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THE EFFECT OF GENETIC ENGINEERING AND BIOTECHNOLOGY ACTIVITIES ON STUDENTS' ACHIEVEMENT, ATTITUDES AND SELF-EVALUATIONS

Research Article

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Abstract

In this study activities related to biotechnology and genetic engineering were prepared and their effectiveness on students' achievement, attitudes towards biotechnology, and self-evaluations were investigated. The activities were implemented in 10th grade biology course. The study utilized mixed method, with qualitative and quantitative data collection tools. Two biology classes of the same teachers' in Ankara were chosen by convenient sampling technique. One experimental group and one control group is formed with random assignment. The quantitative data about students' achievement, attitudes towards biotechnology and self-evaluation were collected before and after the activities using pre-tests and post-tests. Then semi-structured surveys were conducted with experimental group students. Results show that the activities on biotechnology have no positive impact on the students' achievement. Also, students' self-evaluations indicate that they felt better in the activities, the abstract concepts were more concrete for them and it contributed to their learning by helping them to make investigations through inquiry. Based on the qualitative data, students stated that they liked the activities and they had fun. The study suggests integration of such activities to the teaching learning environment for supporting interest in biotechnology and genetic concepts.

Keywords: biotechnology, genetic engineering, achievement, attitude, self-evaluation.

1. Introduction

While genetic engineering and biotechnology applications affect people's lives in socio-economic and cultural terms, the methods used and the fields related to them require interdisciplinary interactions. Biotechnology represents a new and rapidly rising field of scientific research and technological renewal. It also benefits from technology and engineering. Examples of its applications include the diagnosis and treatment of hereditary diseases and other diseases, the pharmaceutical industry, detection of criminals using forensic evidence and, paternity cases and so on. Additionally, plant cell tissue cultures as closely related to the agricultural economy and are also directly related to biotechnology. Furthermore, these disciplines provide fruitful examples to support the impact of science on human life. Therefore, it is very important to integrate such subjects in teaching and learning activities of science and related fields in educational programs. Unfortunately, similar to most conceptual issues, researchers reported misconceptions among students concerning these concepts (Gündüz, Yılmaz, & Çimen, 2016; Semenderoğlu & Aydın, 2014; Yıldırım, Kurtuldu, & Öz Aydın, 2003). Inquiry-based learning environments enriched with daily life examples reinforce students' active engagement and supports conceptual understanding and interest in subject matter (Doğan, Kırvak ve Baran, 2004).

Studies point out that teachers do not have enough awareness about how teaching materials support learning (Grant, Peterson, & Shojgreen-Downer, 1996; Kazu & Yeşilyurt, 2008; Küçükahmet, 2002, p. 109). For this reason, teachers may need support concerning experimental teaching activities and materials aligning with course objectives. In addition, the use of such activities may contribute to cooperation of interdisciplinary concepts, may improve STEM skills, and may facilitate understanding of related concepts. It may also contribute to understanding of cultural and socio-economic contexts, as well as, inquiry and decision-making skills. In that sense, it may be valuable to design activities and experiments that can be applied in the teaching of "biotechnology and genetic engineering" subjects.

Genetics, a branch of biology, examines the hereditary issues in living things. Heredity includes all of the vital features of living things; such as, the human eye, hair, skin color, length, behavior, or the ability to synthesize an enzyme (Saglam, 2000). According to another definition, genetics is a branch of science that examines differences and similarities emerged in different generations of organisms, and try to explain the reasons of such differences (Vardar, 1986). Biotechnology, as representing a new and rapidly rising scientific research field and technological innovation, can also reveal the feasibility and transfer of genetic material from one organism to another organism (Özel, Erdoğan, Uşak, & Prokop, 2009). In 10th grade biology textbook developed by Ministry of Education, there are no experiments related to the biotechnology and genetic engineering. Even the objective "analyzes the effects of biotechnology applications on human life" in 10th grade biology curriculum, there is no teaching activity. There are few studies focusing on the effectiveness of materials developed for better understanding of applications of modern genetic concepts on students' misconceptions, academic achievement, and attitudes towards biotechnology.

