Research Article https://doi.org/10.5281/zenodo.16620381

International Journal of Educational and Artificial Intelligence

Year 2025, Volume 2, Issue 1, page 41-55

ISSN: 3062-228X
http://www.ijedai.com/

Academics' views on problems and solution in biology education in 21st century Türkiye

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Article Info

Submitted: 30.06.2025
Accepted: 24.07.2025
Published Online: 30.07.2025

Keywords

Biology education
Biology curriculum
Biology in the 21st century
Academician views

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Abstract

Purpose: Biology is a comprehensive discipline that studies the patterns, processes and interactions of all living things, including humans. Biology plays a pivotal role in interdisciplinary collaboration, and in addressing pressing problems on an individual, social, and global scale. The purpose of this study is to determine the views of academics' teaching undergraduate biology regarding biology education, its content, its problems, and solutions to these problems in Türkiye in the twenty-first century

Design and Methodology: In the study, phenomenological research design, one of the qualitative research methods, was used. The study was conducted with the participation of 24 academicians (13 female, 11 male) working in 14 different universities in Türkiye. The data were collected through a semi-structured form consisting of 5 demographic and 8 open-ended questions developed by the researchers. The analysis of the collected data was carried out by subjecting the participant responses to content analysis by creating themes and sub-themes.

Results: As a result of the research, the participants stated that biology is a basic science in the education of the 21st century youth, that it has an important place in recognizing nature, the universe and society and in solving current problems, and that biology education in Türkiye does not have sufficient quality and standards. Among the most fundamental problems encountered in biology education, the insufficiency of laboratory practices, the opening of biology departments that produce more graduates than needed and the decrease in course quality due to the lack of specialized academicians in these departments were pointed out.

Implications & Suggestions: Participants stated that National Science Education Standards and a curriculum aligned with contemporary content should be developed, and biology should be integrated with physics, chemistry, mathematics, and computer science. They also recommended that students actively participate in application-oriented projects during their undergraduate education.

To cite this article:

Kuru Kaçmazoğlu, E., & Özmen, N. (2025). Academics' views on problems and solution in biology education in 21st century Türkiye. *International Journal of Educational and Artificial Intelligence*, *2*(1), 41-55. https://doi.org/10.5281/zenodo.16620381

1. INTRODUCTION

Biology (Life sciences), which has an enormous interconnected field of study ranging from a single molecule to organism, ecosystem, and the biosphere that includes all living things on earth, is a very comprehensive discipline that studies the patterns, processes, and interactions of all living things, including humans (National Research Council [NRC], 2009; Quinn et al., 2012). The human species (Homo sapiens sapiens) is both a biological being, as a natural part of the biosphere, and a social being, as part of sociocultural evolution, which has caused major changes in the physical, chemical and biological structure of the Earth. Thanks to technology and, since the 17th century (considered the beginning of modern science), the scientific knowledge systematically accumulated through observation of nature, humans have been able to partially control nature and natural processes, increase their well-being, and achieve economic development. Technology and science closely influence and guide both the biological and social lives of humanity (NRC, 2009).

Some theoretical explanations, discoveries, and technological developments have been critical turning points that have carried science and society in new directions (Brooks, 1994). Until the first half of the 20th century, developments in physics and chemistry (for example, the discovery of the electron) were considered "hard" disciplines because they were the driving force of fundamental applications, new technologies, and economies that enabled social transformation, while biology, one of the most comprehensive disciplines of the natural sciences, was generally perceived as a verbal (a discipline dominated by theoretical explanations) or a "soft" science (Moore, 2007; NRC, 2009, p.39-40). The discovery of the molecular structure of DNA, which governs heredity, in 1953, and the discovery of recombinant DNA technology in the 1970s, revolutionized biology, which had previously focused on macroscopic phenomena, leading to more in-depth and molecular-level investigations on ‘how life works’ (Khan et al., 2016; NRC, 2003 (p.1 and 10-11); Öztürk, 2002). The integration of biological research and "-omics" technologies with new concepts and methods from multiple disciplines such as mathematics, physics, chemistry, computer science, and engineering has led to a tremendous accumulation of knowledge and transformation in the life sciences. This collaboration, particularly through the combination of bioinformatics, information technologies, and the powerful search engines of the internet, has provided access to an enormous amount of information (Misra et al., 2018; Robeva, et al., 2020; Yamin, 2019). This has led to the discovery of increasingly sophisticated ways to compare, predict, and manipulate fundamental commonalities and properties of life sciences, making life science resources accessible for a wide variety of applications (NRC, 2009 p. 13). This rapid flow of information offers enormous promise for addressing environmental, societal, and economic challenges facing humanity, such as improving health, enhancing food resources, and resilience to diverse environmental conditions (Bialek & Botstein, 2004; Khan et al., 2016; Kim, & Diong, 2012; Moore, 2007; Labov et al., 2010; NRC, 2009; Öztürk, 2002; Steitz, 2003).

