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The Presence and Treatment of DNA isolation, PCR and Gel Electrophoresis Techniques in Biology Curricula, Textbooks and University Placement Exams: Are We Keeping up with the Pace of Biotechnology?

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ABSTRACT

Understanding the basic applications of biotechnology is important in order to respond effectively to challenges related to GMOs, forensic science, bioinformatics, and the COVID-19 pandemic, which highlights the importance of biotechnology education. This study aimed to examine the presence and treatment of biotechnological techniques (DNA isolation, PCR, and Gel Electrophoresis) in biology curricula, aligned biology textbooks, and university placement exams). The study adopted a qualitative case study approach, employing a document analysis method. The researchers used Turkish National Biology Curriculum published in 2013 (BC-2013) and 2018 (BC-2018 and SBC-2018), curricula aligned Biology Textbooks, and University Placement Biology Exam Questions (2016-2022) as documents. The findings, regarding the examination of BC and SBC, showed that the basic biotechnological methods were only included in the explanations of the SBC-2018. Regarding the textbooks, the findings highlighted that 12nd grade textbooks included PCR and Gel Electrophoresis but not DNA isolation. Contents of these textbooks revealed some issues when examined in terms of textbook examination criteria. The biology questions in the university placement exams showed that they did not include biotechnological techniques or did not require knowledge of these techniques to choose the right option. This research highlighted the challenges related to the current state of basic biotechnology techniques and emphasized that curricula, aligned textbooks, and university entrance exams struggled to keep up with the pace of biotechnology. The study suggests updating biology curricula and aligned textbooks in terms biotechnological techniques and organizing them coherently to avoid scientific inaccuracies. It also suggests that the questions on university placement exams be revised to include more questions related to present-day biotechnology challenges and advancements.

Keywords: Biology curriculum, biology textbooks, university placement exams, biotechnological techniques, DNA isolation, polymerase chain reaction (PCR), gel electrophoresis

DNA izolasyonu, PCR ve Jel Elektroforezi Tekniklerinin Biyoloji Öğretim Programı, Ders Kitapları ve Üniversiteye Giriş Sınavlarındaki Varlığı ve Ele Alınışı: Biyoteknolojinin Hızına Ayak Uydurabiliyor muyuz?

**Sorumlu yazar*

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ÖZ

Biyoteknolojinin temel uygulamalarını anlamak, GDO'lar, adli bilim, biyoinformatik ve COVID-19 pandemisi ile ilgili zorluklara etkili bir şekilde yanıt vermek için son derece önemlidir, bu durum biyoteknoloji eğitiminin önemini vurgulamaktadır. Buna göre, bu çalışma biyoteknolojik tekniklerin (DNA izolasyonu, PCR ve Jel Elektroforezi) biyoloji öğretim programları, biyoloji ders kitapları ve üniversite yerleştirme sınavlarındaki durumunu incelemeyi amaçlamaktadır. Çalışma, nitel durum çalışması araştırma yaklaşımı izlenen bir doküman incelemesi çalışması olarak tasarlanmıştır. 2013 (BP-2013) ve 2018 (BP-2018 ve FBP-2018) Biyoloji Öğretim Programları, ilişkili Biyoloji Ders Kitapları ve Üniversiteye Giriş Sınavlarında (TYT-AYT) (2016-2022) yer alan biyoloji soruları incelenmiştir. BP ve FBP ile ilgili bulgular biyoteknolojik tekniklerin sadece FBP-2018'in kazanım açıklamalarında yer aldığını göstermiştir. Ders kitapları ile ilgili bulgular ise, PCR ve Jel elektroforezini içerdiklerini ancak DNA izolasyonunu içermediklerini ve içeriğin ders kitabı inceleme kriterlerine göre bazı problemler bulundurduğunu göstermiştir. TYT ve AYT' nin incelenmesi ise biyoteknolojik teknikleri veya soruya doğru yanıt verebilmek için biyoteknolojik tekniklerin bilinmesini gerektiren herhangi bir sorunun bulunmadığını göstermiştir. Sonuç olarak bu araştırma, temel biyoteknoloji tekniklerinin mevcut durumuyla ilgili sorunları ve programların, ders kitaplarının ve üniversiteye giriş sınavlarının biyoteknolojinin hızına ayak uydurmakta zorlandığını vurgulamaktadır. Araştırma, biyoloji öğretim programlarının ve bağlantılı ders kitaplarının biyoteknolojik teknikler açısından güncellenmesini ve bilimsel hatalardan kaçınacak şekilde bir bütünlük içerisinde düzenlenmesini önermektedir. Ayrıca üniversite yerleştirme sınavlarındaki soruların, günümüz biyoteknolojisinin zorlukları ve ilerlemeleriyle ilgili daha fazla soruyu içerecek şekilde gözden geçirilmesini de önermektedir.