Research also emphasize that some teachers may be reluctant to use teaching activities and materials, and most teachers may not spend much effort on how materials can support learning (Grant, Peterson, & Shojgreen-Downer, 1996; Kazu & Yeşilyurt, 2008; Küçükahmet, 2002, p. 109). Thus, preparing some sample activities and experiments aligning with course objectives may encourage teachers to conduct experiments in their classrooms. In particular, the designing materials incorporating new technologies will be more beneficial for teachers. For example, there are varying conceptualization about genetically modified organisms which are a highly controversial in plant biotechnology field (Gündüz, Yılmaz, & Çimen, 2016; Semenderoğlu & Aydın, 2014; Özdemir & Duran, 2010; Yıldırım, Kurtuldu, & Öz Aydın, 2003). This lack of knowledge may affect the ability of people to critically evaluate the benefits and harms of biotechnology studies (Kidman, 2010).

1.1. Literature Review

Studies investigating students' knowledge about biotechnology from elementary to university level, report that the majority of students have incomplete and incorrect knowledge about biotechnology (Dawson, 2007; Uşak, et al., 2009; Özden, et al., 2008). It is seen that most of the studies investigating students' knowledge and attitudes towards biotechnology are conducted in developed countries and focus mostly on high school students (Dawson, 2007; Uşak, et al., 2009; Chen & Raffan, 1999). The findings show that the students accept the idea that gene technology can be used in the field of health (Zechendorf, 1994). This result is in line with the idea that medical applications are more accepted than the other applications of biotechnology. In short, students' attitudes towards biotechnology vary according to the usage areas of biotechnology. In majority of studies, it is seen that there is lack of knowledge about biotechnology among students and prospective teachers and they stresses on informing all students, prospective teachers, and public about biotechnology.

Gerçek (1999), reports that a high majority of students' statement concerning the need for rearranged of biotechnology related issues and requirement for making them interesting. It was concluded that the subject of biotechnology was not sufficiently included in the schools, the knowledge is not interesting, not sufficient, and students could not comprehend the importance of the concept of biotechnology adequately. The study conducted by Olsher and Dreyfus (1999) investigate high school students' understanding about applications of many biotechnological concepts and supports students' questioning skills by critically evaluating biotechnology concepts. Dawson (2007) investigated the students' understanding and attitudes towards the biotechnology with 12-17 year old students and has reached the conclusion that students had difficulties in learning these concepts along with reporting insufficient teacher practices in the topic.

Dori, Tal, and Tsaushu (2003) demonstrate that students' higher order thinking skills will be developed through case studies in teaching biotechnology, and collaboration with teachers and non-science experts supports students' meaningful understanding of concepts of biotechnology and its applications. Also they state that the materials motivate students. In his research, Harms (2002) investigated biotechnology education in schools and the interest of students in genetic engineering and biotechnology. He suggested use of materials of European Biotechnology Initiative in biotechnology education for students around 16 year's age.

Semenderoğlu and Aydın (2014) investigated the misconceptions in biotechnology and genetic engineering using 5E model of teaching. Using activities based constructivist approach in their work, they have found that activities facilitated conceptual understanding, provided retention on learning and they were more effective in eliminating misconceptions. Gündüz, Yılmaz and Çimen (2016) found that there are some misconceptions and deficiencies in expressions, and inaccuracies in evaluation questions in the biology textbook about the concepts of reproduction and heredity chapters. Research shows that students have misconceptions about science concepts, and this makes science difficult to learn (Gülçiçek, 2002; Koray & Tatar, 2003; Ünlü, 2015; Yakışan & Selvi & Yakışan, 2004; Yörük & Çakır, 2004). According to Demirci (1993), if experimental activities are not available to perform with certain tools, science teaching should be linked with the events in the nature and the concrete daily processes. Therefore, the quality of the teacher is important. Achievement in science education can be accomplished with experimental/inquiry-based learning environments provided that the teachers are well-trained on their profession.

1.2. Theoretical Background

One of the main purposes of science education is to develop students' higher order thinking skills (Resnick, 1987). Since 2004-2005 academic years, the curricula in Turkey are based on student-centered activities and support such learning environments (Arslan & Özpınar, 2009) since higher order thinking skills can be developed in this way. Constructivist approach argues that learning does not occur by transferring knowledge, but through student activities such as asking questions, doing investigations, and solving problems. Learning is not about getting passive information, but structuring information. Since individuals' past experiences are not the same, their schemas and interpreting new information are not the same as the understanding of another individual. Prior experiences, information, and learning affect how we interpret new experiences. On the other hand, interpretations have an impact on knowledge construction and acquiring new knowledge.