In today's world, the integration and interaction between biology and computer science has led to the development of new fields and technologies such as bioinformatics, biorobotics, and artificial intelligence. It has enabled the storage, processing, and analysis of large amounts of data, such as gene sequencing and synthetic genomes, and the derivation of new information from them. Today, life sciences are considered a 'hard' discipline, where biology is increasingly transforming into technology (e.g., biorobotics), and technology into biology (e.g., artificial intelligence) (Boodhoo, 2024; Lartigue et al., 2007; Tamborini, 2024).

Biology is now at the point of being able to exploit these fundamental features of the living world and this ability has implications in many sectors. As a result of all these developments, the life sciences today have become a complex, multidisciplinary field with implications for both research and education, often directly affecting daily personal, social and political decisions (Klymkowsky et al., 2003; NRC, 2009). Today, life sciences are considered a 'hard' discipline, where biology is increasingly transforming into technology (e.g., biorobotics), and technology into biology (e.g., artificial intelligence) (Boodhoo, 2024; Lartigue et al., 2007; Tamborini, 2024).

On the other hand, this issue becomes even more salient when we consider the risks and problems it poses, such as information overload, an epidemic of misinformation (infodemic), the potential use of information as a biological weapon, the failure to protect personal data, and ethical issues (Scheufele, & Krause, 2019; Shahrzadi et al., 2024). Therefore, the importance of contemporary biology education has become increasingly important both for undergraduate biology students and for those who will inevitably become consumers of modern life sciences in the future (NRC, 2009).

The aim of this study is to determine the opinions of academics working in undergraduate life sciences programs regarding biology education in twenty-first-century Türkiye, its content, its problems, and the solutions to these problems, and to create a roadmap based on these opinions. To this end, the following questions will be answered:

1. What are academics' opinions on the role of biology and biology education in the education of 21st-century youth?

2. Do academics believe that biology education in Türkiye is of sufficient quality and standards?

3. What are academics' thoughts on the scope of the Biology Program that will meet 21st-century needs?

4. What are academics' thoughts on the fundamental problems in 21st-century biology education?

5. What can be done to improve the quality of biology education in Türkiye, solve its problems, and ensure that it is a priority for academics in career choices?

2. METHOD

2.1. Research Model

This study was conducted using the phenomenological design, a qualitative research method. Phenomenological studies are methods in which individuals or groups who have experienced and can externalize a specific phenomenon form the data source. Phenomenology, a process of inquiry that examines participants' experiences in depth, involves interactive investigation to develop patterns of meaning and relationships related to the phenomenon under investigation (Creswell, 2009; Patton, 2014). Their opinions were sought because academics working in undergraduate biology education, through their research and teaching roles, are the most experienced group capable of best reflecting the importance, problems, and proposed solutions to the life sciences, which constitute the scientific, technological, and economic driving force of the 21st-century world.

2.2. Sample of the Study

Participants comprised 24 lecturers/academics (13 women and 11 men) working at 14 different universities in Türkiye and holding various academic titles. Participants were selected using the criterion sampling technique, a purposive sampling method (Patton, 2014). The criterion for selecting participants was that they were employed in an undergraduate Life Science program. Participants' demographic characteristics are presented in Table 1.

As seen in Table 1, 54.1% of the participants were female, 45.9% were male, their professional experience ranged from 2 to 51 years, and 45% of them were Associate Professor and 37.5% were Professor in terms of academic title. In addition, the participants specialized in three main areas of biology: Botany 25.0%, Hydrobiology 25.0% and Zoology 20.8%.

Table 1. *Demographic Characteristics of Participants*

Demographic characteristics	Participants	Frequency (n)	Percentile (%)
Gender			
Female	P3, P5, P7, P8, P9, P10, P11, P13, P16, P19, P20, P23, P24	13	54.1
Male	P1, P2, P4, P6, P12, P14, P15, P17, P18, P21, P22	11	45.9
Professional Experience(year)			
0-5	P13, P14	2	8.3
6-10	P6, P9, P11,	3	12.5
11-15	P1,	1	4.2
16-20	P2, P3, P5, P7, P10, P19, P23,	7	29.2
21-25	P8, P12, P21	3	12.5
26-30	P15, P18, P22	3	12.5
31 +	P4, P16, P17, P20, P24	5	20.8
Academic Title			
Lecturer	P13, P14,	2	8.3
Assistant Professor.	P11, P6,	2	8.3
Associate Professor.	P1, P2, P3, P5, P7, P8, P9, P10, P12, P19, P23,	11	45.8
Prof. Dr.	P4, P15, P16, P17, P18, P20, P21, P22, P24	9	37.6
Areas of Expertise			
Botanic	P1, P10, P12, P13, P20, P21,	6	25.0
Zoology	P4, P8, P15, P16, P23,	5	20.8
Hydrobiology	P6, P7, P11, P17, P19, P22,	6	25.0
Ecology/Environmental Toxicology	P2, P3, P24	3	12.5
Molecular Biology and Genetics	P14,	1	4.2
Biochemistry	P5, P9,	2	8.3
Evolution	P18	1	4.2
Total		**24**	**100**

