Science Education International
36(4)_2025,470-479
https://doi.org/10.33828/sei.v36.i4.10

ORIGINAL ARTICLE

Evaluation of Science Teacher Candidates' Knowledge and Views on Biotechnology

Ainur Syzdykova[1]*, Dariya Jussupova[2], Arailym Amantayeva[1], Bibizhan Yerniyazova[3], Gani Issayev[4], Aigul Mukhametzhanova[4]

[1]Department of Biology, Institute of Natural Sciences and Geography, Abai Kazakh National Pedagogical University, Almaty, Kazakhstan, [2]Department of Geography and Ecology, Institute of Natural Sciences and Geography, Abai Kazakh National Pedagogical University, Almaty, Kazakhstan, [3]Department of Pedagogy and Methods of Primary Education, E.A. Buketov Karaganda University, Karaganda, Kazakhstan, [4]Department of Biology, Khoja Ahmed Yasawi International Kazakh-Turkish University, Turkestan, Kazakhstan

***Corresponding Author:** ainur.syzdykova@outlook.com

ABSTRACT

The aim of this study is to evaluate science teacher candidates' knowledge and views on biotechnology education. The research was conducted with the phenomenology pattern, one of the qualitative research designs. In the study, quantitative data were collected using the "biotechnology knowledge scale" data collection tool, while qualitative data were collected using the "semi-structured interview form." The sample of the study was science teaching students studying in the fall semester of the 2024–2025 academic year. While the "biotechnology knowledge scale" was applied to a total of 283 students, the "semi-structured interview form" was applied to 36 students. As a result of the research, most of the participants answered yes to the question about getting biotechnology education. Among the answers given to the questions about the harms of biotechnology, ethical issues, biological weapons, ecosystem degradation, threatening health, and most of the participants answered the question as ethical issues. Among the answers given to the question asked to evaluate the views of science teacher candidates on the importance of educating teachers-biologists in biotechnology education, professional ethics and responsibility, increasing quality, and training qualified teachers, most of the participants answered the question as professional ethics and responsibility.

KEY WORDS: Biotechnology, education, science, teacher, technology

INTRODUCTION

The accumulation of knowledge that has increased throughout the history of humanity has also enabled the advancement of technology (Gbadegesin et al., 2018). This advancement in technology has affected and shaped human life and societies, (Tezer et al., 2020). The most important role in the development of countries is the development in the field of science and the transformation of these developments into technology (Thrift, 2005).

Modern biotechnology, which enables problem-solving and producing products with the use of organisms and cells, is advancing at a dizzying pace in terms of the time we live in (James, 2012). Due to these advances, education in science (Meno et al., 2021; Christian et al., 2021) and biotechnology, is becoming increasingly important (Zhu et al., 2020) to catch up with developing technologies and integrate them into our lives (Skinner, 2018; Dicks et al., 2021).

Biotechnology is on its way to becoming the most important scientific revolution of the current century (Campbell and Reece, 2005; Kumar et al., 2022). Humans have used microorganisms, plants, and animals for many years, but the development of biotechnology allows us to genetically modify organisms with new methods and use the products of these organisms to raise our standard of living (Sahu et al., 2019). Applications from hundreds of years ago, such as the use of microbes in cheese and wine production and the selective production of farm animals, are examples of biotechnology (Curtis and Wilkinson, 2001).

Biotechnology provides opportunities to solve many problems that we encounter in our lives (Meisner et al., 2022; Stalidzans and Dace, 2021). It creates opportunities for business development and profit in a wide range of industries, including healthcare, chemical production, agriculture and forestry, fuel and power generation, food technology, and pollution control (Bhatia, 2005). Biotechnology, which was originally developed for humans, plants, and animals to achieve a better quality of life, has been a concern today, because it is dangerous because of the possibility of unforeseen harm or misuse of this technology. Therefore, the effects of biotechnology on the environment and human health raise concerns in terms of religious and moral values (Pathak, 2007).

The field of biotechnology education is quickly evolving, necessitating a robust comprehension among prospective scientific educators. This research seeks to evaluate the knowledge and viewpoints of prospective science teachers regarding biotechnology, focusing specifically on their

readiness to teach and incorporate modern biotechnological concepts in the classroom.

Recent studies underscore the significance of biotechnology education in teacher training programs. Aydin and Cetin (2020) assert that prospective science and classroom instructors possess varying levels of knowledge and attitudes toward biotechnology, highlighting the necessity for programs that foster a more profound comprehension of this essential domain. The variance in knowledge levels prompts significant inquiries regarding the readiness of these individuals to proficiently instruct biotechnological principles. Furthermore, Alanazi (2023) observed that Saudi students and science educators had a deficient comprehension of biotechnology ideas, suggesting pervasive deficiencies in biotechnological literacy that must be addressed within educational institutions.

The incorporation of technology into education is a crucial element in the preparation of teacher candidates for modern classrooms. Firat and Köksal (2019) shown that instruction enhanced by Web 2.0 tools has augmented the biotechnology literacy of prospective educators. This discovery demonstrates the potential of digital tools to enhance candidates' knowledge, which can later influence their teaching effectiveness. While technology can enhance the educational process, its successful deployment relies on a robust understanding of technical pedagogical content knowledge. Irmak and Özgül, in 2019, investigated pre-service science teachers' opinions of Technological Pedagogical Content Knowledge (TPACK) in genetics, emphasizing a crucial connection between teacher preparation and the integration of contemporary scientific concepts into their instructional frameworks.