Individuals learn when they discover their concepts and their own answers form their own interpretations (Koç, 2002). Students construct knowledge effectively and direct the learning with their existing mental schemas. They integrate their new knowledge with their previous learning. Learning takes place in complex and real-life contexts. Knowledge is created by the student's existing value judgments and experiences. The content should be organized from whole to pieces. Thus, students can use their higher order thinking skills. According to the constructivist approach, social interaction is important and students create and interpret information (Vygotsky, 1978). Teachers guide learners to work collaboratively. As this approach is based on learning experiences, different learning activities are needed to organize learning environment to increase interaction. Appropriate learning materials are used to make the meaningful and useful knowledge (Erdem, 2001).

In student-centered approaches, the student constructs new knowledge in his/her mind while reviewing the information she/he has already acquired in the learning process. He determines what he knows about that subject. Learning continues by observing, experimenting, practicing, research, and analyzing during the acquisition of new information. The teacher is only a guide that guides the students in how they learn to learn and guides their thoughts. In student-centered approaches of constructivism, there is a need for teaching methods that will help student to learn the acquired information in a way that is far from memorization, active and more permanent. If learning environment is designed in a way that support student to be more active, engaged, and willing to learn, it will foster mental skills, interests, and understating of concepts in learning process (Ergin, 2006).

Genetic engineering and biotechnology learning objectives took place in high school biology curriculum for the first time in 1998. Although supporting students effectively in concrete practical applications, and future prospective career plans in terms of modern genetic is mentioned in the 10th grade biology curriculum, no activities or experiments were found in the textbooks. According to Kılınçoğlu (2016), effective teaching process in biology course can be planned provided that students, teacher, method of teaching, subject matter are all taken into consideration as a whole. This study designed around these concepts to investigate 10th grade students' attitudes towards biotechnology, achievements in biotechnology and genetic engineering, and their self-evaluations towards the concepts of biotechnology and genetic engineering. Two original activities were applied related to biotechnology. The general research question is: How do biotechnology activities affect students' attitudes, achievement, and self-evaluations compared to traditional methods? How are students' opinions about performed activities?

2. Methodology

In the research, a mixed method design employing quantitative and qualitative data analysis techniques was used. A pre-post quasi-experimental design was used for quantitative part; case study method is used for qualitative part. The quasi-experimental design tests the effect of the independent variable on the dependent variable (Büyüköztürk, 2007). The experiment was implemented by trying to reduce threats to internal validity such as, diffusion of treatment, experimenter expectancy, instrumentation, and history effect.

2.1. Sample

In the study, convenient sampling method was used. In this context, the study was conducted with a total of 28 students from two different sections of the same teachers in the 10th grade biology classes in a science high school in Ankara. Confidentiality is assured using a consent form providing ethical details and students' rights.

Table 1. *Sample size and gender across experimental and control group*

	Gender	N (sample size)	Percentage (%)
Experimental Group	Female	*6*	*46.15*
	Male	*7*	53.85
Control Group	Female	*7*	*42.85*
	Male	8	57.15

Among all, 13 of the students were in the experimental group, and 15 of them were in the control group. The implementation took four weeks and the pre- post measurement process is conducted in the same manner. Table 1 provides sample size across gender and groups.

2.2. Data Collection Tools

Quantitative data collection tools were; Students' Attitude Scale towards Biotechnology (SASTB), Self-Evaluation Forms of Biotechnology and Genetic Engineering and Achievement Test on Biotechnology and Genetic Engineering" were used. In addition, semi-structured interview form was prepared as qualitative data collection tool in order to determine the students' opinions on the activities.

2.2.1. Students' Attitude Scale towards Biotechnology (SASTB),

In order to determine the attitudes of the participants towards biotechnology, attitude towards biotechnology scale were used (SASTB). The scale was developed by Çelik (2009) and consists of 28 items. The scale is a 5-point Likert type and the response categories are given as "strongly disagree", "disagree", "undecided", "agree" and "strongly agree". 11 of the items were negative, and 17 were positive. The Cronbach's alpha reliability coefficient of SASTB calculated by Çelik (2009) is .90, and the scale consists of a single dimension. The reliability coefficient for this study is .78.

