The knowledge of DNA and DNA technologies among pre-service science teachers

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Abstract

The purpose of this study is to determine the alternative conceptions of elementary school pre-service science teachers regarding DNA and DNA technologies. The questions asked in the study related to subjects including the structure and role of DNA molecule, structure of genes, some genetic technologies, Genetically Modified Organism (GMO) plants, etc. The important finding of the study revealed that a majority of the pre-service teachers were not aware of the discovery date of DNA molecule. When the pre-service teachers were asked to write down names of GMOs and GM drugs, 92% didn't respond. A few of the pre-service teachers gave examples including banana, corn and tomato.

Key words: Pre-service teachers, DNA, DNA technology, alternative conceptions

Introduction

In recent years, many science education researchers have focused on students' conceptual development and cognitive processes (Kwon& Lawson, 2000). They mainly accepted that each student had a different cognitive structure because of their different abilities, backgrounds and attitudes (Piaget, 1969). Many science education studies deal with alternative conceptions related to science subjects taught in schools worldwide. The students learn new information daily and tend to commit this learned information in the direction of beliefs and ideas they previously developed through intuition. As a result, students start to restructure scientific events. Educators now generally agree that students come to class with

established ideas that are different from those usually accepted by scientists. These different conceptions generated by students have been called misconceptions (Arnaudin & Mintzes, 1985), children science (Gilbert, Osborn & Fensham, 1982), naive theories (Mintzes, 1984) or alternative conceptions (Fisher, 1985). Widespread misconceptions in formal education are very resistant to change (Wandersee, Mintzes & Novak, 1994). Students seem to have difficulty learning concepts as well as changing previously held alternative concepts from biology and other science courses (Bahar, 2003; Kinchin, 2000; Treagust, 1988; Bloom, 1990). Several reasons suggest that students can hold alternative conceptions; misconceptions could begin during the first school years or even earlier (Bell, 1981; Pines & West, 1986). Alternative conceptions held by students were not easily changed throughout their schooling. These misconceptions adversely affected meaningful learning of new concepts and the ability to make connections with other concepts in science courses (Strike & Posner, 1982).

With the goal to help individuals become science and technology literate, some of the most important aims of science education are to make sure that students learn and understand the natural world, experience the excitement and intellectual prosperity of it and use proper scientific processes and principles while making personal decisions. Today, biotechnology and genetic engineering have considerably improved issues such as drug production, criminal DNA testing, cloning, gene transfer, the human genome project and nutrition production. The studies made in biotechnology and genetic engineering fields shed light on a good deal of unknown subjects; however, at the same time, they are met with reservations by some members of the scientific community due to possible future outcomes. Specifically, the ethical discussions about the development of biotechnology and its area of usage are subjects of many studies (Oka & Macer, 2000). In their study to identify high school students' stance towards biotechnology in Taiwan and England, Chen and Raffan (1999) pointed out that students' opinions concede that genetic intervention can be made on plants, but the genes of the animals shouldn't be messed with. In their studies, Dawson and Schibeci (2003) determined 15-year-old students' knowledge about modern biotechnology in West Australia, and they concluded that approximately 1/3 of the students have little or no information about biotechnology; moreover, they are confused about the future uses of the biotechnology. Dawson and Schibeci (2003) have also revealed the stance of the 15-year-old students in West Australia toward modern biotechnology, and they concluded that more than 90% of the students concede to biotechnological practices on plants. The ethical discussions about the development of biotechnology and its area of usage are subjects to many studies (Oka & Macer, 2000). Dawson and Soames (2006) have discovered a positive improvement in students' knowledge who were taking biotechnology lessons, however they disapproved of the usage of humans in biotechnological studies. Ozdemir (2005) revealed that elementary education students have misconceptions about genetics and biotechnology. The researcher pointed out that the main concepts of genetics and biotechnology should be taught more thoroughly, in an interrelated way and with tangible examples. In their study on genetic concept comprehension levels of both students and pre-service in four different populations in Israel, Marbach-Ad (2001) revealed that both the students and pre-service teachers were in need of genetic education.

In our society, genetic engineering and biotechnology information and their application is learned about through the media rather than in educational institutions. Students' views of biotechnology and its application areas tend to be impacted by various discussions about the subject. In addition, having a good grasp of the main scientific concepts rather than specific details is considered to be more valuable. For this reason, a better understanding of biotechnology and genetic engineering will allow students to make more correct and

conscious decisions related to application areas of biotechnology. In many countries, the subjects related to biotechnology and genetic engineering are included in the high school biology program in Turkey. However, upon scanning the literature, not many studies were found concerning the knowledge and stance of the students towards genetic engineering and biotechnology in Turkey. Determining the biotechnology and genetic engineering knowledge and stance of pre-service teachers will be helpful for designing new teaching materials for the subject.