2.3. Data Collection Tools and Process

The study utilised a semi-structured interview form, comprising five demographic characteristics and eight open-ended questions, as a data collection instrument. The form was prepared by the researchers to ascertain the opinions of academicians on the role of biology, as the locomotive discipline of the 21st century, in undergraduate education, the fundamental problems it addresses, and the solution suggestions put forward by researchers.

The questions to be included in the interview form were formulated on the basis of a review of the extant literature, with a view to achieving the objectives of the study. The preliminary form was submitted to three experts in the fields of biology, one in science education and one in Turkish education, in order to ascertain its content validity. The form was finalised following adjustments made in accordance with expert opinions. The form is comprised of two sections. The first section includes personal information such as gender, title, years of professional experience, university of employment and areas of specialization. The second part of the questionnaire comprises eight questions pertaining to the quality, content, problems and solutions of biology education in 21st-century education. The participant information text is incorporated within the form.

After obtaining the consent of the participants that they were volunteers, the responses were collected in writing.

2.4. Analysis of Data

The personal data section of the interview form was analyzed descriptively, and the responses to the open-ended questions in the second section were analyzed through content analysis. Content analysis involves the systematic identification, organization, and interpretation of meaningful patterns in qualitative data. This allows recurring themes to be identified and the relationships between these themes to be evaluated with a holistic approach (Creswell, 2009).

Validity in qualitative research is achieved by observing the phenomenon under investigation as objectively as possible. The data obtained as a result of the research were examined impartially and reported as is, increasing validity. To ensure the reliability of the research, the authors coded the obtained data separately, created subthemes, compared them, and identified points of consensus and disagreement after all comparisons (Yıldırım & Şimşek, 2013). Consistency between the codes was calculated using the formula [Reliability = Agreement / (Agreement + Disagreement) x 100] (Miles & Huberman, 1994). Accordingly, the percentage of agreement was calculated as 91.7%. Where there were disagreements, the authors discussed and reached a common theme. The data were interpreted as themes and subthemes, and the findings were presented in tables. The themes in the table were supported by direct quotes from the participants' opinions. To protect the participants' personal rights, codes (P1, P2, … P24) were used instead of names.

3. RESULTS / FINDINGS

This section should give results obtained from the study. In this section, you must present the findings you obtained from your research in order according to the sub-objectives of your research.

3.1. The Place of Biology Education in Twenty-First Century Türkiye

Participants were asked an open-ended question as ‘What is the place of biology education in the education of 21st century youth?’. The participants' views on the place of biology education in the 21st century were grouped under 4 themes and the findings are given in Table 2.

Table 2. *Academics' Views on the Place of Biology Education in the Education of 21st Century Youth*

Thema	Codes	Participants	Frequency (n)
21st Century Biology Education	Provides the solution of current world problems.	P2, P3, P5, P8, P9, P11, P20, P22	8
	It is a basic science that forms the basis for many disciplines.	P1, P7, P9, P10, P22, P23, P24	7
	It is necessary to recognise the universe, nature and society.	P4, P7, P10, P20, P22	5
	Integrated with technology.	P19, P21	2

To the question ‘*What is the place of biology education in the education of 21st century youth*?’, all of the participants emphasised the importance of biology education in the 21st century and stated that biology is a basic science that covers every subject related to living things and nature, that it is a discipline that forms the infrastructure for disciplines in many fields from agriculture to health and engineering, that it is important for the individual to recognise himself, his environment and nature, and that it is a discipline that forms the 21st century technology. Some of the participants' responses to the themes in Table 2 are presented below:

P5: "*Today, most of the problems facing our country and the world—environment, population growth, production, health, nutrition, and infectious diseases—are of biological origin. Biology education is crucial in solving these problems. The existence, location, benefits, and importance of species in nature can only be understood through knowledge of biology. People need biology education in many areas, such as a beautiful and natural environment, healthy living, reproduction, and nutrition."* emphasizes the problem-solving aspect of biology.