2.2.2. Biotechnology and Genetic Engineering Self-Evaluation Form (BGESE)

These forms were used to determine the self-evaluation of the 10th grade students on biotechnology and genetic engineering. The forms were developed by the researcher and included 21 items in the biotechnology form, and 14 items in the genetic engineering form. The forms are 3-point Likert type and the response options are given as 'know', 'somehow know' and 'I do not know' '. During the development process of BGESE, firstly the related literature was examined, and themes related to biotechnology and genetic engineering were created. An item pool was created for each theme with the questions from the literature and the questions prepared by the researchers. Questions were selected from the item pool together with a field expert and BGESE was formed. Cronbach's alpha reliability of BGESE is given in Table 2.

Table 2. *Reliability coefficients of biotechnology and genetic engineering self-evaluation questionnaire*

Instrument	Group	Administration	Cronbach's Alpha	Number Items
Genetic Engineering	Experimental	Pre-	,639	21
	Control	Post-	,723	
	Control		,851	
Biotechnology	Experimental	Pre-	,815	14
	Control		,536	
	Experimental	Post-	,917	
	Control		,477	

2.2.3. Biotechnology and Genetic Engineering Achievement Test (BGEAT)

BGEAT was used to determine the achievements of 10th grade students regarding ”Modern Genetic Applications. The scale was developed by the researcher and with 28-items in multiple-choice format of 5-choices. Removing one question based on related statistics, 27 questions were applied. In the development process of BGEAT, firstly the related literature was examined and themes related to biotechnology and genetic engineering was created. An item pool was created for each theme with the questions from the literature and the questions prepared by the researchers. Questions were selected from the item pool together with a field expert and a draft BGEAT was created. The pilot test was applied to 180 students in the 11th grade. According to the results of the pilot administration, item discrimination coefficients and item difficulties were calculated. It was found that item difficulties ranged from 0.09 to 0.79 and the average difficulty of the test was 0.41 at medium difficulty.

Item discrimination varies between -0.13 and 0.69. The average item discrimination of the test was calculated as 0.31. Since the questions with high item discrimination and medium difficulty are needed, items whose item discrimination coefficients were lower than 0,19 were excluded from the test in the first evaluation. A total of 9 items (items: 4, 5, 9, 12, 21, 24, 25 26 and 27) were excluded from the test form. When the 9 items were excluded from the test, the KR-20 reliability was found to be 0,756 and the high internal consistency was observed in remaining 18-items.

2.2.4. Semi-Structured Interviews

At the end of the activities, semi-structured interviews were conducted with 13 students in the experimental group about “Paternity Test Activity” and “Rapid Reproduction in Tobacco Plant Activity” in order to determine their opinions about the activities.

2.4. Implementations in Experimental and Control Groups

The implementation period of the study was carried out simultaneously with all students in 4 weeks. First, the teacher was trained about the activities by the researchers. Teaching process was carried out by the teacher of the biology course. In the control group, the instruction was structured around the textbook materials within the curriculum framework. During the teaching process, the students of both groups are supported to engage in inquiry process in an active learning environment.

Table 3. *Details of treatments in experimental and control groups*

Weekly Course Schedule	
1st Week: 3 course hours	**Experimental Group:** Before the activities, pre-tests (achievement, attitude and self-evaluation) were administered. The teacher explained the concepts of biotechnology and genetic engineering in the “Modern Genetic Applications” chapter. He talked about traditional and modern biotechnology applications and plant and animal breeding in the world and in the country. The course is instructed with active students’ engagement throughout inquiry. He cited examples of biotechnology practices in the textbook and stated about Rapid reproduction of Tobacco Plant as an example to biotechnology activity.
	Control Group: Before the activities, pre-tests (achievement, attitude and self-evaluation) were administered. The teacher explained the concepts of biotechnology and genetic engineering in the “Modern Genetic Applications” chapter. He talked about traditional and modern biotechnology applications and plant

