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American elementary education pre-service teachers' attitudes towards biotechnology processes

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This study examined elementary education pre-service teachers' attitudes towards biotechnology processes. A sample comprised 88 elementary education pre-service teachers at a mid-sized university in the Midwest of the USA. Sixty and 28 of these pre-service teachers were enrolled in Introductory Science Methods course and Advance Science Methods Course, respectively. Data were collected using a questionnaire which had 15 statements on a 3 Likert-scale and required students to indicate whether each statement is acceptable or unacceptable. The results indicated that elementary education pre-service teachers from both courses generally held a wide range of attitudes towards biotechnology. Notably, majority of the pre-service teachers approved the genetic modification of microorganisms and plants, but disapproved the processes that involved the insertion or removal of genes in humans and animals. Implications for science teacher education, curriculum as well as recommendations for further research are discussed.

Keywords: biotechnology, teacher, attitude, elementary education

Introduction

Biotechnology is one of the science disciplines that have undergone rapid growth in the 21st century (Dawson et al., 2006; Buyukgungor et al., 2009; Usak et al., 2009). However, there has been a confusion surrounding the definition for biotechnology among different organizations (Buyukgungor et al, 2009; Wells, 1995). For example, America's Office of Technology Assessment [OTA] (1988) defined biotechnology as any technique that uses living organisms or parts of organisms, to make or modify products to improve plants, animals, or to develop microorganisms for specific uses. The European Federation of Biotechnology [EFB] (1999) defined biotechnology as the integration of natural sciences and engineering in order to achieve the application of organisms, cells, parts thereof and molecular analogues for products and services. Furthermore, the international Organization for Economic Cooperation and Development [OECD] (2005) defined biotechnology as the application of science and technology to living organisms (e.g. microorganisms, enzymes, cells of animal and plant), as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods (e.g. products of the industries concerning food, drink, drug and biochemical substances), and services (e.g. treatment of environmental waste and pollution). Despite the various biotechnology definitions provided by different organizations, there are three elements essential to what biotechnology involves (Wells,

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1995). First, biotechnology involves the use of *living organisms* which include plants, microbes, animals as well as human beings. Second, biotechnology involves *parts of organisms or components* within the organisms that can be used in isolation from the organism, and include pieces of DNA, enzymes or internal cell organelles. Third, biotechnology involves *specific processes or techniques* for making or modifying living organisms or parts thereof, and these include genetic engineering or genetic modification. Therefore, in this paper, biotechnology is broadly referred to as the use of biologically based technologies and processes to produce different products.

The biotechnology processes have impacted our personal lives and society at large, particularly in areas of sanitation, agriculture, food industry and in medicine (Davison, et al, 1997; Dawson, 2007). For example, in sanitation industry, genetically engineered microorganisms (such as bacteria) have been used to break down human sewerage wastes. In agriculture it is now possible to genetically engineer certain plant species to either make them drought resistant or pest resistant. In the food industry, most foods currently produced are genetically engineered to either make them taste better or make them have a longer life span. In the medical industry, biotechnologies have been developed to identify individuals vulnerable to certain diseases and to cure some of the diseases. With respect to career advancements, biotechnology is laden with professional opportunities, making it a crucial field for both scientific and economic progress (Kidman, 2009; Solomon, 2001; Steele & Aubusson, 2004).

The varied benefits of biotechnology suggest the need for students, teachers and citizens at large to be scientifically literate so that they can appreciate how biotechnology is impacting their lives and societies. To ensure that teachers and their students are informed about the advances of biotechnology, some national curriculum frameworks worldwide strongly support and include biotechnology education. For example, the English National Curriculum incorporates ethical issues in relation to biotechnology (Chen & Raffan, 1999). New Zealand (Conner, 2000) and Australia (Dawson & Schibeci, 2003) also recognize the importance of biotechnology in their curriculum. In South Africa, the Department of Science and Technology embarked on a strategy to create a more informed South African public about biotechnology through the establishment of regional innovation centers in 2001 (Pouris, 2003). However, parallel to its rapid developments, biotechnology is surrounded by intrinsic issues which include the social, ethical and acceptable risks with regard to genetic engineering, cloning, and genetically modified foods (Bailey et al, 2002). As such, Chen et al. (1999) warn that biotechnology education should equip individuals with the current knowledge and opportunities for them to form their own views based on their understandings of modern biotechnology.