In addition to technological proficiency, pedagogical approaches significantly influence the instruction of biotechnology. Hursen (2021) examined a problem-based learning approach facilitated by web 2.0 tools and its beneficial impact on academic achievement and critical thinking abilities among teacher educators. This method engages students and equips them to address real-world scientific challenges, ensuring they can proficiently convey intricate biotechnology concepts to their future pupils.

The incorporation of the argumentation-based survey inside the program influences the approach of teacher candidates to biotechnology education. Sonmez et al. (2021) noticed that activities derived from this teaching style have significantly enhanced the critical thinking skills of teacher educators, a vital competency for navigating the complexities of biotechnology. These pedagogical tactics promote student engagement with socio-scientific issues, which are increasingly pertinent in educational discussions. Sıbıç and Topcu (2020) observed that pre-service science instructors exposed to socio-scientific problems exhibit enhanced engagement in conversations about biotechnology, hence fostering a more knowledgeable generation.

With the evolution of the educational landscape, particularly due to the emergence of Industry 4.0, it is imperative to modify teacher training programs to incorporate pertinent biotechnology principles. Sari and Wilujeng (2020) advocate for a transformation in educational paradigms to incorporate biotechnology, positing that the assimilation of contemporary scientific advancements can enhance the preparedness and significance of educators in the classroom. This aligns with a global necessity for ongoing professional development among scientific educators to guarantee they stay current with biotechnology advancements.

The opportunities for project learning indicate the trends influencing the methodologies of teacher education applicants. Mirici and Uzel (2019) examined perspectives and self-efficacy among educators participating in project training, emphasizing that hands-on experiences enhance candidates' readiness for future educational problems, particularly in areas like biotechnology. The results indicate that exposure to experiential learning opportunities may significantly enhance the confidence and competence of teacher candidates in delivering biotechnology content.

The requirements for professional growth also encompass the wider educational framework. Smalley et al. (2019) emphasized the perceived necessity for professional development among agricultural education teachers in schools, highlighting the requirement for specialized training in areas such as biotechnology. This underscores the necessity of ongoing tutoring for teacher candidates, assuring their preparedness to address modern issues related to teaching biotechnology topics. The requirements for professional development also encompass the broader educational framework. Smalley et al. (2019) emphasized the perceived need for professional development among agricultural education teachers in schools, emphasizing the need for specialized training in areas such as biotechnology.

This highlights the need for ongoing tutoring for preservice teachers and ensures that they are prepared to address modern issues related to teaching biotechnology topics. For these reasons, determining the biotechnology knowledge entry behaviours of science education students entering university should be considered a research gap as a priority.

Purpose of the Research

The purpose of this research is to evaluate science teacher candidates' knowledge and views on biotechnology and biotechnology education. In accordance with the purpose of the study, answers were sought to the following questions:

1. What is the biotechnology knowledge level of teacher candidates?
2. Is there a difference in biotechnology and knowledge levels of teacher candidates based on their gender?
3. Is there a difference in the biotechnology knowledge levels of teacher candidates depending on the grade they study in?
4. What is the status of science teacher candidates receiving biotechnology education?
5. What is the situation of science teacher candidates finding biotechnology useful?

6. What are the views of science teacher candidates about the benefits of biotechnology?
7. What are the views of science teacher candidates about the harms of biotechnology?
8. What are the views of science teacher candidates on the importance of educating teacher-biologists for biotechnology education?

RESEARCH METHODOLOGY

General Background

In this study, it was tried to determine the opinions of science teacher candidates about the importance of educating teachers-biologists for biotechnology education. Qualitative research and phenomenology design were used in the study. Studies carried out with phenomenology design are studies in which the meaning attributed to the experiences of a relatively limited number of participants is examined and this meaning is described (Stolorow and Atwood, 2018). In this direction, the meaning attributed to this experience by the science teacher candidates, who have a certain experience in biotechnology, was described according to their own perspectives. For this reason, it was found appropriate to use the phenomenology method in our research.

Sample/Participants/Group

Survey research participants

The sample of the study consisted of science teacher candidates studying in the department of science teaching at a university in Kazakhstan in the 2024–2025 academic year. In this study, a random sampling method was used to select the sample. The sample consisted of university students studying science education in the faculties of education in Almaty, Karaganda, and Astana cities of Kazakhstan. Two-thirds of the universities operating in Kazakhstan are located in these cities. Careful attention was paid to the sampling distribution by city in the collection of quantitative and qualitative data. Table 1 contains data on the gender of science teacher candidates.

In Table 1, of the prospective teachers who participated in the survey research, 50.5% were female and 49.5% were male. It is seen that the gender distribution is equal.

Table 1: The survey research participants' gender differences

Gender	Frequency	Percent	Cumulative percent
Female	143	50.5	50.5
Male	140	49.5	100.0
Total	283	100.0	

Qualitative research participants

In Table 2, demographic distributions of science teacher candidates participating in the research regarding their gender are given.

In Table 2, gender distributions of science teacher candidates participating in the qualitative research are given. Of the science teacher candidates participating in the study, 20 were female and 16 were male.

Table 2: Gender distribution of science teacher candidates

Gender	Female	Male	Total
Sum	20	16	36

Instrument and Procedures

Biotechnology knowledge scale (BKS)

Following the literature analysis performed in this study, Atasoy et al., in 2020, determined to utilize the "biotechnology knowledge scale (BKS)." The initial version of the scale comprises 17 items designed to assess students' comprehension of biotechnology concepts linked with the curriculum. The Cronbach's alpha reliability coefficient for BKS is calculated at 0.770, indicating a strong level of consistency.