	and animal breeding in the world and in the country. The course is based on constructivist approach. Students read biotechnology applications in the world and in our country from the textbook. A power point slide show on ''tissue cultures'is demonstrated. Question-answers were made and end-of-chapter questions in the textbook were interpreted as question-answer by activities.
2nd Week: 3 course hours	**Experimental Group:** He asked the students to wear their lab coat at the entrance to the laboratory. The teacher attracted the students with the power point presentation about 'tissue cultures'. He divided the students into groups and presented the activity material in the laboratory and distributed handed out sheets including instructions to be applied during the activity. The teacher demonstrated how to do the activity to the students by explaining and applying it. Then, the students were divided into groups and did the activity on their own based on the directions given on the worksheets. At the end of the activity, the students asked to complete self-evaluation form about the activity. **Control Group:** The activity is demonstrated via presentation and evaluation form is distributed. The teachers started to the introduction to genetic engineering.
3rd Week: 3 course hours	**Experiemental Group:** The teacher explained the main concepts of biotechnology and genetic engineering in the 'Modern Genetic Applications' chapter. Start discussion on the effects of genetic engineering applications on human life. Gene technologies, DNA fingerprint analysis; stem cells have given examples of such applications. Teacher created an inquiry environment with questions. He showed examples of genetic engineering practices from the textbook, and then in the laboratory he presented the paternity test activity material to the students. The students followed the instructions and constructed the activity by focusing on teacher demonstration. Then, students were divided into groups and applied the works provided on their own worksheets. At the end of the activity, students' the opinions were taken. **Control Group:** The teacher explained the concepts of biotechnology and genetic engineering in chapter of 'Modern Genetic Applications '. Explained effects of genetic engineering applications on human life referring related course objective. Provided examples about applications of Gene technologies, DNA fingerprint analysis, stem cells. In the control group, students were taught genetic engineering applications from the textbook, they read content from the text book, end of chapter questions are explained. As they did not implement the activities, no feedback was obtained from the control group regarding the rapid growth of tobacco plant and related to paternity test activity.
4th Week: 3 course hours	**Experimental Group:** End-of-unit evaluation questions from the textbook were answered. Post-tests were administered. **Control Group:** End-of-unit evaluation questions from the textbook were answered. Post-tests were administered.

2.5. Data Analysis

Non-parametric tests are used in cases where the number of quantitative data is less than 30 (Büyüköztürk, 2007). Statistical Package for the Social Sciences (SPSS) version 21 package program was used in the analysis. Mann Whitney U-Test and Wilcoxon Signed Ranks Test were used. The Mann-Whitney U Test was used to determine the difference between the experimental and control groups in the applied tests. The Wilcoxon Signed Ranks Test was used to determine the difference between the pre-test and post-test scores of the experimental and control groups. For qualitative data, descriptive content analysis is employed; students were expected to provide descriptive information about activities, whether activities supported their learning, and whether they had impact on their attitudes, thoughts.

The students were asked about ‘Rapid Reproduction in Tobacco Plant’ activity and ‘Paternity Test’ activity, they explained about what did they think about doing the activity before doing it, explained whether it was difficult, easy, boring, fun. Also they were asked whether they want to do the activity again and why. Whether students could do the activity without help is also asked in order to reveal about skill development. Qualitative data were collected through the interview questionnaire form. In the content analysis process, first open coding is done to obtain similar data pattern, data were interpreted by making bricolage of themes (Yıldırım & Şimşek, 2011: 227). After axial and selective coding, themes were created and the code list was finalized. The data obtained from interview forms were analyzed by two different field experts for consensus. Consistency among the experts is calculated as .85.

3. Results

First, the difference between the pre-test and post-test achievement scores, second, difference between attitude scores of the experimental and control groups were analyized, then the difference between the mean scores of self-evaluations were calculated. Finally, opinions of the experimental group about the activities were given in this part. Results of first question are presented in Table 4.

Table 4. *Pre- and Post- Achievement scores across experimental and control groups*.

Pre/Post Measurements		N	Mean	SD	U	p
Pre- Achievement	Experimental	12	67,59	18,48	68,000	,816
	Control	12	66,67	11,11		
Post- Achievement	Experimental	11	74,24	18,13	72,500	,800
	Control	14	70,63	16,80		

As seen from Table 4, the mean difference of achievement scores of experimental group was relatively higher than the control group before the implementation. However, this difference was not statistically significant ($p= .816$). When the post-test mean scores were examined, it was seen that the control group has higher scores. Again the difference was not statistically significant.