Therefore, it is imperative that pre-service science teachers' attitudes towards biotechnology are investigated primarily because teacher attitudes determine the extent to which they would be receptive to biotechnology and consequently determine whether they would teach biotechnology to their students. In this study, the term attitude is defined as an evaluation showing favorable (approve) or unfavorable (disapprove) feelings towards a physiological object, in this case the object is biotechnology. Attitudes have significant influences on individuals' desire to learn a particular course or topic (Germann, 1988; Richardson, 1996). As such, elementary education pre-service teachers' willingness to learn more about biotechnology processes can depend on their attitude towards them. Young (1998) also argued that if pre-service teachers' attitudes towards a subject or topic are important, then it is essential to know what those attitudes are if changes to the curriculum are to be made. Our interest in the attitudes and expectations that pre-service teachers bring to our elementary science education courses is critical, since such factors can impede their learning of biotechnology or hinder the extent to which they will develop useful biotechnology intuitions and appreciation for how biotechnology is useful in their personal lives and for their students.

Several studies have investigated students and teachers' attitudes towards biotechnology processes, particularly genetic engineering and modification of microbes, plants, foods, animals as well as human cells (e.g. Chen et al, 1999; Dawson, 2007; Dawson et al., 2003; Dawson et al., 2006; Gunter et al., 1998; Kidman, 2009; Lock et al., 1993; Pouris, 2003; Prokop et al., 2007; Usak et al., 2009). Table 1 shows some previous studies (in chronological order) and the corresponding student attitudes.

Six aspects became evident from the reviewed literature on attitudes towards biotechnology and its processes. First, nearly all studies show that there was a broad and higher approval rating of biotechnology and genetic modification applied to microorganisms and plants, but less approval was found in use of biotechnology in human cells and animals (e.g. Chen et al., 1999; Dawson et al., 2003; Gunter et al., 1998; Lock et al., 1993; Usak et al., 2009). According to Dawson et al. (2003), the main reason for the higher approval for the use of microorganisms and plants is the beneficial aspect to humanity; whereas the main reason for the rejection of genetic modification of animals and humans is that the process is unethical and unnatural.

Second, the studies that compared attitudes to enrolment in biology courses found conflicting results (e.g. Chen et al., 1999; Hill et al., 1999; Prokop et al., 2007). For instance, Chen *et al* (1999) found that Taiwanese and UK students studying biology had more favorable attitudes toward biotechnology and genetic engineering than those not studying biology. Hill et al (1999) also found that biology students were more likely to approve genetically engineered foods than those not studying biology. In contrast, Prokop *et al* (2007) found that although students enrolled in biology courses had better knowledge of biotechnology, their attitudes towards genetic engineering were not favorable, and were similar to those who were not studying biology.

Third, some studies that compared attitudes towards biotechnology to gender (e.g. Chen et al, 1999; Prokop et al, 2007), found some differences between females and males. For instance, Prokop et al (2007) found that females showed lower approval ratings than males toward biotechnology, particularly with respect to genetically modified products. Moerbeek et al (2005) explained this trend using the "gender paradox" hypothesis, which proposes that females have more tentative attitudes towards new products than males because they buy food for children. However, Prokop et al (2007) warn that caution about comparisons between males and females are needed given the large disparity in numbers in most studies, including our current study. To address this low sample size for females in our study, we calculated Cohen's *d* value, which is independent of sample sizes (see the Methodology and Results sections).

Fourth, some studies compared attitudes towards biotechnology among respondents from different educational levels such as high school and university students (e.g. Usak et al., 2009). These researchers found that the attitudes were not influenced by education level. Particularly, Usak et al. found that both high school and university students indicated similar attitudes toward the use of cloning for saving of endangered species; towards the transfer of genetic materials between plants and animals; all did not agree with improving taste or freshness maintenance of genetically modified products through genetic modification; all had favorable attitudes towards the use of genetically modified microbes in decomposing human sewage; almost same proportions of students (67% of high school and 70% of university students) indicated that it was not acceptable to insert genes from people to animals.

Fifth, most studies have investigated high school and university students, and very few studies have been done on pre-service teachers (e.g. Prokop et al, 2007). Yet, research shows that attitudes affect science teachers' behavior and influence how well teachers would approach good science teaching in schools (Cantrell, Young, & Moore, 2003). Sixth, most of the studies on biotechnology attitudes have been conducted in Australia, Britain and central Europe, and only a few in the USA (e.g. Schmidt et al, 2005; Wie et al, 1998). However, Wie et al and Schmidt et al's studies were not conducted among school-going age populace or pre-service university students; instead they were conducted among working health professionals (i.e. registered American dietitians, nurses, and physicians). The limited studies on elementary education pre-service teachers' attitudes towards biotechnology as well as the dearth of research from the American students' perspective are the rationales for the current study.