Language equivalence study

The BKS, translated into Kazakh, was initially rendered from its original language by proficient linguists fluent in both languages. All translation operations were executed concurrently by two linguistic specialists. The Kazakh translation of the scale form was reverted to its original language after 2 weeks. Efforts were made to guarantee that the translation had the same meaning as the original text. The objective was to guarantee uniformity across the translations produced by two language specialists, with a 2-week gap between each translation. Moreover, the translations were meant to faithfully convey the meanings of the items in the original version, so, preserving the scale's structure in relation to the construction was supposed to measure. Ultimately, 2 weeks later, two specialists translated the scale from their native language back into Kazakh and produced the final Kazakh version of the scale.

Pilot application: At this phase, a pilot sample group of 98 candidates for biology teaching was established. The sample size of 98 students satisfies the requirement of being a minimum of 5 times the number of items necessary for analytical investigations, hence ensuring the statistical validity of the analysis (Ritchie et al., 2013). Cronbach's alpha reliability coefficient for BKS is computed to be 0.86.

The semi-structured interview form

The research data were collected through face-to-face interviews using a "semi-structured interview form" developed by the researchers to suit the purpose of the study. The interview form created by the researchers based on the relevant literature and the questions in the form was submitted to the opinions of three experts, two of whom work in the field of faculty of education science professor, one in the field of measurement and evaluation professor and other is biology professor. Qualitative research was determined as a criterion in the determination of these experts. The interview form, which was finalized based on expert opinions, was presented to a

faculty member working in the field of language and literature to evaluate its suitability in terms of language and expression, and the form was given its final form.

Procedures

In the process of preparing scientific research, it is important to comply with ethical rules and to produce information that is valid and reliable (Ritchie et al., 2013). In this study, ethical rules were followed in the creation of data collection tools and in the process of recording the data. After explaining the purpose of the research to the participants, the participants were asked to participate in the research voluntarily by obtaining their consent with informed consent forms. Students were asked in both data collection tools whether they had received biotechnology training before. It was explained to the students that the training included seminars, workshops, sections within the course, conferences, and similar activities, regardless of the duration.

Biotechnology and knowledge scale was applied by the researchers with the permission of the instructor who had the course. A total of 30 min was given to the students. First-year science education students were asked to carefully mark the most correct answer on the given answer sheet without writing their names.

After a certain period, the semi-structured interview form was applied. The interviews were recorded with a voice recorder. In addition, in terms of respect for private life and not harming private life during the interview, attention was paid to not reveal the identity information and to give each participant a place with codes such as A1, A2, A3, and to keep the interview records confidential and not to be shared with third parties. After all the interviews were finished, the audio recordings were listened to and transcribed in Microsoft Word. The interviews lasted approximately 35 min. The interviews were conducted in the form of individual interviews in the conference hall of the school, in a time frame determined by all participants in a way that would not affect the courses of the science teacher candidates. Data were collected over a month period.

Data Analsis

BKS

The data obtained from the scale were made using the Statistical Package for the Social Sciences statistical analysis program. While the incorrect answers given by the prospective teachers were coded with 1, the correct answers were coded with 2. The data obtained were made using frequency (f), percentage (%), mean, and independent t-test data analysis techniques.

The semi-structured interview analysis

In the analysis of the data in our study, induction and analysis technique was used to reach detailed findings to evaluate the views of science teacher candidates about their biotechnology education status. Inductive analysis is the categorization of data through coding, revealing the relationships between categories and forming common themes and sub-themes (Patton, 1990). The transcription of the data, the accuracy of the transcripts, the preparation of the indexes, and reliability studies were carried out. Before the data analysis, three experts from the field took part voluntarily to carry out the reliability study of the research. To ensure the reliability of the interviews, audio cassettes, and written interview forms were selected.

In the study, three experts independently listened to the recordings given to them, read the transcripts, and wrote the descriptive index and interviewer comments sections. Afterward, the researcher and other experts came together and made comparisons. In cases where consistency was not achieved, consistency was achieved after the common ideas of the researchers and experts. After the forms were finalized, page numbers were given to the data, coding of the data, duplication of the coded data, creation of the data constituting the themes and sub-themes, matching of the themes and sub-themes, reading the themes and sub-themes, and making necessary corrections. In terms of the reliability of the study, common themes, and sub-themes were decided and given in tables with frequency and percentage calculations. In addition, the views of the participants supporting the themes are included under each table by directly quoting along with their codes.

RESEARCH RESULTS

Results of Biotechnology Knowledge

Descriptive statistical results obtained from the BKS are given in Table 3.

Table 3 shows that science education teacher candidates received the lowest score of 17 and the highest score of 32 from the BKS. However, the highest score that can be obtained from this measurement tool is 34. When we look at the general average, it is seen that the students received a score (M = 21.45, standard deviation [SD] = 3.52) below the average score (M = 25.5). According to this result, it can be said that the biotechnology knowledge level of 1st-year science education teacher candidates is below the expected average and is at a low level.

Gender Differences

The independent samples test analysis results of the averages obtained by science education teacher candidates from the "biotechnology knowledge scale" according to their gender are shown in Table 4.