Purpose

The purpose of this study is to determine the alternative conceptions of elementary school pre-service science teachers on DNA and DNA technologies. The questions we tried to answer include: What do the students know about DNA and DNA Technologies? What are the alternative answers of the pre-service science teachers about DNA and DNA Technologies?

Methods

This qualitative research study was carried out using a scanning model. In order to determine the knowledge of the pre-service science teachers in this study, questions related to DNA and roles, structure of DNA, Genetically Modified Organisms, in addition to some questions related to DNA technologies developed by Mahajan and Chattopadhyay (with permission) were used. This survey was carried out during the spring semester of the 2006-2007 academic year with the participation of the elementary school pre-service science teachers of the Faculty of Education at Selcuk University. The students were informed that this was not an examination, and enough time was given to students to complete the questionnaire. Percent statements are used for the analysis of the data.

Pre-service teachers had learned DNA and DNA technology informations in their biology lessons during their education. The answers pre-service teachers gave to the questions were analyzed separately. The questions used in the survey were open ended.

Questions about DNA and DNA technology:

1) Who discovered the **structure of DNA** and in which year?

2) What is the structure of **B-DNA ?** Briefly write in your answers in the choices given below:

a) Number of strands:

b) Chemical composition:

c) Types of bonds involved in the DNA structure:

d) Measurements (width, number of base pairs per turn, length of DNA per turn, etc.):

e) Complementary strands:

f) Any other important information regarding the DNA structure:

3) The term **gene expression** refers to what? Write in short sentences.

4) Make a flow chart to explain the concept of **'Central Dogma'** (e.g., A è B è CèDè…).

5) What is **cloning**? Write as bullet points.

6) What is **gene cloning**? Write as bullet points.

7) What is **animal cloning**? Write as bullet points.

8) **"DNA fingerprinting** has become a useful tool to solve many criminal cases/settling disputes in blood relations." What is DNA fingerprinting? Write as bullet points.

9) Who should have **access to the genetic profile** of an individual? Tick one or more options given below and give reasons for your choice.

(a) No one **(b)** Doctor and only the person concerned **(c)** Person and immediate family

(d) Person and all family members **(e)** Police and other security agencies

(f) Employer **(g)** School/college authorities **(h)** Any other individuals **(i)** The scientist

Reasons for your choice:

10) Name a few GMOs or GM drugs.

11) If GM plants are to be cultivated in Turkey on a large scale:

i) Should these plants (and other GMOs) be free to be introduced in the open fields and markets so that the farmers and the industry make good profits? **Yes/No**

ii) Or, should there be some checks? **Yes/No.**

iii) Have you any ideas about these checks/regulations? **Yes/No**

iv) If yes, give a few details about these regulations. Write as bullet points.

v) Name one GM plant introduced in Turkey?

Sample

144 elementary school pre-service science teachers studying at the Faculty of Education in Selcuk University during the 2006-2007 academic year who were taught biology lessons in high school formed the sample of this study. The ages of the pre-service teachers who participated in this study were between 19 and 23. Pre-service teachers were from the different regions in Turkey. These students learned biotechnology and genetic engineering information during biology lessons while attending high school.

Results

A detailed analysis of the student answers is given below. When we look at the answers of the pre-service teachers concerning the discoverers of the B-DNA molecule and the discovery year of B-DNA, we see that 17% of the students gave correct answers about the name of the discoverers, and 83% answered incorrectly or didn't answer at all. In addition, 96% of the pre-service science teachers gave wrong answers to discovery date of DNA (1950, 1937, etc.). The responses given by the 144 pre-service science teachers to the question about the structure of B-DNA including details like the number of DNA strands, chemical compositions, types of bonds, specific dimensions and complementary nature are shown in the Table 1.