P1: "*Biology education must be paramount in the education of 21st-century youth. This is because medicine, pharmacy, and some engineering departments are rooted in biology, one of the fundamental sciences. Every development in biology also impacts developments in these branches*." This statement highlights the interdisciplinary dimension of biology.

P10: "*Biology is the most important basic science. … The fact that it forms the foundation of important fields such as agriculture, forestry, and medicine, and that biologists undertake important roles and achieve success in research studies at relevant institutions, demonstrates the importance of biology education. … This course should be given due importance not only in universities but also in middle and high schools so that each individual can understand themselves and their environment and live their lives more consciously and meaningfully."* This statement highlights both the interdisciplinary dimension of biology and its contributions to the individual.

P2: "*Science, and biology in particular, will be decisive in shaping human life today and in the future, defining human-environment relationships, and humanity's survival as a part of the ecosystem in which it is a part. In this respect, biology education is important*."

P21: "Biology should be taught by integrating technology and biology in line with technological advancements. … Emphasis should be placed on biotechnology."

P24: "*Biological science is a basic science that forms the basis of applications in the fields of food, agriculture, forestry, health, and the environment. Subsequently, fields such as biotechnology, materials science, and bioengineering have evolved from this basic science."*

As can be seen from the explanations above, the vast majority of academicians stated that biology science has a multidisciplinary structure (7 participants), is necessary to recognize nature and society (5 participants) and provides solutions to today's problems (8 participants), while only 2 participants stated that it is integrated with technology.

3.2. Quality and Standarts of Biology Education in Türkiye

Participants' responses to the question, "Does applied biology education in Türkiye have sufficient quality and standards?" are presented in Table 3.

Table 3. *Academics'* Views on the Quality of Current Biology Education in Türkiye

Theme	Sub-themes	Codes	Participants	Frequency (n)
The Quality of Current Biology Education	Insufficient	Inadequate physical structure and technical equipment	P1, P4, P6, P7, P9, P10, P13, P24	8
		Insufficiency of academic staff	P1, P4, P6, P10, P15, P24	5
		Education based on rote learning	P3, P4, P5, P19, P21	5
		Frequent changes in curricula	P3,	1
		Inadequate research and support facilities	P1, P24	2
		Lack of standards and accreditation	P14, P17, P22,	3
		Political inconsistencie	P2, P10,	2
		Inadequate student quality and interest	P8, P11, P23,	3
	Partially Sufficient		P16, P20,	2
	Sufficient		P12	1

In response to the question of whether the quality of biology education in practice in our country is sufficient, 21 people "*insufficient*," two "partially sufficient," and one answered "*sufficient*." Those who answered partially adequate stated that large or major universities are adequate, but provincial and newly opened universities are inadequate.

Examples of participants' responses to the themes in Table 3 are presented below.

P1*: "Definitely not. The number of faculty members, elective courses and their contents, laboratory conditions, research facilities and financial support for research are different in each biology department."*

P4*: "It is not sufficient. Because firstly, there are not enough tools and physical facilities. Secondly, the educators working in Biology education unfortunately cannot establish a relationship between the subjects and convey their importance in our daily lives to the students. Therefore, the Biology course is reduced to a position where the information given is completely memorised and useless."*

P8: "In my opinion, current biology education does not have sufficient quality and standards. One of the reasons for this is that the students do not show sufficient interest in the department due to the problems in education and the lack of job opportunities."

P17*: "There is a lot of material, but there is a lack of application and presentation. Quality and standards are very low. There is a gap between the quality and standards of biology education between schools."*

As the examples of participants' statements above show, they explained that the quality of biology education in our country is insufficient and lacks a certain standard. The situations that the participants stated to be insufficient were insufficient of physical and technical equipment (8 participants), insufficient of staff (5 participants) and rote-based education practices (5 participants) ranked in the top three.

3.3. Content of the Curriculun for Biology Education to Meet the Requirements of the 21st Century

Participants' responses to the question "What should a Biology Curriculum include to meet the needs of the 21st century?" were grouped under three themes and the findings are presented in Table 4.