Table 4 shows that there is a statistically significant difference

Table 3: The descriptive statistical results obtained from the biotechnology knowledge scale

n	Minimum point	Maximum point	M	Standard deviation	Avarage
283	17.00	34.00	21.45	3.52	Low level

Table 4: Differences by gender

Gender	n	M	Standard deviation	t	df	p
Female	143	21.92	3.50	0.038	281	p<0.05
Male	140	21.06	3.50			

between female (M = 21.92, SD = 3.50) and male (M = 21.06, SD = 3.50) in the scores obtained from the "biotechnology knowledge scale" according to gender ($p<0.05$). This significant difference favors female students.

Difference in Getting Education

The independent samples test analysis results of the averages obtained by science education teacher candidates from the "biotechnology knowledge scale" according to difference in getting education are shown in Table 5.

Table 5 shows that there is a statistically significant difference between no (M = 19.61, SD = 2.03) and yes (M = 24.45, SD = 3.33) replied in the scores obtained from the "biotechnology knowledge scale" according to getting education ($p<0.001$). This significant difference favors students who have previously received biotechnology knowledge training.

Summary of Quantitative Results

Table 6 summarizes the results obtained from the quantitative data in Tabular form.

Table 6 shows that university students have a low level of biotechnology knowledge, female students have higher knowledge than male students, and those who have received prior training have a higher level of knowledge.

Results of the semi-structured interview form.

Science teachers on the questions asked to determine the importance of educating teachers-biologists for biotechnology education.

Science teacher candidates who participated in the research voluntarily were gathered in five categories: Their views on biotechnology education, their opinions on whether they find biotechnology useful, their views on the benefits of biotechnology, their views on the harms of biotechnology, and their views on the importance of educating teachers-biologists for biotechnology education. Biotechnology education status of science teacher candidates is given Table 7.

In Table 7, biotechnology education status of the science teacher candidates participating in the research is given. About 55.5% of the science teacher candidates stated that they received biotechnology training, 44.4% stated that they did not receive biotechnology training. When Table 2 is evaluated, it is seen that most science teacher candidates receive biotechnology education. Table 8 shows the data on the science teacher candidates' finding biotechnology useful.

Table 8 shows the data on the science teacher candidates' finding biotechnology useful. 27.7% of the science teacher candidates stated that they found biotechnology useful, 25% found it useful, 13.9% found it partially useful, 19.4% did not find it useful, and 13.9% did not find it useful at all. When Table 3 is evaluated, it is seen that most science teacher candidates find biotechnology useful. Table 9 shows the opinions of science teacher candidates about the benefits of biotechnology.

Table 5: Differences in getting an education

Getting education	N	M	Standard deviation	t	df	p
No	173	19.61	2.03	15.172	281	p<0.05
Yes	110	24.45	3.33			

Table 6: Results of dependent and independent variables

Dependent and independent variables	Results
Biotechnology knowledge	Low level
Gender differences	Female students have higher
Difference in getting education	Those who have received prior training have a higher level of knowledge.

Table 7: Science teacher candidates' status of receiving biotechnology education

Education status	F	Percentage
Yes	20	55.5
No	16	44.4
Total	36	100

Table 8: Science teacher candidates' finding biotechnology useful results

Themes	F	Percentage
I find it helpful	10	27.7
I find it useful	9	25
I find it somewhat useful	5	13.9
I do not find it useful	7	19.4
I don't find it helpful	5	13.9
Total	36	100

Table 9: Science teachers on the benefits of biotechnology

Themes	Sub-themes	F	Percentege
Health benefits	Development of vaccines and drugs	23	63.8
	Reducing genetic diseases		
	Treatment of infectious diseases		
Benefits in agriculture and livestock	More efficient livestock	14	38.8
	Prevention of food poisoning		
	Production of more efficient food		
	Development of new plant species		
	Artificial seed production		
Life quality	Prolonging life span	7	19.4
	Providing a healthier life		
I do not find it useful	Ethical issues	5	13.9

In Table 9, the opinions of the prospective science teachers participating in the research on the benefits of biotechnology are evaluated. Science teacher candidates' views on the benefits of biotechnology are grouped into four categories: benefits in the field of health, benefits in agriculture and animal husbandry,

quality of "life" and 'I do not find it useful. Of the science teacher candidates participating in the research, 63.8% stated that biotechnology is beneficial in the field of health, 38.8% stated that biotechnology is beneficial in the field of agriculture and animal husbandry, 19.4% stated that it positively affects the quality of life, and 13.9% did not find biotechnology useful.

The opinions of science teacher candidates regarding the benefits of biotechnology are given below:

A4 coded science teacher candidate. Recently, we all have seen that health is our most important value. With biotechnology, it is possible to hope for the treatment of many diseases such as cancer. It also plays a key role in the production of vaccines to be used to prevent future diseases. A9 coded science teacher candidate. It has benefits such as producing more productive animals and developing efficient meat and dairy products. A11 coded science teacher candidate. In addition to the benefits such as the development of new plant species and the positive development of seeds, which will enable the farmers to yield better than before, I think that there are also benefits such as the production of animals that will produce more milk. It also has benefits such as increasing life expectancy by offering people a healthier life. A14 coded science teacher candidate. Prolonging the healthy life span with its positive contribution to the diagnosis and treatment of diseases can be counted among the benefits of biotechnology. A21 coded science teacher candidate. I think that it will cause harm rather than benefit because everything natural is spoiled by biotechnology, and I do not find biotechnology useful. Table 10 shows the opinions of science teacher candidates about the harm of biotechnology.

In Table 10, the views of science teacher candidates participating in the research on the harms of biotechnology are evaluated. The views of science teacher candidates about the harms of biotechnology were gathered in four categories: Ethical problems, biological weapons, disruption of the ecosystem, and "threatening health." About 41.6% of the science teacher candidates participating in the research stated that ethical problems, 30.5% biological weapons, 22.2% ecosystem degradation, and 19.4% threatening health are among the harms of biotechnology.