Table 1. Analysis of responses of 144 pre-service teachers regarding the B-DNA structure

Structural details of B-DNA	Completely correct response (%)	Incorrect/Partly correct response (%)	Not attempted (%)
Number of strands	46	44	10
Chemical composition	60	35	5
Types of bonds	6	49	45
Specific dimensions	6	40	54
Complementary nature	49	51	0

While 46% of the pre-service teachers responded correctly to the number of DNA strands, 44% gave wrong responses or responses without scientific relevance. 10% of the pre-service teachers didn't respond to the question. 60% answered correctly to the question regarding the chemical composition of DNA. 35% gave wrong responses and 5% didn't answer. Some of the non-scientific alternative responses given by the pre-service teachers included amino acids and ribose saccharin. Some alternative conceptions about types of DNA bonds are Van der Waal's bonds and covalent bonds. As for the question about the specific dimensions of DNA, a few of the pre-service teachers, 6%, gave correct responses, while the majority (94%) gave wrong answers or didn't respond. While 49% of the pre-service teachers correctly answered the question about the complementary nature of DNA, 51% gave wrong and non-scientific responses (Table 1).

The question which asked what the gene does as a means of expression, approximately 50% of the pre-service teachers gave correct answers, while the other half gave wrong answers or answers without scientifically relevant responses.

When asked to draw the schema of the central dogma, it was revealed that 80% of the pre-service teachers couldn't draw or didn't give any responses. (For example RNA-DNA-Protein).

For the questions asked to learn about the knowledge of the pre-service teachers regarding cloning, gene cloning, animal cloning, 42% of the pre-service teachers mentioned both animal and gene cloning. When the question regarding gene cloning was specifically asked, 11% of the pre-service teachers gave scientifically valid, meaningful responses. When asked specifically about animal cloning, only 6% of the pre-service teachers were knowledgeable about the subject. Some of the pre-service science teachers were aware of cloned animals like Dolly.

Some of the acceptable thoughts of the pre-service teachers about cloning, gene cloning and animal cloning are as follows:

Acceptable ideas about cloning:

It is the forming of a genetic copy of an organism or cell. It is copying the same type of organism from someone's cell. It is the copying of genetic material of an organism. It is copying; copying an organ may be the cure to most illnesses. It is copying DNA that carry the same genotype of an individual. Cloning means copying, in other words,forming a characteristic from the same characteristic. It is forming the same or similar organism by transferring a DNA to ovule.

Acceptable ideas about gene cloning:

It is the copying of the genetic code of an organism that carries all its vital characteristics. It is the exact copying of a gene with its codes. It is the transfer of a gene taken from the stem cell of an organism to another organism. It is the forming the double of a gene with the same characteristics. It is forming another gene with the same characteristics of a gene. As a defense against illnesses, it is transferring the genes of an organism to other organisms.

Acceptable ideas about animal cloning:

It is the forming a duplicate of an organism by copying the genetic material of an animal. It is the copying of an animal.

Some examples of the alternative conceptions of the pre-service science teachers with no scientific validity about cloning, gene cloning, animal cloning;

Alternative conceptions about cloning:

It is obtaining a new organism 100% similar to previous organism. It is transferring the characteristic of an organism to another organism. They are copied cells without any genetic change. It is creating the same DNA batch with another DNA batch. It is creating more cells from one cell with the help of fertilization. It is creating a new organism from an existing organism. It is creating individuals with the same phenotype and genotype. It is the studies in which the DNA bond is multiplied in artificial environment for creating organisms.

Alternative conceptions about gene cloning:

It is creating the same gene. It is the copying of genes without making any changes in their genetic structure. It is the process of creating new genes by the genes through other genes. It is transferring the gene of an organism to the new organism which will form. It is copying a characteristic of an organism. It is creating a new individual with the same DNA sequence but different kind.

Alternative conceptions about animal cloning:

It is copying all the animal's genes. It is creating a new kind of animal type based on strong characterized egg and sperm cell from the animals. It is transferring the egg of the helper mother, which was impregnated in an outside setting to the carrier mother.

As for the question about DNA fingerprinting, only 22% of the pre-service teachers responded with meaningful opinions, while 78% didn't answer or responded with no scientific validity.

As for the question which regarding who should be able to access to the genetic profile of an individual, 51% of the pre-service teachers stated the doctor and only the person concerned, 28% replied the person and immediate family members, 10% replied the police and security agencies, 11% responded as nobody, employer, school and college officials etc (Table 2).

Table 2. Pre-service teachers' choices about the preference to access genetic information.

	%
Doctor and only the person concerned	51
Person and immediate family members	28
Police and security agencies	10
Other	11

When the pre-service science teachers were asked if they ever heard of GMOs, 86% stated that they had not and that they had no idea how the GMOs were created. From those who said they had heard of GMOs, they didn't give any meaningful responses.