Table 1. Summary of students' attitudes towards biotechnology, in percentages

	Researchers who identified the corresponding attitudes						
Categories of attitudes towards biotechnology, as identified by different researchers	Lock et al (1993) n=188 (14-16 year old British students)	Wie et al (1998) n=269 (American registered dietitians)	Chen et al (1999) n=336 (183 Taiwanese &	Dawson et al (2003) n=905 (Australian high	Dawson (2007) n=465 (Australian high	Prokop et al (2007) n=378 (Slovakian pre-	Usak et al (2009) n=628
Use of microorganisms for specific processes							
Using yeast to produce wine and beer.	77^{A}, 3^{D}, 21^{NS}				74^{A}		
Using genetically engineered microorganisms to enable more efficient breaking down of human sewerage.	81^{A}, 3^{D}, 17^{NS}				79^{A}		100^{A}
Growing yeast for animal food.	61^{A}, 7^{D}, 31^{NS}				64^{A}		
Average Mean	***73^{A}, 4^{D}, 23^{NS}***			***90^{A}***	***73^{A}***		***100^{A}***
Genetic modification of plants/food							
Altering plant genes so that they grow better /quickly	76^{A}, 10^{D}, 14^{NS}		64^{A}		68^{A}		
Adding genes to yeast to make better tasting bread/beer.	69^{A}, 12^{D}, 19^{NS}				55^{A}		
Adding genes in plants to increase nutritional value.					58^{A}		
Altering plant genes to make them more resistant to insect damage		3.4-4.8^{MAR}					
Altering genes in fruit (food) to improve taste.	78^{A}, 10^{D}, 13^{NS}				50^{A}	58^{D}	100^{D}
Altering genes in tomatoes to make them ripen more slowly and have a longer shelf life.	53^{A}, 28^{D}, 19^{NS}		76^{A}		46^{A}	54^{D}	100^{D}
Inserting genes from microorganisms into crops to provide pesticide resistance.					56^{A}	13^{A}	

Purpose of the Study

The purpose of this study, therefore, was to examine American elementary education pre-service teachers' attitudes towards biotechnology and its related processes namely: *Use of microorganisms for specific processes; Genetic modification of plants/foods; Genetic modification of animals; Genetic modification of human genes*.

The two research questions that guided this study were: (a) What are pre-service teachers' attitudes towards biotechnology processes? (b) Are pre-service teachers' attitudes towards biotechnology processes influenced by these demographics (i.e. science education course level enrolled in, teaching subject major, having taken biology courses previously, and gender)?

Significance of the Study

There is need to establish elementary education pre-service teachers' attitude towards biotechnology processes since attitudes have an effect on science instructional practice. The findings would be helpful in identifying the aspects of biotechnology and its related processes that are problematic among elementary education pre-service teachers and recommend possible changes to science courses in teacher education. As such, this study should be of interest to science educators who are involved in science teacher preparation and science education outreach programs. Science teacher educators should be aware of elementary education pre-service teachers' attitudes towards biotechnology processes if they have to help them learn more about biotechnology, and subsequently teach it in their classrooms. In addition, this study is significant as it will add new insights of pre-service teachers 'attitudes towards biotechnology from an American perspective.

Methodology

Participants

A sample comprised 88 elementary education pre-service teachers who were enrolled in two science methods courses at a mid-sized university in the Midwest of the USA. The Introduction to science teaching course prepares students to have strong understanding and skills of science process skills and inquiry. Some of the topics covered in the course are: nature of science, relationship between science and technology, basic and integrated science process skills, learning cycle model of science instruction, and inquiry levels. The Advanced science methods course prepare students to have an understanding of science concepts in Earth, Life and Physical sciences, and how to teach them in elementary and middle schools. There is no designated course on biotechnology for these elementary education pre-service teachers in the teacher education program. The age range of the participants was 23-35 years and average age was 23 years with a SE of 0.47. All the participants had already taken, prior to this study, two integrated science content courses that cover life science, earth science and physical science concepts outlined in the national and state science education standards. Table 2 below provides profiles of the participants.

Table 2. Participants' Profiles

Demographics	*Category*	*Science Methods Course*		*Participants (N=88)*
		Introductory (n=60)	Advanced (n=28)	
Teaching subject major	Science	13	5	18
	Non-science	47	23	70
Taken biology courses	Yes	48	22	70
	No	12	6	18
Gender	Male	8	6	14
	Female	52	22	74

Biotechnology Attitude Questionnaire

Several researchers have used attitude questionnaires to determine respondents' attitudes towards biotechnology (e.g. Chen et al, 1999; Dawson et al, 2003; Gunter et al, 1998; Lock et al, 1993; Usak et al, 2009). However, some attitude statements in some questionnaires are suited for respondents with sound scientific background knowledge and understanding of biotechnology processes. For our study, the participants were elementary education pre-service teachers who are not required to take advanced biology or biotechnology courses; instead they are only required to take introductory level science courses. Therefore, this group of participants would only provide usable data if the attitude items are those that do not demand advanced scientific conceptual understanding, but indicate the outcomes which anyone with limited scientific understanding can relate to (such as improving nutritional value in food by genetic modification, or treating diseases in humans by genetic modification of genes, etc.). As such, Dawson's (2007) Biotechnology Attitude Questionnaire was appropriate for our pre-service teachers because the attitude statements ranged from benign uses such as *using yeast in the production of wine and beer* (at least anyone with limited scientific knowledge could relate to what wine or beer is) to more controversial procedures such as *altering genes of human tissue cells to treat a genetic disease* (at least anyone with limited scientific knowledge could relate to what a disease is and importance of treating a disease).