Table 4. Academics' Views on the Curriculum of a Biology Education to Meet 21st-Century Needs

Theme	Sub-themes	Codes	Participants	Frequency (n)
Biology Curriculum	Aims	For today's problems and solutions	P2, P11,	2
		Context-based	P18,	2
		Biology literate	P3,	1
	Content	Nature-based, system approach, holistic and sustainable	P4, P5, P7, P10, P14, P15, P17, P18, P19, P22, P24	11
		Compatible with scientific and technological developments	P5, P6, P7, P14, P15, P19, P22	7
		Connected to current developments	P7, P8, P18, P21, P22, P24	6
		Providing specialisation at the undergraduate level / with emphasis on departments	P1, P6, P7, P10, P13, P23	6
		Interdisciplinary	P9, P10, P11, P20, P24	5
	Learning-Teaching Approaches	Application-oriented	P3, P4, P9, P10, P11, P12, P14, P15, P16, P19, P20, P23, P24	13
		Developing scientific process skills	P4, P5, P7, P14, P15, P16, P18, P19, P22	9
		Inquiry	P4, P5, P7, P14, P15, P19,	6
		Project-based	P1, P9, P20, P23, P24	5
		Student-centered	P3, P10, P19	3
		Contex-based	P10, P18	2

Participants' views on the aims of the "content of the biology program that will meet the needs of the 21st century" were grouped under 3 titles: "For today's problems and solutions" (2 participants), "Context-based" (2 participants) and "Biology literate" (1 participant). In the content of the biology curriculum; 5 sub-themes were identified as "Nature-based, System approach, Holistic and Sustainable" (11 participants), "Compatible with scientific and technological developments" (7 participants), "Linked to current developments" (6

participants), "Providing specialization at undergraduate level / Departments weighted" (6 participants) and "Interdisciplinary" (5 participants). Learning-teaching approaches were grouped under 5 themes: "Developing scientific process skills" (9 participants), "Inquiry" (6 participants), "Project-based" (5 participants), "Student-centered" (3 participants) and "Context-based" (2 participants). The participants did not express any opinion about the measurement and evaluation process.

P3: *"First of all, it should be a program that will take students away from ready-made request, make them more active, develop their ability to learn by doing and experiencing, and make them truly biology literate."*

P10: "*In order for the science of biology to take its real place and value in our country, it should be revised, ... innovative approaches should be taken in the research fields and education of biology. Since biology is a multidisciplinary branch, interdisciplinary collaborations should be established to transfer knowledge to application areas. ... From the 3rd grade onwards, students should be allowed to specialize by taking into account their areas of interest. Since this branch of science is a life science, students should be provided with access to nature ...."*

P18: *"-Bearing basic scientific criteria, -Comprehending nature from a holistic and rational perspective, - Directly related to society and individual life, - With a content at the level of contemporary knowledge."*

P24: "*Biology education as a basic science in the twenty-first century should emphasize bioinformatics, laboratory applications and field studies. Innovative approaches should be followed with international programs, ... students should take part in scientific projects and learn science ethics, culture and scientific approaches ..."*

The most frequently emphasized views of the participants in order to educate the 21st century individual were that; the aim should be oriented towards today's problems and solutions and be Context-based; the content should be "Nature-based, System-oriented, Holistic and Sustainable" and the approach should be application-oriented.

3.4. Main Problems in the Biology Education Process

The participants' answers to the question "What are the main problems in 21st century biology education?" were grouped under 2 themes and the findings are given in Table 5.

Table 5. Academics' Views on the Main Problems in 21st Century Biology Education

Thema	Sub-themes	Codes	Participants	Frequency (n)
The Main Problems in Biology Education	Problems Related to the Teaching and Learning Process	Rote learning and decontextualized approaches	P1, P2, P9, P19, P20, P21,	6
		Inadequacy of practice and experience	P19, P23,	2
		Outdated content	P2, P14, P21, P22,	4
		Students' negative attitudes, low motivation and inadequate preparedness	P1, P2, P19,	3
		Inadequate quality and/or quantity of teaching staff	P1, P2, P3, P4, P6, P18, P19, P24	8
	Institutional, Social and Political Challenges	Inadequate technical and physical facilities	P2, P3, P4, P6, P14, P19, P24	7
		Society's lack of interest in science	P13, P18,	2
		Financial constraints	P14	1
		Recruiting more students than needed	P23,	1
		Political and bureaucratic barriers	P1, P6, P10, P11, P12, P18, P24	7
		Anxiety about the future/not finding a job	P7, P11, P16, P17, P23	5

The main problems in 21st century biology education were grouped under 2 main themes and 11 sub-themes (Table 5). Examples of participant views in Table 5 are given below.