Anahtar Kelimeler: Biyoloji öğretim programı, biyoloji ders kitapları, üniversiteye giriş sınavları, biyoteknolojik teknikler, DNA izolasyonu, polimeraz zincir reaksiyonu (PZR), jel elektroforezi

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Introduction

Biotechnology, a rapidly advancing field utilizing organisms and biological systems for diverse applications, is often perceived as complex (Lázaro-Silva et al., 2015; Phillips et al., 2008; Suryanti et al., 2019; Thieman & Palladino, 2013). Scientists employ various techniques, including DNA isolation, spectrophotometer evaluation, agarose gel electrophoresis, and polymerase chain reaction (PCR), in their work to understand this complexity (Lázaro-Silva et al., 2015). These techniques find applications in genetic fingerprinting, paternity testing, criminology, genetic disease diagnosis, molecular systematics, and genetic barcoding (Henter et al., 2016), even becoming part of daily life (Janštová & Rusek, 2015; Sıcaker & Öz Aydın, 2015). Thus, developing and enhancing biotechnology education is essential to equip individuals with the skills needed in this dynamic field (Chen & Raffan, 1999; Fonseca et al., 2012; Nordqvist & Aronsson, 2019; Orhan & Şahin, 2018).

The COVID-19 pandemic has accentuated the importance of biotechnology education, given the swift development of diagnostic PCR tests to detect the virus (Yang et al., 2020) and the urgent demand for vaccine development (Krammer, 2020; Mulligan et al., 2020). Understanding biotechnological concepts behind tests like PCR and mRNA vaccine production is important for informed health and vaccination decisions (Drenkard et al., 2021; Öz Aydın et al., 2022; Rybnicky et al., 2022;). Hence, the pandemic underscores biotechnology's relevance, not just in research and diagnosis but also in addressing global health crises, making it essential for biotechnology education to keep pace with these developments (Krammer, 2020).

No single curriculum can cover all the skills currently needed in the biotechnological industry or those that will be required in the future (Lebrón et al., 2023) and biotechnology evolves faster than curricula can adapt (Liebal et al., 2023). However, considering the significant influence of curricula (Dawson & Schibeci, 2003; Saher & Kashif, 2020) and textbooks on science education (Chiappetta & Fillman, 2007; Duda et al., 2022; Saher & Kashif, 2020) and recognizing that one of the primary factors contributing to the shortcomings in biotechnology education is the insufficient incorporation of biotechnology in curricula (Orhan & Şahin, 2018), a thorough examination of the presence and treatment of biotechnological techniques within biology curricula, aligned textbooks, and university placement exams is one of the possible ways to evaluate the progress of high school biotechnology education in Türkiye. Such an examination allows educators to ensure alignment between textbooks and curricula, enhancing consistency in instruction, assessment, and evaluation (Saher & Kashif, 2020). Aligning educational materials with current biotechnology advances prepares students for the field's dynamic demands. Our study investigates the presence and treatment of basic biotechnological techniques (DNA isolation, PCR, and Gel Electrophoresis) in these educational components, aiming to assess their alignment with the fast-paced world of biotechnology. This analysis will help us determine if our educational systems effectively address the challenges and opportunities posed by biotechnology, particularly in light of events like the COVID-19 pandemic.

Theoretical Framework

Biotechnological Techniques

The field of biotechnology, encompassing techniques such as DNA isolation, Polymerase Chain Reaction (PCR), and Gel Electrophoresis, has undergone significant advancement, revolutionizing biology and spanning various scientific domains (Yarden & Yarden, 2010). Students engaged in biotechnology labs have the opportunity to acquire skills used by molecular biology researchers, enhancing their comprehension of genetics and microbiology. These techniques are pivotal for comprehending genetic processes, conducting research, and tackling crucial challenges like disease diagnosis and vaccine development (Rybnicky et al., 2022; Yarden & Yarden, 2010). While the DNA isolation technique was initially described in 1961 (Marmur, 1961), it took approximately 30 years before it was considered for inclusion in high school curricula abroad. Nonetheless, over time, it has been simplified and introduced to undergraduate, high school, and secondary school students through hands-on activities involving DNA isolation protocols (Lázaro-Silva et al., 2015; Miller, 1994; Sitaraman, 2012; Tibell & Rundgren, 2010). In Türkiye, DNA isolation from living cells was first integrated into the curriculum in 1998 (Yıldırım et al., 2003).