Data was collected through a biotechnology attitude questionnaire adopted from Dawson (2007). Unfortunately, Dawson did not state the reliability value for this instrument. However, in our study this instrument had a Cronbach's alpha coefficient value of 0.87, indicating a high reliability of the attitude instrument.

The instrument had 15 attitude items on a 3 Likert-scale (acceptable, unacceptable or not sure) that addressed pre-service teachers' attitudes towards biotechnology processes. Pre-service teachers were asked to indicate whether each statement was acceptable, unacceptable or if they were not sure about it. Each attitude item was assigned to a construct depending on whether it involved: *use of microorganisms for specific biotechnology process; genetic modification of plants/foods; genetic modification of animals; and genetic modification of human genes*. Table 3 shows the constructs and corresponding attitude items.

Data Analysis

Data analyses involved computing reliability value for the instrument, and frequency counts, descriptive statistics and statistical methods which included t-tests, and one-way ANOVA for the data. One Way ANOVA was conducted to test for any differences among the four constructs of

Table 3. Constructs and Attitude Items

Construct	***Attitude items***
Construct 1 Use of microorganisms for specific processes	• Using yeast to produce wine and beer. • Using genetically engineered micro-organisms to enable more efficient breaking down of human sewerage. • Growing yeast for animal food.
Construct 2 Genetic modification of plants/food	• Altering plant genes so that they grow better in salty soils. • Adding genes to yeast that is used to make better tasting bread. • Adding genes to plants to increase their nutritional value. • Altering genes in fruit to improve taste. • Altering genes in tomatoes to make them ripen more slowly and have a longer shelf life. • Inserting genes from microorganisms into crops to provide pesticide resistance.
Construct 3 Genetic modification of animals	• Changing the genetic makeup of farm animals to improve the quality of meat and milk. • Using genetically engineered cows to produce medicines for human use. • Inserting genes from plants into animals.
Construct 4 Genetic modification of human genes	• Altering the genes of human tissue cells to treat a genetic disease (e.g., cystic fibrosis). • Altering the genes in a human embryo to treat genetic disease. • Inserting genes from humans into the fertilized eggs of mammals.

the attitude aspects for all the 88 participants. The t-tests were conducted to compare attitudes towards biotechnology among the following subgroupings: introductory and advanced science education course level; science and non-science teaching majors; taken biology courses or not previously; and between females and males.

Since some demographic groups in this study were below acceptable sample sizes for parametric tests (see Table 2), an effect size measure with Cohen's *d* which is independent from sample sizes was calculated. The Cohen's ***d*** score indicates the strength or practical significance of the association(s) being explored. The two values required to calculate Cohen's ***d*** value are means and standard deviations of the two groups being compared. We used an online calculator through Google search engine to calculate Cohen's *d*. Effect sizes in value are less than 1. Interpretations vary, but in general, a *d* value of 0.2 indicates only a small effect; value of 0.5 indicates a medium effect; and value of 0.8 or greater indicates a large effect. The *d* values are presented along with the *t*-tests results in Table 6.

Results

Attitudes towards Biotechnology Processes

This subsection reports on the results gathered from all the 88 pre-service teachers on the 15 attitude items, as shown in Table 4. On average, the pre-service teachers in both science methods courses showed that the biotechnology processes were acceptable, in the following descending order: *use of microorganisms for specific biotechnology process; genetic modification of plants/foods; genetic modification of human genes; and genetic modification of animals*. Specifically, the following trends were found: (a) 62% of the students viewed the *use of microorganisms for specific processes* (such as using yeast to produce beer, using microorganisms to break down human sewerage etc.) as acceptable. However, a third of the students (32%) indicated that they were not sure about the *use of microorganisms for specific processes;* (b) 52% of the students viewed the *genetic modification of plants/food* (such as altering plant genes so they can grow better, adding genes to plants to increase nutritional value, altering genes in tomatoes to make them ripen slowly etc.) as acceptable, but 18% of them did not approve of this process. Furthermore, 31% of the students were not sure about the *genetic modification of plants/food*; (c) About a third of the students (32%) viewed the *genetic modification of human genes* (such as altering genes in human tissue cells or human embryo to treat genetic diseases, etc.) as acceptable. Almost the same proportion of students (30%) viewed it as unacceptable. However, 38% of the students were not sure about this the *genetic modification of human genes*. A noticeable finding under the *genetic modification of human genes* construct was that about half of the students from both courses (50% and 46% of students in introductory and advanced courses, respectively) did not accept the idea of "inserting genes from humans into fertilized eggs of mammals"; and (d) a fifth of the students (20%) viewed the *genetic modification of animals* (such as changing genetic makeup of animals to improve quality of meat or milk, using genetically modified cows to produce medicines for human use etc.) as acceptable. However, almost half of the students (47%) were not in favor of this process. In addition, quite a number of the students (33%) were not sure about this process. One remarkable finding under the *genetic modification of animals* construct was that slightly less than half of the students from both courses (43% and 43% of students in introductory and advanced courses, respectively) did not accept the idea of "inserting genes from plants into animals".

