and writings reflected their scientific concepts related with biotechnology, and their associating these concepts with their daily life and expressing them in their spoken expressions. What is important here is to configure the concepts accurately and to state them academically correctly. Yet, it was found in prospective teachers' words of response in relation to biotechnology that they could not associate adequately and accurately, and that the unscientific concepts hey encountered in real life caused them to form misconceptions. Misconceptions were mostly observed in their drawings. On analysing their drawings, it was found that some of them had misconceptions about the production of GMOs and about the DNA structures of bacteria/viruses. Two participants (F32 and F18) produced drawings showing that they confused the application of growth hormone with the production of GMOs. Participant with the code K6 confused in his/her drawing vaccination of trees with the production of GMOs. Participant K19, on the other hand, confused the DNAs of bacteria with the DNAs of viruses, and used the concept of virus DNA for the shape of a plasmid he/she drew.

Conclusions

According to the research findings, almost half of the prospective teachers had correct and appropriate associations for biotechnology, whereas a considerable part of them did not have adequate conceptual associations. Consequently, it may be said that conceptual structure was not adequately formed in prospective teachers in terms of biotechnology which is very important for these participants, who are to become biology teachers after graduation from university. Therefore, teacher training programmes should be revised, prospective teachers' conceptual knowledge should be improved and meaningful learning as well as interest in the subject should be supported. Yet, it should be remembered that learning concepts is the outcome of the interaction of the scientific knowledge which is taught and of knowledge learnt in daily life. Research findings indicate that prospective teachers' cognitive structures about biotechnology are also influenced by mass media (drawings of GMOs, stem cells, etc.). In this case, teaching biotechnology by relating it with daily life issues and raising consciousness in prospective teachers in relation to the developments in biotechnology will ensure that they can approach the ideas they encounter in a critical way, and that they can correctly understand the risks and benefits of the applications. Besides, visits to research centres in biotechnology classes and inviting experts into these classes will provide prospective teachers with knowledge about the developments and applications in biotechnology.

Another finding obtained in this research was that prospective teachers had misconceptions about biotechnology. These misconceptions cannot be ignored in teacher training in particular. It may be assured that they have permanent and accurate cognitive structures by educating them in using the cognitive strategies effectively during their training. In addition to that, efforts should be made to remove the existing misconceptions by using appropriate teaching strategies.

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Received: *June 17, 2016* Accepted: *August 12, 2016*

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