The second research question of the study was about whether a difference between the pre-test and post-test attitude scores of the experimental and control groups exist or not. The results are shown in Table 5. As seen from the Table, the attitudes of the control group before the treatment were relatively higher than that of experimental group, however, this difference was not statistically significant ($p=.445$).

Table 5. *Pre- and Post- Attitude scores across experimental and control groups. *p<0.05*

Pre/Post Measurements	Groups	N	Mean	SD	U	p
Pre-Attitude	Experimental	13	2,96	0,28	64,000	,445
	Control	12	3,04	0,25		
Post-Attitude	Experimental	13	3,10	0,35	-	-
	Control	12	-	-	-	-

Becasue of some timing problems, control group students could not take a post-attitude measurement. Thus, it was not possible to make a between group comparison. We could only compare pre-post scores of experimental group using a within group comparison with dependent sample t-test. A significant difference in favor of posttest was found to be t (13) = 2.460, p<.05 for experimental group which means positive changes were observed in the attitudes of students who applied to biotechnology and genetic engineering activities.

Results of the third research question concerning difference between the pre-/post- self-evaluation scores of experimental and control groups are given in Table 6.

Table 6. *Pre/Post- Self-Evaluation scores across experimental and control groups (*p<0.05)*

Pre/Post Measurements		N	Mean	SD	U	p
Pre-SEPTA	Experimental	11	2,48	0,21	-	-
	Control	No measurement				
Pre-SERRTPA	Experimental	13	1,77	0,28	41,500	,046*
	Control	12	1,96	0,20		
Post-SEPTA	Experimental	12	2,92	0,14	4,000	,000*
	Control	14	2,31	0,30		
Post-SERRTPA	Experimental	12	2,75	0,35	17,000	,001*
	Control	14	2,14	0.24		

SEPTA: Self-Evaluation on Paternity Test Activity; RRTPA: Self-Evaluation on Rapid Reproduction of Tobacco Plant Activity; (*p<0.05)

The mean score of 'Paternity Test' is 2.48 out of 3 before the treatment for experimental group. In the control group, self-evaluations about paternity test could not be measured before the treatment. Therefore, scores could not be compared across the groups. The pre-mean self-evaluation scores of the 'Rapid reproduction in the tobacco plant' activity of the control group were relatively higher than that of experimental group. If we were able to compare post-scores, this difference would serve as a covariate. When comparing post- mean scores of self-evaluations on 'paternity test' of the experimental and control groups, experimental group had higher mean scores than the control group and this difference was statistically significant (p =. 000). Finally, the mean scores of post- self-Evaluation on rapid reproduction of tobacco plant activity are compared across experimental and control groups, as seen from table 6 experimental group had higher mean score (2.75). This difference was statistically significant (p =. 001).

3.1. An Overall Evaluation of All Quantitative Results

Wilcoxon test was used to test whether there were statistically significant differences between the pre-post self-evaluations of 'paternity test', pre- post self-evaluations of 'rapid reproductive in tobacco plant', achievement scores, and attitude scores for experimental group. The results were given in Table 7.

*Table 7. Within group comparisons of experimental group scores based on dependent variables using Wilcoxon Test (**$p<0.05$*)*

Experimental Group		N	Mean (X)	SD	Z	p
SEPTA	Pre-	11	2,48	0,21	-2,941	,003*
	Post-	11	2,91	0,15		
SERRTPA	Pre-	12	1,78	0,29	-3,063	,002*
	Post-	12	2,75	0,35		
Achievement	Pre-	11	68,69	18,97	-,766	,443
	Post-	11	74,24	18,13		
Attitude	Pre-	13	2,96	0,28	-1,435	,151
	Post-	13	3,10	0,35		

According to the Wilcoxon test results in Table 7, a significant difference was found between the pre- post self-evaluation on 'paternity test' for experimental group (p =.003). Similarly, in the experimental group, a significant difference was found between pre-post self-evaluations on 'rapid reproduction in tobacco plant' (p =.002). There was no significant mean difference between pre-post achievement scores for experimental group (p=.443). There was no significant mean difference between pre-post attitude scores for experimental group (p=.151).