The above trends were also true for each science education course level. For instance, 67% and 62%, 48% and 51%, 33% and 30%, and 20% and 19% of the students from the introductory and advanced courses, respectively, approved the *use of microorganisms for specific biotechnology process, genetic modification of plants/food, genetic modification of human genes, and genetic modification of animals*.

Attitudes towards the Four Constructs of Biotechnology

A One Way ANOVA was conducted to test for any differences among the four constructs of the attitude items for all the 88 participants. Table 5 shows that there were statistically significant differences in the four constructs for attitudes, $F(3, 348) = 261.39$, $p = 0.00$. The results of the post hoc test indicated that all four constructs were significantly different from each other. In descending order, the pre-service teachers had favorable approval ratings towards the *genetic modification of plants/foods* (Mean=13.97), followed by the *use of microorganisms for specific processes* (Mean=7.84), then *genetic modification of human genes* (Mean=6.07), and lastly the *genetic modification of animals* (Mean=5.17).

A further analysis with One Way ANOVA was conducted to test for any differences in attitudes towards the biotechnology processes [*constructs*] between the pre-service teachers enrolled in introductory and advanced science education level courses. There was a statistically significant difference among the four biotechnology processes in the Introductory Science Methods course, (F(3, 236) = 192.45, p = 0.00). In descending order, the pre-service teachers in the Introductory Science Methods course had more approval ratings for the *genetic modification of plants/food* (Mean= 13.8, SD=3.2), *use of microorganisms for specific processes* (Mean=7.9, SD=1.1), *genetic modification of human genes* (Mean= 6.2, SD=1.8), and *genetic modification of animals* (Mean= 5.2, SD=2.1).

Similarly, there was a statistically significant difference among the four constructs for the Advanced Science Methods course, F (3, 103) = 72.45, p = 0.00. However, the post hoc test showed that there was no statistical difference between the *genetic modification of animals* and the *genetic modification of human genes*. In descending order, the pre-service teachers in the Advanced Science Methods course approved the *genetic modification of plants/food* (Mean=14.4, SD=4.8), followed by the *use of microorganisms for specific processes* (Mean= 7.8, SD=1.2), then *genetic modification of human genes* (Mean= 5.8, SD= 1.9), and lastly *genetic modification of animals* (Mean=5.2, SD=1.9).

Comparing Attitudes towards Biotechnology by Demographics

The pre-service teachers' attitudes towards biotechnology processes were compared with the following subgroupings: introductory and advanced science education course level; science and non-science teaching majors; taken biology courses or not previously; and between females and males. Table 6 shows the results. There were no significant differences between demographics of pre-service teachers with regard to their attitudes towards biotechnology processes. That is, pre-service teachers had similar attitudes regardless of: the science education course level enrolled in (t (86) =0.085, p = 0.932); being a science or non-science teaching major (t (86) = 0.197, p = 0.844); whether they had previously taken biology courses or not (t (86) = -0.083, p = 0.934); and whether they were female or male (t (86) = -1.084, p = 0.282).

Given that some demographic groups had low sample sizes (e.g. 18 science teaching majors versus 70 non-science majors; 74 females versus 14 males), a Cohen's d, which is independent of sample sizes, was calculated in order to determine the strength of the association between the demographics being compared. The Cohen's d values are presented in Table 6. In general, a d value of 0.2 indicates only a small effect; value of 0.5 indicates a medium effect; and value of 0.8 or greater indicates a large effect. The results of Cohen's d show that there was no association between the following demographics: introductory and advanced science course levels (d = -0.015); science and non-science teaching majors (d = 0.016); those who had taken biology courses previously and those who had not (d = 0.032); and between female and male respondents (d = -0.277). These low values for Cohen's d confirms that the mean differences obtained in the t-tests are really non-significant, regardless of sample sizes.