Science teachers about the harms of biotechnology is given below:

B5 coded science teacher candidate. Besides the benefits of biotechnology, there are many disadvantages as well. While it is a big question mark about who will benefit from the benefits resulting from biotechnology, the consequences of malicious use of biotechnology by malicious people can be painful for humanity. B8 coded science teacher candidate. Two major harms of biotechnology are biological weapons and environmental pollution. The health of many innocent people could be compromised, and animals could become extinct. B23 coded science teacher candidate. With the emergence of environmental pollution, the disposal of new wastes, and the formation of new species, the natural balance may be disturbed. We have seen many examples of this throughout history. The decrease and proliferation of things in nature can negatively affect many species and systems. B30 coded science teacher candidate. I am afraid of the emergence of new insects. Larger and even human flesh-eating insects may appear. Nature likes rules and systematic work, any disruption in these rules or the system affects many situations negatively. B31 coded science teacher candidate. Even the foods we call healthy lately have been genetically modified. I think we will experience the results of these years later by losing our health. Table 11 presents the views of science teacher candidates on the importance of educating teachers-biologists for biotechnology education.

In Table 11, the opinions of the prospective science teachers participating in the research on the importance of educating teachers-biologists in biotechnology education are evaluated. The opinions of science teacher candidates on the importance of educating teachers-biologists in biotechnology education were gathered in three categories: Professional ethics and "responsibility," increasing "quality," and "training qualified teachers." About 47.2% of the science teacher candidates participating in the research stated that professional ethics and

Table 10: Science teacher candidates on the harms of biotechnology

Themes	Sub-themes	F	Percentage
Ethical issues	The use of sides	15	41.6
	Genetically modified organisms		
	Ethical issues in the healthcare industry		
Bioweapon	Use of pesticides as biological weapons	11	30.5
	Use in making biological weapons		
Disruption of the ecosystem	Many living things die	8	22.2
	Environmental pollution		
	The emergence of new pest species		
Do not threaten health	More allergies	7	19.4
	Health problems caused by modified agricultural products		
	Health problems caused by toxic waste		

Table 11: Opinions of science teacher candidates on the importance of educating teacher-biologists for biotechnology education

Themes	Sub-themes	F	Percentage
Professional ethics and responsibility	To comply with ethical rules	17	47.2
	To be responsible		
	Work with discipline		
	Become an expert		
	Think through		
Improve quality	Increasing the quality of education	12	33.3
	Increasing quality in agriculture and health		
	Increasing quality in the workplace		
	Preventing information pollution		
To train qualified teachers	Mastery of the subject	9	25
	Using the appropriate method		

responsibility, 33.3% of them to increases the quality, and 25% of them stated that training qualified teachers is important in biotechnology education.

Science teachers on the importance of educating teachers biologists in biotechnology education are given below:

B15 coded science teacher candidate. The training of expert teachers in biotechnology education is a necessary step to prevent ethical problems that may develop later. I think that undergraduate educators who do their job consciously and have deontology knowledge should be trained. B17 coded science teacher candidate. The trainer is very important in biotechnology education. Students who will work in the field of biotechnology should be educated by an expert trainer to be trained responsibly and consciously, and to easily solve problems that may cause ethical problems. B28 coded science teacher candidate. Training teachers in biotechnology education is important in terms of increasing the quality of education. Improving the quality of education largely depends on the teacher and the student. B29 coded science teacher candidate. Training of teachers who are knowledgeable and skilled in biotechnology. It increases productivity in many areas such as health, agriculture, and genetics. B34 coded science teacher candidate. The choice of method to be used and the technology to be used while educating teachers-biologists for biotechnology education plays a key role in the transfer and implementation of the subject.

In Table 12, the opinions of the science teacher candidates who voluntarily participated in the research about their biotechnology education status, their opinions on the status of finding biotechnology useful, their views on the benefits of biotechnology, their views on the harms of biotechnology, and their views on the importance of educating teachers-biologists for biotechnology education were evaluated.

Table 12: Science teachers on the importance of training teacher-biologist for biotechnology education

Themes	Sub-themes	Science teacher candidate	
		F	Percentage
Education status	Yes	20	55.5
	No	16	44.4
Sum		36	100
State of finding biotechnology useful	I find it helpful	10	27.7
	I find it useful	9	25
	I find it somewhat useful	5	13.9
	I do not find it useful	7	19.4
	I don't find it helpful	5	13.9
Sum		36	100
Benefits of biotechnology	Health benefits	23	63.8
	Benefits in agriculture and livestock	14	38.8
	Life quality	7	19.4
	I do not find it useful	5	13.9
Harms of biotechnology	Ethical issues	15	41.6
	Bioweapon	11	30.5
	Disruption of the ecosystem	8	22.2
	Do not threaten health	7	19.4
The importance of training a teacher-biologist	Professional ethics and responsibility	17	47.2
	Improve quality	12	33.3
	To train qualified teachers	9	25