Same analyses are conducted for control group. Wilcoxon test was used to test whether there were statistically significant differences between pre-post self-evaluation mean scores on 'paternity test', 'rapid reproduction in tobacco plant', pre-post achievement scores, and pre-post attitude scores are indicated in Table 8.

Table 8. *Within group comparisons of control group scores based on dependent variables using Wilcoxon Test*

Control Group		N	Mean (X)	SD	Z	p
SEPTA	Pre-	No measurement			-	-
	Post-	14	2,31	0,30		
SERRTPA	Pre-	12	1,96	0,20	-2,503	,012*
	Post-	12	2,16	0,26		
Achivement	Pre-	12	66,67	11,11	-,563	,574
	Post-	12	68,52	17,30		
Attitude	Pre-	12	3,04	0,25	-	-
	Post-	No measurement				

*$p<0.05$

No statistical comparison could be conducted for pre-post mean scores of self-evaluation on 'paternity test' since no pre measurement in control group. A significant difference was found in the control group across pre-post mean scores of self-evaluation on 'rapid reproduction in tobacco plant' (p=.012). There was no statistically significant mean difference between achievement scores of pre-post measurements in the control group (p=.574). As mentioned before, for attitude scores of control group no comparison could be conducted.

3.1. Findings of Qualitative Data concerning Students' Opinions

The students were asked about their opinions on 'rapid reproduction in tobacco plant' and these opinions are summarized in Table 9.

Table 9. *Students' opinions concerning rapid reproduction of tobacco plant activity.*

Opinion	f	%	Sample students' excerpts (S: Student)
Opinions changed	5	38.5	S1: I thought it would be boring, but it was fun. S3: I thought it might be more difficult and require too much effort but it was easy and quick.
Nature of Activity (opinions not changed)	8	61.5	S4: I always enjoy this type of experiments and I think this experiment is quite necessary than our routine class hours. After doing the experiment, my opinion was the same since it was funny and useful for us. S10: I thought it would be fun. That's what happened. It was a very practical experiment that can be done in routine course hours at school. It was also easy to do this experiment. S12: I thought it would be fun. It was easy and fun.

Before the activities, some students thought them to be boring and difficult to conduct, after the implementations, they developed more positive opinions. Students also stated some views about affective issues such as like, interest, and enjoy. The codes related to the these theme included: "boring, difficult, enjoyable, applicable, easy, necessary, etc...". The students were asked whether they want to do the activity again. Almost all students stated that they would like to repeat such biotechnology activities. Before doing the 'paternity test" activity and after doing it, students were asked about what they thought about the activity. While 30.76% (f = 5) of the students prior to activity thought that it would be difficult, it was seen that they changed their ideas positively after the activity. For example, a student said, "I thought it might be very difficult and requires too much effort, but then when doing it, I realized that it was a enjoyable experiment that needed attention". Another student said that "I thought it might be difficult. But it was funny and easy". Before the activities, two of the students (15.38 %) thought that the activities would be easy and fun, but they changed their ideas after the activity. In addition, 53.86 % (f = 7) of the students who participated in the study stated that they had positive thoughts both before and after the activities. During the interview, the students were asked to do the activity again, 76.92% (f = 10) of the students stated that they wanted to repeat the 'paternity test'. A high majority of the students (92.3%) stated that they could do the activity without any further help. They are very interested in these kinds of activities. However, 7.7% (f = 1) of the students who participated in the study thought that they could not perform the activity alone.

In using qualitative data researchers tried to make triangulation of measurement about student's opinions about biotechnology and genetic engineering activities in modern genetics applications.

4. Discussion and Conclusion

In this study biotechnology and genetic engineering activities are used to compare experimental and control group students' attitudes, achievement and self-evaluations. No significant differences were observed across the pre-/post- mean scores of the control and experimental groups. Having almost similar pre- scores may be considered as homogeneity of groups which indicates no selection bias across group. The fact that there was no significant difference between the attitudes scores before and after the treatments of both groups may be due to the high curiosity level of students since these students are in a science high school, and their high level of exam-oriented knowledge (Yavuz, Gülmez, Özkaral, 2016; Aslan, 2015; Altun et al., 2011). The fact that there was no significant difference before and after the biotechnology and genetic engineering activities in both groups, may be aroused from students' high levels of readiness for academic achievement, and their preparation for the university exam.