Table 4. Participants' Attitudes towards Biotechnology

Attitude items	Introd. Science (N = 60) %			Advanced Science (N = 28) %			All Students (N = 88) %		
	Acceptable	Unacceptable	Not sure	Acceptable	Unacceptable	Not sure	Acceptable	Unacceptable	Not sure
Construct 1: Use of microorganisms for specific processes									
• Using yeast to produce wine and beer.	78	1	20	68	0	32	75	1	21
• Using genetically engineered micro-organisms to enable more efficient breaking down of human sewerage.	65	5	33	68	0	32	58	3	33
• Growing yeast for animal food.	57	3	40	50	7	43	54	4	41
Average Mean	***67***	***3***	***31***	***62***	***2.3***	***36***	***62***	***3***	***32***
Construct 2: Genetic modification of plants/food									
• Altering plant genes so that they grow better in salty soils.	52	5	43	57	25	18	53	11	35
• Adding genes to yeast that is used to make better tasting bread.	47	10	43	54	18	28	49	13	39
• Adding genes to plants to increase their nutritional value.	60	8	32	68	14	18	63	10	27
• Altering genes in fruit to improve taste.	45	25	30	64	25	11	51	25	24
• Altering genes in tomatoes to make them ripen more slowly and have a longer shelf life.	47	27	27	68	18	14	53	24	23
• Inserting genes from microorganisms into crops to provide pesticide resistance.	38	20	42	50	25	25	43	22	36
Average Mean	***48***	***16***	***36***	***51***	***17***	***19***	***52***	***18***	***31***
Construct 3: Genetic modification of animals									
• Changing the genetic makeup of farm animals to improve the quality of meat and milk.	22	53	25	18	50	32	20	52	27
• Using genetically engineered cows to produce medicines for human use.	23	48	28	21	43	36	23	47	31
• Inserting genes from plants into animals.	15	43	42	18	43	39	16	43	41
Average Mean	***20***	***48***	***32***	***19***	***45***	***36***	***20***	***47***	***33***
Construct 4: Genetic modification of human genes									
• Altering the genes of human tissue cells to treat a genetic disease (e.g., cystic fibrosis).	48	13	38	43	28	28	47	18	35
• Altering the genes in a human embryo to treat genetic disease.	38	17	45	32	36	32	36	23	41
• Inserting genes from humans into the fertilized eggs of mammals.	13	50	37	14	46	39	14	49	38
Average Mean	***33***	***27***	***40***	***30***	***37***	***33***	***32***	***30***	***38***

Table 5. Comparison of Attitudes Among The Constructs

Construct	*Mean (SD)*	*F*	*df*	*Sig.*	*Result*
Construct 1: Use of microorganisms for specific biotechnology process	7.84 (1.09)	261.39	3 348	0.00	Significant
Construct 2: Genetic modification of plants/foods	13.97 (3.55)				
Construct 3: Genetic modification of animals	5.17 (2.01)				
Construct 4: Genetic modification of human genes	6.07 (1.82)				

Table 6. Comparison of Attitudes and Demographics

Demographic		N	Mean (SD)	t	df	p-value	Sig	Cohen's d
Science education course level	Introductory	60	33.0 (6.2)	0.085	86	0.932	NS	-0.015
	Advanced	28	33.1 (7.1)					
Teaching subject major	Science	18	33.3 (6.74)	0.197	86	0.844	NS	0.016
	Non-science	70	32.9 (6.38)					
Taken biology courses previously	Yes	70	33.1 (6.6)	-0.083	86	0.934	NS	0.032
	No	18	32.9 (5.7)					
Gender	Female	74	32.7 (5.96)	-1.084	86	0.282	NS	-0.277
	Male	14	34.7 (8.26)					

Sig at p<.05; NS means Not Significant

Discussion

Attitudes towards Biotechnology Processes

The findings of our study indicate that the American elementary education pre-service teachers hold a wide range of attitudes towards biotechnology processes. In particular, our study revealed that the pre-service teachers approve, in descending order, the *use of microorganisms for specific processes* (62%), *genetic modification of plants/food* (52%), *genetic modification of human genes* (32%), and *genetic modification of animals* (20%). Another interesting finding was that about a third of the students were not sure about the *use of microorganisms for specific processes* (32%), *genetic modification of plants/food* (31%), *genetic modification of human genes* (38%), and *ge-*

netic modification of animals (33%). The *not sure* responses from our study are critical in that they convey two messages. First, these responses could imply that the pre-service teachers do not conceptually understand what actually goes on during these biotechnology processes (i.e. *use of microorganisms for specific processes*; *genetic modification of plants/food*; *genetic modification of human genes; and genetic modification of animals*). Second, the pre-service teachers may not be fully aware of the ethical, social and cultural issues related to biotechnology. An awareness of these aspects is vital in determining the extent to which an individual will be receptive to biotechnology. A lack of understanding of what actually happens during genetic modification and a lack of awareness about the ethical, social and cultural implications of biotechnology processes (especially genetic modification of human genes and animals) are part of the reasons why most students believe biotechnology (especially genetic modification) is unethical or unnatural (Dawson et al, 2003).