In Table 12, the views of science teacher candidates participating in the research on their status of receiving biotechnology education, their views on whether they find biotechnology useful, their views on the benefits of biotechnology, their views on the harms of biotechnology, and their views on the importance of educating teachers-biologists for biotechnology education are evaluated. About 55.5% of the science teacher candidates stated that they received biotechnology training, and 44.4% stated that they did not receive biotechnology training. 27.7% of the science teacher candidates stated that they found biotechnology useful, 25% found it useful, 13.9% found it partially useful, 19.4% did not find it useful, and 13.9% did not find it useful at all. About 63.8% of science teacher candidates stated that biotechnology has benefits in the field of health, 38.8% said that it has benefits in the field of agriculture and animal husbandry. About 19.4% stated that it increased their quality of life, and 13.9% did not find it beneficial. About 41.6% of science teacher candidates stated that biotechnology is harmful due to ethical problems, 30.5% stated that it is harmful in terms of biological weapons, 22.2% stated that it is harmful in terms of ecosystem degradation, and 19.4% stated that it is harmful in terms of threatening health. About 47.2% of science teacher candidates stated that raising biologist-teacher in biotechnology education is important in terms of professional ethics and responsibility, 33.3% stated that it is important in terms of increasing quality, and 25% stated that it is important in terms of training qualified teachers.

DISCUSSION

According to quantitative results, it can be said that the biotechnology knowledge level of 1st-year science education teacher candidates is below the expected average and is at a low level. Similarly, Atasoy et al. (2020) found a similar result in their study. This result can be attributed to the fact that the students are studying in the first year of university and do not receive sufficient "biotechnology education."

This study found a significant difference in favor of women, although the difference was small. In contrast to this result, Simon (2010) found that education and biotechnology knowledge had independent effects on attitudes for men, but when knowledge was controlled for, education had no effect on attitudes toward biotechnology for women. Prokop et al. (2007) found no gender differences in a group of students that did not graduate from biology courses. Therefore, we cannot make a serious conclusion about gender differences.

It is an expected result that there will be a significant difference in favour of the fields according to the status of university students getting "biotechnology knowledge" education. Here, regardless of the duration of the education, it is a scientific

result that is accepted to have a low or high-level effect on the given subject. In this study, according to the qualitative research result, the status of getting biotechnology education, the majority of science teacher candidates answered yes to the question asked to evaluate the views of science teacher candidates about their biotechnology education status. In a study conducted by Lamanau and Makarskaitė-Petkevicienė (2008) to measure the attitudes and knowledge of teachers and students toward biotechnology, they found that pre-service teachers' biotechnology knowledge levels were insufficient. It is thought that getting education/knowledge about biotechnology will positively affect students' attitudes toward biotechnology. In the studies Lock et al. (1995), which supports this idea, it was found that students' attitudes changed positively after taking a course on biotechnology and its applications.

In this research, the majority of science teacher candidates answered the question asked to evaluate the situation of science teacher candidates finding biotechnology useful. It is thought that the fact that most of the students had previously received biotechnology education has an effect on this result. In the study of Gunter et al. (1998), it was found that upper-class students developed more positive attitudes toward biotechnology applications. Similarly, Chen and Raffan (1999), in their study, investigated the knowledge and attitudes of students from England and Taiwan about biotechnology. They found that students' attitudes increased positively after taking a course related to biotechnology. Dawson and Schibeci (2003) found that taking the biotechnology course did not affect students' attitudes toward biotechnology in a positive way. In addition, as a result of the study conducted by Klop and Severiens (2007) with 574 secondary school students to investigate students' attitudes toward biotechnology. The majority of the students concluded that they were not sure about the use of biotechnology, and that 22% of the students strongly supported biotechnology.

In our research, the majority of science teacher candidates answered the question asked to evaluate the views of science teacher candidates about the benefits of biotechnology. This was one of the answers given by the candidate teachers. There are also benefits in agriculture and animal husbandry, quality of life, and answers that I do not find useful. Massarani and Moreira (2005) conducted a study to investigate the attitudes of high school students toward modern genetics and biotechnology in Brazil, and most of the students stated that they believed that transgenic food could be beneficial and should be encouraged.

In our research, the majority of science teacher candidates answered ethical problems to the question asked to evaluate the views of science teacher candidates about the harms of biotechnology. This was one of the answers given by the candidate teachers. There are also responses to biological weapons, ecosystem degradation, and threatening health. Sheykhha et al. (2006) conducted a questionnaire on the risks and benefits of biotechnology and genetically modified foods to a total of 600 people, 300 university students, and 300 non-university students, to evaluate the knowledge level of society about the dangers and opportunities of genetic modification. As a result of the research, while only 12% of the students considered ethical problems, 52% of the non-students stated that genetically modified foods are risky due to ethical problems.

In this research, the majority of science teacher candidates gave the answer of professional ethics and responsibility to the question asked to evaluate the views of science teacher candidates on the importance of educating teacher-biologists in biotechnology education. There are also answers to increase quality and train qualified teachers. Turan and Koç (2012) in their study, determined the attitudes of science teacher candidates toward biotechnology applications. He stated that since the subject of biotechnology is complex and abstract, it is explained by teachers with insufficient knowledge and attitude, which makes the subject more incomprehensible for students. He stated that pre-service teachers who received an effective biotechnology education during their university education will also give an effective biotechnology education to their students in the future.

CONCLUSION AND IMPLICATIONS

This study aimed to evaluate the views of prospective science teachers regarding the importance of training biology teachers who possess knowledge and skills in biotechnology education. First-year university students aspiring to teach science had a low and below-average level of biotechnology understanding. Female students have higher "biotechnology knowledge" than male students. It is very important for students to receive biotechnology knowledge training during their high school education.