The findings of this study are consistent with the findings of other studies. Çelik and Erişen (2009) reported that biology course activities had a positive impact on attitudes towards biotechnology subjects. They reported that laboratory applications should be included in the curricula in order to support meaningful learning of biotechnology and genetic engineering subjects, as well as enriching curricula with more visual materials. This study aims to contribute to the field on providing materials and testing their effects on students, since teachers may feel lack of materials about these concepts. Demirci and Yüce (2018) have also obtained partially similar results. They report that biotechnology and genetic engineering laboratuvar activities support students' achievement and their attitudes.

The fact that there was a statistically significant difference between the mean values of the self-evaluations of the experimental and control groups for both activities in the study could be evaluated as the effect of such activities on the students' interest. Doğan et al. (2004) study point out that learning environment in which the students are active in both supports understanding and interest in learning. The effects such as teacher's effective implementation of the activity, narration of theoretical parts by linking the activity to the concepts, and showing tobacco materials grown in tissue culture may have influenced the self-evaluation of the students.

At the end of the semi-structured interviews; activities were evaluated and generally positive opinions were obtained. The activities positively affected the students' views on biotechnology concepts based on the qualitative data they provided. Creating a inquiry-based learning environment with questioning, the teacher conducting the activities, demonstrations, examples from daily life, as well as active students participation might have impact on the results. Doğan et al. (2004) revealed the effect of this kind of constructivist learning environments on students. Most of the students stated that they liked the biotechnology activity very much, wanted to do it again with different plants and felt like a scientist in doing the experiments and they felt that they are doing very important job. It is very important to carry out such activities with the students who are at the beginning of their career steps in raising potential researchers interested in the subject. Niles and Harris Bowlsbey (2013) defined career awareness as an individual's career planning and determination of choices according to their interests and skills. The fact that students are not informed about their career opportunities in these fields at an early age is an effective factor in decreasing their interest in the occupations in these fields. The students' views indicate that the students are also affected from these activities about these issues. In addition, the students stated that they could do the activities on their own and they felt like scientists in doing them. Kahya (2009) point out that if students have materials that they would carefully examine like scientist, their interest and conceptual learning will be supported more.

It would be appropriate to say that the activities attracted the attention of the students; they had fun and learned while doing. Similar works indicate the effect of activities enriched biology teaching on students' interest and career plans, linking knowledge to daily life, concretization of abstract concepts, and the quality of teaching (see, Aşçı & Demircioğlu, 2007; Atun, et al., 2011). In such learning environments, the student uses almost all his or her senses, making learning more effective, easy. Altun et al., (2011) state that students' skills acquired during activities are in line with the basic skills that scientists have in accessing information.

In addition, the students completed the activities within the given time and did not have any problems about time. This shows the applicability of the activity in the school hours.

Other studies are suggested to examine the development of students' science process skills through such activities. Or students may be encouraged to create their own problem sentences, and conduct their own scientific inquiry investigations. When such activities are employed, students can gain skills such as evaluation and observation (Yılmaz, 2018), therefore, investigations about scientific inquiry, the nature of science and science process skills will also contribute to the literature. Future studies can be used with simple table-top versions and simulations of such activities. Implementations can be done for a longer time to influence the attitude more.

To summarize, this research points out the effects of biotechnology and genetic activities that present interdisciplinary subjects on students' on achievement, attitudes, and self-evaluations. The limitations of the study include the small and not employing a representative sample, for these reasons it not possible to make generalization. Also, conducting research with top-level students, such as science high schools, may have affected the results because these groups of students may more exam-oriented. Furthermore, it is a limitation that some tests such as attitude and self-evaluation cannot be given to the control group as a post-test due to some disruptions in the application period, due to that appropriate statistical analysis may not be employed. Qualitative data were collected to support quantitative data. As a result, although there is no difference in achievement and attitude, student self-evaluations support their interest in the learning environment and activities.

Note: This study is produced from first author's master thesis.

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