P2: "*Today,* the *amount of knowledge in every branch of science is increasing very much. It is not possible, nor is it meaningful, to provide all knowledge through education. The lack of education based on practice and experience, and even the lack of material and intellectual knowledge of how to do this, leads the system towards information overload. ..."*

P10: *"Due to the constantly changing national education programs and examination systems, students who come to the biology department come to the department not willingly, but only with the understanding and approach of "being a university graduate". Unfortunately, students who come to provincial universities outside of metropolitan cities come with insufficient basic knowledge about science from primary school years, which causes students' communication with the courses and their indifferent and reluctant approach to the department courses."*

P17 *"Biological science is not seen as a viable career option for students. The outputs of biological science are mostly owned by the fields of agriculture, medicine, veterinary and environmental engineering."*

P18: *"Society's apparent disinterest in science, deficiencies the academic community and its outputs (students, theses, publications, patents, products), and the absence of government and state policy."*

P21*: "Emphasizing classical education rather than current needs ...*

P23*: "Even students studying in the 4th grade do not have a biological" perspective. Students do not give due importance to undergraduate education due to unemployment anxiety. Inadequate applied education. The high number of students enrolled in biology departments. .. practices of the current governments that weaken and do not support basic sciences."*

P24: *the establishmentof a large number of new universities even with insufficient quality and infrastructure; ... scholarships for doctoral candidates are not augmented and allocated in accordance with political preferences, resulting in a paucity of doctoral researchers.."*

As can be seen from Table 5 and the quotes above, some of the problems academics have expressed regarding biology education in Türkiye (physical, technical, and personnel inadequacy, inadequate student preparedness, and negative attitudes) are expressed under all circumstances.

As can be seen from Table 5 and the quotes above, some problems with biology education in Türkiye (physical, technical, and personnel inadequacy, inadequate student preparedness, and negative attitudes) are expressed under all circumstances.

3.5. Actions to Improve the Quality of Biology Education, Solve Problems, and Ensure It Becomes a Priority Choice

Participants' opinions on what needs to be done to improve the quality of biology education, solve its problems, and ensure it becomes a priority choice are presented in Table 6.

As seen in Table 6, the participants' views on what needs to be done to improve the quality of biology education, solve problems and make it one of the priorities consist of 3 themes and 13 sub-themes**.**

P8: *"... students should be taught current issues. An education system that aims to raise a student mass that asks and researches, away from rote memorization should be implemented. ..."*

P14*: "Education curriculum with more practice and constantly renewed information resources….*

P24*: "Department quotas should be reduced to the optimum level due to quality assurance and scientific approach. Joint education and exchange programs should be carried out with foreign countries in order to follow the innovations in the fields of basic sciences in the world. ... The importance of basic sciences should be included in the programs of the governments in a way to create awareness in the society. ...Research (R&D) should be given the necessary importance. For example, research-oriented institutes should be established in higher education institutions, independent of undergraduate programs. ...The first 10,000 students who enter with high scores at the undergraduate level should be given basic sciences scholarships based on their preferences. More support from EU funds…*

As can be seen from Table 6 and the example explanations, the most prominent recommendations include increasing job opportunities, addressing research, physical, technical, and teaching personnel shortages, implementing inquiry-based, application-based, and project-based teaching, increasing research and scholarship support, and prioritizing R&D.

Table 6. Academics' Views on What Needs to be Done to Improve the Quality of Biology Education, Solve Problems and Make it a Priority Choice

Thema	Sub-themes	Codes	Participants	Frequency (n)
Actions to Improve the Quality of Biology Education	Things that should be done on a professional level	Increasing job opportunities	P2, P3, P4, P6, P10, P11, P12, P13, P14, P17, P19, P21, P22, P24	13
		Establishment of a professional chamber	P1, P4, P10-15, P24	9
		The quality and quantity of teaching staff should be increased	P1, P3, P4, P6, P14, P15, P19, P21	8
	Things that should be done during the Teaching-Learning Process	Applied and project-based teaching	P1, P3, P7, P8, P9, P14,	6
		Inquiry and awareness-raising education should be provided at all levels	P5, P7, P16, P19, P21, P22, P23	7
		Lessons should be updated	P3, P7, P8, P14, P22	5
		Accreditation should be ensured	P1,	1
		Inter-institutional cooperation and joint projects should be established	P8,	1
	Things that should be done at the political level	R&D activities should be emphasized and state support should be increased	P20, P23, P24	3
		Scholarship opportunities should be provided	P8, P10, P24	3
		Increasing physical and technical facilities	P4, P6, P7, P14	4
		Number of students should be reduced	P1, P6, P17, P5, P23, P24	6
		Research centers, science centers and natural history museums etc. should be established	P17,	1

4. DISCUSSION and CONCLUSION

In this section, the findings obtained from the analysis of academics' views on the problems and solutions in biology education in 21st-century Türkiye are discussed in light of the relevant literature.