Science teacher candidates' views on biotechnology education, whether they find biotechnology useful, the benefits and harms of biotechnology, and the importance of educating teachers-biologists for biotechnology education were questioned. Most of the participants answered yes to the question about getting biotechnology education. To the question about whether science teacher candidates find biotechnology useful, most of the participants answered that they find it useful. The answers given to the question about the benefits of biotechnology are listed below. Benefits in the field of health, benefits in the field of agriculture and animal husbandry, quality of life, and I do not find useful answers to the question, most of the participants gave the answer in the field of health. Among the answers given to the questions about the harms of biotechnology, ethical issues, biological weapons, ecosystem degradation, threatening health and most of the participants answered the question as ethical issues. Among the answers given to the question asked to evaluate the views of science teacher candidates on the importance of educating teachers-biologists in biotechnology education, professional ethics and responsibility, increasing

quality, and training qualified teachers, most of the participants answered the question as professional ethics and responsibility.

The conclusion is that the readiness of science teacher candidates to instruct and incorporate bio-technology concepts is influenced by various aspects, notably knowledge levels, technological integration, pedagogical techniques, and ongoing professional development. By focusing on these areas, educational institutions can enhance the readiness of teacher candidates to impart essential biotechnology knowledge, eventually helping future generations of students. As biotechnology advances, it is more essential for teacher training programs to evolve to address emerging issues, ensuring that educators are adequately prepared to foster comprehension and dedication to this crucial scientific domain.

ACKNOWLEDGMENTS

Acknowledgements of people, grants, funds, etc., should be placed in a separate section not numbered at the very end of the paper.

REFERENCES

Alanazi, F.H. (2023). Saudi students' and science teachers' knowledge of and attitudes towards biotechnology. *Journal of Biological Education*, 57(1), 196-213.

Atasoy, B., Atıcı, T, Taşar, MF., & Taflı. T. (2020). Development and validation of biotechnology knowledge scale (bks). *Hellenic Journal of Stem Education*, (1)1, 33-42.

Aydin, S., & Cetin. K. (2020). Science and classroom teacher candidates' knowledge and attitudes about biotechnology. *International Journal of Education Technology and Scientific Research*, 5(11), 631-656.

Bhatia, S.C. (2005). *Textbook of Biotechnology*. Atlantic Publishers and Distributor. Available from: https://books.google.com/books?id=vgyqpem7rlwc&printsec=frontcover&hl=en&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false [Retrieved on 2025 December 20].

Campbell, N.A., & Reece, J.B. (2005). *Biology*. Pearson: Benjamin Cummings. Available from: https://www.academia.edu/36779522/campbell_reece_biologia [Retrieved on 2025 December 20].

Chen, S.Y., & Raffan, J. (1999). Biotechnology: Student's knowledge and attitudes in the LJk and Taiwan. *Journal of Biology Education*, 34(1), 17-23.

Christian, K.B., Kelly, A.M., & Bugallo, M.F. (2021). Ngss-based teacher professional development to implement engineering practices in stem instruction. *International Journal of Stem Education*, 8, 1-18.

Curtis, A., & Wilkinson, C. (2001). Nanotechniques and approaches in biotechnology. *Trends in Biotechnology*, 19(3), 97-101.

Dawson, V., & Schibeci, R. (2003). Western Australia high school students' attitudes towards biotechnology process. *Journal of Biology Education*, 38(1), 7-12.

Dicks, A., Bhatia, H., Clemens, A.W., Locke, M.C., Mueller, E.A., Murphy, D., Pomper, N., Robinson, A.E., & Schoch, K.M. (2021). Improving scientific communication with service, education and career development. *Nature Biotechnology*, 39(10), 1309-1313.

Firat, E.A., & Köksal, M.S. (2019). Effects of instruction supported by web 2.0 tools on prospective teachers' biotechnology literacy. *Computers and Education*, 135, 61-74.

Gbadegesin, I. D., Olanrewaju, A. M., & Issa, A. I. (2025). A Review of the Effectiveness of Virtual and Augmented Reality Technologies in Physical Education. *World Journal on Educational Technology: Current Issues,* 17(4), 212–222. https://doi.org/10.18844/wjet.v17i4.9612

Gunter, B., Kinderlerer, J., & Beyleveld, D. (1998). Teenagers and biotechnology: A survey of understanding and opinion in britain. *Studies in Science Education*, 32, 81-112.

Hursen, C. (2021). The effect of problem-based learning methods supported by web 2.0 tools on academic achievement and critical thinking skills in teacher education. *Technology Knowledge and Learning*, 26(3), 515-533.

Irmak, M., & Özgül, Y.T. (2019). Investigating pre-service science teachers' perceived technological pedagogical content knowledge (tpack) regarding genetics. *Research in Science and Technological Education*, 37(2), 127-146.

James, M.L. (2012). *Analysis of North Carolina's Local Education Administration Superintendents' Awareness of Biotechnology Education in Secondary School* [phd Thesis, Agricultural and Technical State University]. Available from: https://www.proquest.com/docview/1318661494?pq/origsite=gscholar&fromopenview=true [Retrieved on 2025 December 20].

Klop, T., & Severiens, S. (2007). An exploration of attitudes towards modern biotechnology: A study among dutch secondary school students. *International Journal of Science Education*, 29(5), 663-679.

Kumar, R., Aadil, K.R., Mondal, K., Mishra, Y.K., Oupicky, D., Ramakrishna, S., & Kaushik, A. (2022). Neurodegenerative disorders management: State-of-art and prospects of nano-biotechnology. *Critical Reviews in Biotechnology*, 42(8), 1180-1212.