When the pre-service teachers were asked to write down some of the GMOs and GM drug names, 92% didn't responded. A few of the pre-service teachers gave examples of banana, corn and tomato.

To the question that asked, "should GM plants allowed to be grown in Turkey", 38% of the pre-service science teachers responded positively. Among those who replied negatively, they gave such responses as "they might create health problems, it is not ethical, ...''

Discussion

In their study on comprehension levels of both the students and pre-service teachers about genetic concepts in four different populations in Israel, Marbach-Ad (2001) revealed that the students and pre-service teachers are in need of genetic education. Lock & Miles revealed that the students approve of meddling with the genetic structure of animals, however female students don't approve of meddling with the genetic structure of farm animals (Lock & Miles, 1993).

Similar results were obtained from English and Taiwanese students about biotechnology and its application areas. Approximately half of the English and Taiwanese students were able to give examples about biotechnology (Dawson & Schibeci, 2003; Chen & Raffan, 1999). In another study, it was revealed that approximately 1/3 of the students in West Australia have little or no knowledge about the developments in biotechnology; moreover, they are confused about the future uses of the biotechnology (Dawson & Schibeci, 2003; Schibeci, 1999). In a study about students' stance towards biotechnology, it was revealed that more than 90% concede to using microorganisms in biotechnological practices.

In addition, a majority of the students are more open to meddling with plant genetics and microorganisms than animals and humans (Dawson & Schibeci, 2003). It was revealed that the students approved of meddling with the genetic structure of animals, however female students did not approve of meddling with the genetic structure of farm animals (Lock & Miles, 1993). Schibeci (1999) discovered that high school teachers showed a more positive approach to gene technology than pre-service teachers. Massarani & Moreira (2005) discovered that most of the students believe meddling with the nutritional genes can be beneficial. The results obtained from this study in no way contradict with the results of other studies made.

Bal & Keskin (2002) revealed that a big majority of the university science students concede to studies made on microorganisms, plants and animals in order to improve health conditions of humans, rather than genetic engineering studies made on humans.

In their study on 108 biology students who had taken classes on microbiology and biotechnology in India, Mahajan & Chattopadhyay (2004) asked questions about as the structure and role of DNA, the structure and role of genes, some genetic technologies, and genetically modified organisms (GMO); and as a result, they found that a majority of the students have inadequate knowledge about the molecular structure of DNA, and cloning, etc., and they have alternative responses about the subject of genes. The results of that study are very similar to results of our study.

Conclusion and Recommendation

This study was done on pre-service science teachers of Selcuk University. The questions asked in the study included subjects like the structure and role of DNA molecule, structure of genes, some genetic technologies, Genetically Modified Organism (GMO) plants, etc. The important finding of the study was that a large majority of the pre-service teachers were not aware of the discovery date of the DNA molecule. Pre-service teachers did have some knowledge about general structure of DNA, however they had partial knowledge about dimensions of DNA and types of bonds. Their knowledge about the definition and structure of the gene was considerably low, and a large majority of the pre-service teachers (80%) couldn't draw the flow schema of the central dogma correctly.

The questions that were asked to assess the knowledge of the pre-service teachers about cloning, gene cloning, animal cloning, 42% of the pre-service teachers mentioned both animal and gene cloning. When asked specifically about gene cloning, 11% of the pre-service teachers gave scientifically valid, meaningful responses. When asked specifically about animal cloning, only 6% of the pre-service teachers were knowledgeable about the subject. Some of the pre-service teachers were aware of cloned animals like Dolly. It was revealed that pre-service teachers not only had acceptable opinions about cloning, gene cloning, and animal cloning (Example: It is the forming of a genetic copy of an organism or cell), but they also had alterative opinions without scientific validity (It is creating a new individual with the same DNA sequence but different kind).

Recent studies show that science teachers need a genetic and biotechnology education. Some factors are limiting the genetic biotechnology education. These factors are lack of expert teachers in the field, a lack of appropriate teaching activities and a lack of sufficient teaching material and time (Dawson, 2001). An effective genetic biotechnology education not only enhances the knowledge of the students, but it also helps them understand the risks, disadvantages and advantages of modern biotechnology. Evaluating the perceptions and stances of the students about genetics and biotechnology will help in the teaching phase. The students should be given opportunities to discuss genetics and biotechnology. In addition, teachers should be aware of the missing knowledge and misconceptions of the students about the subjects of genetics and biotechnology.

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