The contemporary world is confronted with a series of interrelated challenges, including, the escalating human population, food shortages resulting from population growth, the depletion of natural resources, the destruction of the natural environment, the loss of biodiversity, and other related issues. Essentially, all of these problems appear to be the problems that biology focuses on (Kim, & Diong, 2012). These are problems that can be solved with the concepts, methods, theories and technologies of biology. The solution to problems is possible through effective, inquisitive, context-based quality education that includes up-to-date information (United Nations [UN], 2015; Wibowo & Saidikin, 2019). Biological science and biology education show how to use natural resources in sustainable ways and how to overcome problems with scientific methods.

NRC (2009) calls biology in the 21st century world as “new biology” and emphasizes that in order for new biology to be a research community capable of solving scientific, social and economic problems that will meet the needs of the 21st century, it should be integrated and restructured with many sub-disciplines within itself and with computational disciplines such as chemistry, mathematics, engineering, physics and computer science (Kim & Diong, 2012; Labov, et al, 2010; Osman, et al., 2013; Wake, 2008; Zaikina, 2007). In their answers to the first research question of the study, “What is the place of biology education in the education of the youth of the 21st century?”, the academics stated that 21st century biology education should be

multidisciplinary, and integrated with technology in order to produce solutions to current problems and to enable the youth to recognize society, nature and the universe (Table 2).

Curricula are one of the basic components of the formal education process. It consists of four basic components: planning, content, implementation and evaluation processes, including objectives for a certain field, what (content) and how (learning-teaching approach-strategy-method-technique) will be taught to achieve these objectives, and measurement-evaluation approaches to determine how much of these objectives have been achieved (Demirel, 2005).

Since curricula have a dynamic and variable structure, its need to be revised or changed. According to Atik (2023), the biology curriculum in Türkiye has changed six times (1924, 1935-1957, 1976, 1985, and 1998) from the founding of the Republic until the 2000s (Atik, 2023). After the 2000s, radical changes were made not only in biology but in all programs almost every six years (Ministry of National Education [MoNE], 2007, 2013, 2018, and 2024), perhaps to adapt to the rapid changes in 21st-century information technologies. On the other hand, fundamental changes are rarely made at the undergraduate level. The achievement of the desired goals of the developed programs depends on the effective participation of all stakeholders and the improvement of all conditions. In addition, it is necessary to conduct research in the field in order to identify the shortcomings of the developed programs, the problems encountered in their implementation, to find solutions to these problems, and to make comparisons (Demir & Demir, 2012). Since the 2000s, studies on biology programs developed in Türkiye can be grouped into two categories: research aimed at identifying problems and deficiencies, and research on program outcomes. Studies have been conducted with teachers (İpek, et al., 2021; Öztaş & Özay, 2004), students (Yeşilyurt & Gül, 2008), and academics (Vekli, 2018) to determine the problems and deficiencies in the program. Although the target group is different, in all these studies, the problems related to the problems in biology teaching such as inadequate physical and technical facilities, especially laboratories, inadequate readiness of students, negative attitudes towards biology course and rote learning are the findings that have been included in most of the studies conducted from past to present and show continuity. However, these problems are not unique to Türkiye; similar issues have also been highlighted in studies conducted in other countries (Hambabi, et al., 2024; Wei, 2020). These findings were also found in the current study (Table 3).

The findings of this study suggest that biology education should have the qualities mentioned above. The academicians stated that the biology curriculum should be solution-oriented, aiming to educate biologically literate individuals, allowing specialization at the undergraduate level, learner-centered, inquisitive, project-based and interdisciplinary cooperation, current, system-oriented, holistic and sustainable nature (Table 4).

A study by Atik and Yetkiner (2021) examined the integration of 21st century skills within the middle school biology curriculum. The study found that while 21st century skills were incorporated, the implementation was not adequate. Furthermore, the distribution of these skills across different classes was found to be imbalanced. Specifically, skills related to learning and innovation were more prevalent in all classes, while life and career skills were comparatively less represented. Additionally, skills such as higher-order thinking, information, and media literacy could not be developed sufficiently (Atik & Yetkiner, 2021). In the study conducted by Çakır and Senemoğlu in 2016, it was determined that the analytical thinking skills of university students were low, but the effectiveness of the education they received at university and the richness of their learning experiences contributed to the development of their analytical thinking skills..

Atmaca and Bumen (2023), in their study on the interdisciplinary nature and interconnectedness of the 2018 Biology Curriculum (MoNE, 2018), noted that the program exhibited a partially interdisciplinary nature and was interconnected with other courses (Atmaca & Bumen, 2023). Similarly, Köse (2016), in here study comparing the interdisciplinary status of various biology curricula in Türkiye, England, Germany, and the United States, noted that, unlike the other three countries, biology programs in Türkiye lacked an interdisciplinary approach and insufficient courses focused on this approach, and that existing courses were electives (Köse, 2016).