Our findings are supported by what other researchers found (e.g. Lock et al 1993; Dawson et al 2003; Dawson, 2007). For instance, Lock et al (1993) found the following trends: 73%, 66%, 32% and 37% of students approved the *use of microorganisms for specific processes*, *genetic modification of plants/food*, *genetic modification of human genes,* and *genetic modification of animals,* respectively. Lock *et al* also found that about a fifth of the 188 British students were not sure about the *use of microorganisms for specific processes* (23%), *genetic modification of plants/food* (19%), *genetic modification of human genes* (20%), and *genetic modification of animals* (19%). Other studies which support our findings include those conducted among the Slovakian pre-service university students (Prokop, et al, 2007) and among Australian high school students (Dawson, 2007) in which the *genetic modification of plants* was more approved than the genetic modification of animals. To the contrary, other findings do not support ours (e.g. Usak et al, 2009). Usak *et al* found that all (100%) of the Turkish students in their study disapproved the *genetic modification of plants/food,* and nearly all (90%) disapproved the *genetic modification of animals.*

The findings suggest that the American pre-service teachers investigated believe it is alright to genetically modify microorganisms and plants, but not doing so to animals and human genes. Why did the teachers have such a viewpoint? Well, in his study, Dawson et al (2003) found out that the main reason for the higher approval for use of microorganisms and plants was the beneficial aspect to humanity; whereas the main reason for the rejection of genetic modification of animals and humans was that the process is unethical and unnatural. Therefore, it is possible that the American elementary education pre-service teachers also had similar reasons.

Comparing Attitudes and Science Education Course Level

From the results of our study, it became apparent that the pre-service teachers' attitudes towards biotechnology processes were not influenced by the level of the science education courses they were enrolled in. As stated under the "Methodology" section, the Introductory science methods course prepares students to have strong understanding and skills of science process skills and inquiry, whereas the advanced science methods course prepares students to have understanding of science concepts in Earth, Life and Physical sciences, and how to teach them in elementary and middle schools. Therefore, one of the reasons why elementary education pre-service teachers' attitudes were not influenced by the level of the science education courses they were enrolled in could be that these two courses do not cover any component on biotechnology. During our literature review, we did not find any study that compared the attitudes of pre-service teachers from two different science methods courses.

Comparing Attitudes and Teaching Subject Major

Our study showed that the pre-service teachers' attitudes towards biotechnology processes were not influenced by their teaching subject major (i.e. science and non-science teaching majors). All the elementary education pre-service teachers are required to take two integrated science content courses (Science 210A and 210B) that cover life science, earth science and physical science concepts outlined in the American national and state science education standards. However, the science teaching majors do not take any additional science content courses besides Science 210A and 210B. At the time this study was conducted, all the participants had already taken the two integrated science courses. Therefore, a postulation for the non-influence of their teaching subject major on the attitudes towards biotechnology could be that biotechnology concepts are not explicitly taught in Science 210A and 210B. Dawson (2007) also stated that despite the increasing importance of biotechnology in our society, it is not regularly taught in schools. Therefore, the biotechnology processes need to be included in teacher education curriculum if teachers are to be well informed and consequently teach them in schools. Again, our literature review search did not reveal any study that compared the attitudes of pre-service teachers with teaching subject major.

Comparing Attitudes and Enrolment in Biology Courses

The pre-service teachers' attitudes towards biotechnology processes were not influenced by their previous enrolment/study in biology courses. Our results are supported by other researchers such as Prokop et al (2007). Prokop et al found that although the Slovakian students enrolled in biology courses had better knowledge of biotechnology, their attitudes towards genetic engineering were not favorable, and were similar to those who did not study biology. In contrast, however, other previous studies do not support our results (e.g. Chen et al, 1999; Hill et al, 1999). For instance, Chen et al (1999) found that most of the Taiwanese and UK students studying biology had more favorable attitudes toward biotechnology processes than those not studying biology. In another study, Hill et al (1999) found that biology students approved genetically engineered foods more than those not studying biology.

Comparing Attitudes and Gender

The results of our study showed that the pre-service teachers' attitudes towards biotechnology processes were not influenced by whether they were female or male. Our findings are different to what other researchers have found (e.g. Moerbeek et al, 2005; Prokop et al, 2007). Prokop *et al* found that females showed lower approval ratings than males toward biotechnology, particularly with respect to genetically modified products. Other researchers such as Moerbeek et al (2005) explained that females have more favorable attitudes towards genetically modified products than males because they buy food for children. However, Prokop et al (2007) warned that caution about any comparison of gender is needed because of the large disparity in numbers in most studies, including our current study. In our study, the issue of low sample sizes was taken care of by calculating Cohen'*d*, which is independent of sample sizes. With respect to gender, our Cohen's *d* value was -0.277. This low *d* value confirms that the mean difference obtained in the t-tests is really non-significant.

Implications for Science Education Curriculum

The attitudes of pre-service teachers toward biotechnology and its related processes could have an effect on how they would present the biotechnology aspects to their students. As a trusted source of information among elementary students, it is critical for pre-service elementary teachers to be well informed about the benefits and challenges of biotechnology. If these would-be teachers are well informed, then they would possess attitudes that would reflect unbiased and correct information.