Lamanau, S.V., & Makarskaitė-Petkevicienė, R. (2008). Lithuanian university students' knowledge of biotechnology and their attitudes to the taught subject. *Eurasia Journal of Mathematics Science and Technology Education*, 4(3), 269-277.

Lock, R., Miles, C., & Hughes, S. (1995). The influence of teaching on knowledge and attitudes in biotechnology and genetic engineering context: Implications for teaching controversial issues and the public understanding of science. *School Science Review*, 76(276), 47-59.

Massarani, L., & Moreira, I. (2005). Attitudes towards genetics: A case study among Brazilian high school students. *Public Understanding of Science*, 14, 201-212.

Meisner, A., Wepner, B., Kostic, T., Van Overbeek, L.S., Bunthof, C.J., De Souza, R.S.C., & Microbiomesupport Consortium. (2022). Calling for a systems approach in microbiome research and innovation. *Current Opinion in Biotechnology*, 73, 171-178.

Meno, S., Leng, C.H., Naimie, Z., Danaee, M., & Abuzaid, R.A. (2021). Impact of teacher communication behavior on student's motivation in learning primary school science. *New Trends and Issues Proceedings on Humanities and Social Sciences*, 8(3), 92-97.

Mirici, S., & Uzel, N. (2019). Viewpoints and self-efficacy of teachers participated in project training towards project-based learning. *International Online Journal of Education and Teaching*, 6(4), 1037-1056.

Pathak, R. (2007). *Introduction to Biotechnology*. Atlantic Publishers and Distributor. Available from: https://books.google.com/books?id=598t00j86vkc&printsec=frontcover&hl=en&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false [Retrieved on 2025 December 20].

Patton, Q.M. (1990). *Qualitative Evaluation and Research Methods.* 2nd ed. London: Sage.

Prokop, P., Lešková, A., Kubiatko, M., & Diran, C. (2007) Slovakian students' knowledge of and attitudes toward biotechnology. *International Journal of Science Education*, 29(7), 895-907.

Ritchie, J., Lewis, J., Nicholls, C.M., & Ormston, R. (eds.). (2013). *Qualitative Research Practice: A Guide for Social Science Students and Students.* Sage. Available from: https://tinyurl.com/yc8rbjm7 [Retrieved on 2025 December 20].

Sahu, J.N., Zabed, H., Karri, R.R., Shams, S., & Qi, X. (2019). Applications of nano-biotechnology for sustainability water purification. *Industrial Applications of Nanomaterials*, 2019, 313-340.

Sari, W.K., & Wilujeng, I. (2020). Education change in the industry 4.0: Candidate science teacher perspective. *Journal of Physics Conference Series*, 1440, 012090.

Sheykhha, M.H., Kalantar, S.M., Vahidi, A.R., & Faghihi, M. (2006). Public knowledge and perceptions of biotechnology and genetically modified organisms in Iran. *Iranian Journal of Biotechnology*, 4(2), 130-136.

Sıbıç, O., & Topcu, M.S. (2020). Pre-service science teachers' views towards socio-scientific issues and socio-scientific issue-based instruction. *Journal of Education in Science Environment and Health,*

6(4), 268-281.

Simon, R.M. (2010). Gender differences in knowledge and attitude towards biotechnology. *Public Understand Science*, 19(6), 642-653.

Skinner, N. (2018). Teaching biology in schools: Global research, issues and trends: Edited by k. kampourakis and mj reiss, London and New york, Routledge, uk£ 34.99 (paperback), Isbn 9781138087989, uk£ 31.48 (e-book), isbn 9781315110158, uk£ 120 (hardback), isbn 9781138087941. *Studies in Science Education*, 56, 153-156.

Smalley, S.W, Hainline, M.S., & Kelsey, S. (2019). School-based agricultural education teachers' perceived professional development needs associated with teaching, classroom management, and technical agriculture. *Journal of Agricultural Education*, 60(2), 85-98.

Sonmez, E., Esra, K.M., & Yerlikaya, Z. (2021). The effect of practices is based on an argumentation-based inquiry approach on teacher candidates' critical thinking. *Educational Studies*, 47(1), 59-83.

Stalidzans, E., & Dace, E. (2021). Sustainable metabolic engineering for sustainability optimization of industrial biotechnology. *Computational and Structural Biotechnology Journal*, 19, 4770-4776.

Stolorow, R.D., & Atwood, G.E. (2018). *The Power of Phenomenology: Psychoanalytic and Philosophical Perspectives*. Routledge. Available from: https://www.taylorfrancis.com/books/edit/10.4324/9780429448584/power-phenomenology-robert-stolorow-george-atwood [Retrieved on 2025 December 20].

Tezer, M., Ulgener, P., Minalay, H., Ture, A., Tugutlu, U., & Harper, M.G. (2020). Examining the relationship between academic procrastination behaviors and problematic internet usage of high school students during the covid-19 pandemic period. *Global Journal of Guidance and Counseling in Schools Current Perspectives*, 10(3), 142-156.

Thrift, N. (2005). From birth to mad: Technology, biology and space. *Transactions of the Institute of British Geographers*, 30(4), 463-476.

Turan, M., & Koç, I. (2012). Attitudes of science teacher candidates towards biotechnology applications. *Trakya University Journal of Education Faculty*, 2(2), 74-83.

Zhu, G., Huang, Q., Ding, Y., Pi, J., Zhan, L., & Wu, S. (2020). Establishing standardized biomedical laboratory technician education for the development of biotechnology research in china. *Chinese Medical Sciences Journal*, 35(2), 179-185.