Natural sciences in general (since they encompass physics, chemistry, biology, earth sciences, environmental sciences, and similar disciplines), and biology in particular, are inherently interdisciplinary. Furthermore, the multifaceted interaction between technology, science, and society has radically changed the way we live, work,

and interact (Alemayehu Tegegn, 2024). Therefore, interdisciplinary competence and collaboration are crucial in both academic and business settings, as well as in solving global problems (Braßler, 2020; Holman & Švejdarová, 2023; Labov et al., 2010; Organisation for Economic, Co-operation and Development [OECD], 2019). In today's world, individuals, researchers, and consumers, exposed to the overload of information ('big data') easily generated and disseminated through digital tools, need certain skills and competencies (e.g., metacognitive skills such as accessing accurate information, sorting, analyzing, evaluating, and synthesizing information, as well as critical and context-based thinking, effective communication, and information, media, technology, and scientific literacy) that will facilitate their adaptation to the 21st century (Partnership for 21st Century Skills [P21], 2009). Therefore, all curricula and educational processes, particularly those in science and biology, need to be restructured to cultivate individuals who are knowledgeable about interdisciplinary, collaborative, and effective communication methods, who can think critically, analytically, and holistically, and who have developed problem-solving skills—in short, who are equipped with 21st-century skills.

Studies on science education in Türkiye have highlighted common problems such as the qualitative and quantitative inadequacies in physical, technical, and teaching personnel, and low student readiness and motivation(Ayvacı & Bebek, 2018; Balbağ et al., 2016; İpek et al., 2021; Vekli, 2018; Kuru Kaçmazoğlu & Taşcan, 2019). In addition to these problems, academics stated that undergraduate biology programs are outdated, traditional, and disconnected from context. Furthermore, students are not sufficiently involved in the application, research, or even learning process. Instead of specializing in a specific field, they believe learning a little bit of everything is sufficient. This situation increases the anxiety about not finding a job and the future. Furthermore, they also noted political and bureaucratic obstacles (Tablo 5). The quality of the teaching staff is a crucial factor in integrating program changes into the educational process and achieving the desired outcomes. Therefore, the qualifications of teachers and academics must be enhanced through pre-service and in-service training (Hambabi, et al., 2024). Similarly, the academics participating in the study recommend a promising education system that includes improved physical conditions, highly qualified educators, research, inquiry, project-based student-centered practices, and interdisciplinary integration and collaboration, all in line with 21st-century conditions (Table 6).

In light of the study's findings, the following recommendations are offered for biology education that will foster 21st-century individuals and biologists:

● National Science Education Standards should be developed.

● Comprehensive and continuous professional development programs should be developed to improve the knowledge, skills, and attitudes of program implementers.

● Biology curriculum should be updated from preschool to graduate level.

● A professional chamber should be established, and programs tailored to contemporary content, free from political pressures, should be developed.

● Starting with graduate education, biology should be fully integrated with disciplines such as physics, chemistry, mathematics, computer science, and bioinformatics, and this should be gradually implemented down to lower levels. Furthermore, to ensure full integration and collaboration, biology should be included as a compulsory course in the programs of these fields.

● Instead of centralized, multiple-choice exams, alternative methods and techniques should be implemented to develop context-appropriate, critical, and creative problem-solving skills, enabling students to analyze, synthesize, and evaluate, as well as develop metacognitive skills through case studies and problems.

● Life sciences should be structured as a faculty-level educational unit, and bioinformatics, molecular biology, genetics, evolution, bioengineering, biomedical engineering, environmental engineering, and similar disciplines should be structured under this unit.

In conclusion, in the 21st century, do we want biologists and biology teachers to be future bioinformatics scientists or bioinformatics technicians? We must decide! We must restructure our paradigm of "doing" science and "teaching" science in a way that responds to the challenges and changes in life in the 21st century (Kim, & Diong, 2012 p.1-4), is sustainable, holistic, interdisciplinary collaborative, and provides life skills.

Acknowledgments

*This research was presented as an oral presentation at the 2nd International Painting Exhibition and Symposium on Philosophy, Education, Arts and History of Science held at Muğla Sıtkı Koçman University from May 3-7, 2017, and was subsequently developed and updated.

Declaration of Conflicting Interests and Ethics

The authors declare no conflict of interest. This research study complies with research publishing ethics. The scientific and legal responsibility for manuscripts published in IJEDAI belongs to the author(s).

Authorship Contribution Statement

Emine KURU KAÇMAZOĞLU: Conceptualization, Methodology, Analysis and Interpretation, Writing,
Nesrin ÖZMEN: Conceptualization, Methodology, Analysis, Writing, Data collection,

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