As biotechnology continues to play a pivotal role in our society, elementary teachers will have an important role in informing younger students about these technologies. Therefore, university teachers are charged with developing science education curriculum materials that would enable pre-service teachers to acquire the following: (a) relevant and current information about what biotechnology contributes to our personal and societal lives as well as its shortfalls. Such a section in the science curriculum would ensure that pre-service teachers have an understanding of both the benefits and intricacies of biotechnology (Chen et al, 1999); (b) an understanding of ethical, social and cultural issues related to biotechnology. Biotechnology processes such as genetic engineering/modification of plants, food, animals and human cells is an area of public concern and is widely reported by the media (Lock et al, 1993). Therefore, science education curricula should better equip the pre-service teachers for understanding such issues, and place teachers in a position where they can make up their own mind about biotechnology (Chen et al, 1999). In finding their own opinions, pre-service teachers should have an opportunity to consider the views of others and extend their own knowledge. Doing so would enable these would-be teachers know where their stance is on the controversies, and consequently develop unbiased attitudes towards biotechnology.

Recommendations for Future Research

Biotechnology is indeed a fast growing field that is influencing our livelihoods today. As such students' scientific literacy in this area must be improved. However, as Dawson (2007) noted, it is not regularly taught in most of the schools. The reasons for not teaching biotechnology in schools include students' inability to understand it (Steele et al, 2004), and lack of sufficient resources and expertise among teachers in the biotechnology content area (Macer et al, 1996). One question which then arises is: How can science education researchers help improve and promote the teaching of biotechnology processes? We believe science education researchers should direct their investigations on designing teaching and learning resources that science teachers and their students can use. Given the advent of computer simulations, we argue that simulated visuals showing what goes on during genetic modification would go a long way in promoting both conceptual understanding among students as well as "seeing" the potential risks of biotechnology processes – aspects which are critical in helping students make their own decisions about biotechnology.

Conclusions

This study examined 88 pre-service teacher's attitudes towards biotechnology and its related processes. Most pre-service teachers in both science methods courses approved the *use of micro-organisms for specific processes*, and *genetic modification of food/plants*. However, majority of the pre-service teachers disapproved the *genetic modification of human genes*, and *genetic modification of animals*. Another point to note is that the pre-service teachers' attitudes were not influenced by science methods course level enrolled in, teaching subject major, previous enrolment in biology courses, or by gender.

As such, the results of this study provide compelling evidence for extensive and explicit instruction on biotechnology processes in teacher education programs. Doing so would create opportunities for the pre-service teachers to be fully informed about biotechnology, and subsequently teach it and make their students biotechnology literate. Usak et al (2009) mentioned that better understanding is related to more favorable and unbiased attitudes toward biotechnology. Therefore, to ensure unbiased attitudes and to improve understanding of biotechnology processes amongst pre-service teachers and their students, the science curriculum should increase coverage of basic principles and applications of biotechnology. The results presented in this study also suggests that biotechnology aspects should be included in science teacher professional development initiatives and should be taught explicitly so that in-service science teachers are well informed about biotechnology and appreciate its applications.

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Amerikalı İlköğretim Öğretmen Adaylarının Biyoteklojik Süreçlere Yönelik Tutumları

Bu çalışma ilköğretim öğretmen adaylarının biyoteknolojik süreçlere yönelik tutumlarını saptamaktadır. Amerika Birleşik Devletlerinin Ortabatı bölgesinde orta büyüklükte bir üniversiteye devam etmekte olan ilköğretim öğretmen adaylarından 88'i bu çalışmanın örneklemini oluşturmaktadır. 60 ve 28 ilköğretim adayı sırasıyla Bilimsel Yöntemlere Giriş ve İleri Düzeyde Bilmsel Yöntemler derslerine kayıtldır. Üçlü Likert tipi ölçeğin ve 15 soruluk ifadelerden oluşmuş bir anket veri toplama aracı olarak kullanılmıştır. Anketteki her bir ifadenin kabul edilip edilmediğine karar vermeleri öğrencilerden istenmiştir. Sonuçlar incelendiğinde her iki dersi de alan öğretmen adaylarının biyoteknolojiye yönelik tutumlarında çeşitlilik olduğu görülmektedir. Dikkat çeken bir husus, öğretmen adayları mikroorganizme ve bitkilerdeki genetik değişiklikleri onaylarken insan ve hayvan genleri üzerindeki ekleme veya çıkarma süreçlerini onaylamamalarıdır. Fen Bilimleri öğretmen eğitimi, müfredat ve farklı ararştırmaya yönelik sonuç ve öneriler tartışılmıştır.

Anahtar Kelimeler: Biyoteknoloji, öğretmen, tutum, ilköğretim eğitimi