The Polymerase Chain Reaction (PCR) technique, originally documented by Mullis and colleagues (Mullis et al., 1986), serves as the fundamental method underpinning most rapid detection procedures employing DNA and RNA (Pleitner et al., 2014). It represents a robust and swift method that has transformed the field of biology and is widely applied across numerous disciplines. The PCR process involves a series of cycles where the purified DNA sample undergoes denaturation, primer annealing, and sequence-specific extension. After each cycle, the newly synthesized copies, termed amplicons, serve as templates for the subsequent cycle. Consequently, within a few hours, millions of copies of the original small DNA sample are generated, enabling enhanced visibility or storage (Bustin et al., 2005; McDonald & Lehman, 2012). PCR techniques can be taught both as molecular methods in undergraduate programs and as fundamental applications conveying the core principles of these molecular techniques at the high school level (Altun et al., 2011; Bowlus & Grether, 1996; Martin et al., 2004; McMiller et al., 2006; Phillips et al., 2008).

To observe the DNA copies produced by PCR, the theory of DNA Electrophoresis was introduced in 1985 (Lumpkin et al., 1985). Gel electrophoresis is a method that separates macromolecules such as DNA, RNA, or

proteins based on their migration rate through a gel influenced by an electric field (Atherly, 1999). Initially, DNA is digested into restriction fragments using enzymes. These charged fragments are placed in wells at one end of a gel supported by glass plates and surrounded by a buffer solution. An electric current is applied, causing the DNA fragments to migrate through the gel towards the opposite charged electrode. The rate of migration, determined by the molecule's charge and size, is inversely proportional to molecular size, with smaller fragments moving faster. Ethidium bromide staining creates fluorescent bands, allowing the determination of fragment sizes by comparing them to known molecular weight patterns. Like PCR, versions suitable for students have been created, allowing nucleic acids to be observed by transmitting them in an electric field (Altun et al., 2011; Kubo, 1998; Phillips et al., 2008). Harms (2002) also suggests gel electrophoresis for use in biology classrooms and provides examples of biotechnology experiments and lesson plans for high school students. Polymerase chain reaction (PCR) and gel electrophoresis, commonly incorporated into undergraduate curricula, provide an interactive approach that integrates wet lab experiences and inquiry-based activities, allowing students to grasp molecular techniques within real-world scenarios using diverse learning methods (Phillips et al., 2008).

Research on using Biotechnological Techniques in Science Education

The biotechnological revolution has led to the integration of biotechnology into curricula worldwide (Klop & Severiens, 2007). However, instructing biotechnological techniques for the first time presents a myriad of challenges for educators, encompassing the identification and rectification of misconceptions and the creation of assessments to gauge student comprehension of learning objectives (Phillips et al., 2008). Research conducted in countries like South Korea, Portugal, Scotland, Spain, and New Zealand has revealed that educators often avoid teaching biotechnology-related topics due to perceived deficiencies in training, limited access to experimental resources, time constraints, and a dearth of infrastructure and instructional materials (Bryce & Gray, 2004; Cebesoy & Öztekin, 2018; Chabalengula et al., 2011; Fonseca et al., 2012; Gelamdin et al., 2013; Hanegan & Bigler, 2009; Kwon & Chang, 2009; Tsuzuki et al., 1996; Steggles, 1987). Additionally, the rapid and continuous evolution of modern biology and biotechnology fields further exacerbates educators' difficulties (Bouakaze et al., 2010). Moreover, educators may lack confidence in their ability to impart these techniques (Boulay et al., 2010) and may perceive practical activities as insufficient (Steele & Aubusson, 2004). For instance, some teachers may feel ill-prepared to instruct on DNA isolation from cells (Kidman, 2010). Furthermore, research indicates a misalignment between students' interests and curriculum requirements, with students showing more enthusiasm for hands-on activities involving natural antibiotics, DNA, and cloning, while educators tend to emphasize the theoretical aspects of lessons (Hagay & Baram-Tsabari, 2012; Kidman, 2010). These situations underscore the necessity of incorporating student-centered approaches into the curriculum to enhance student engagement and interest in biotechnology topics.

DNA isolation, PCR, and gel electrophoresis stand as essential techniques, forming the cornerstone of a comprehensive understanding in biotechnology and molecular biology (McDonald & Lehman, 2012). These techniques serve as prerequisites for meaningful scientific discussions on subjects like GMOs, paternity testing, transgenic organisms, virus outbreaks, debates surrounding virus identification methods such as RT-PCR, viral evolution, and scientific progress (Erasmus, 2021; Shah et al., 2013). They offer simplicity, cost-effectiveness, and sufficiency for conveying the fundamentals of molecular biology and biotechnology (Lázaro-Silva et al., 2015). Utilizing affordable and easily accessible PCR kits, such as the one developed by Merta et al. (2020), has proven effective in enhancing students' grasp of base pairing mechanisms and nucleic acid sequence synthesis. Similarly, Bilgican Yılmaz et al. (2021) discovered that supplementing DNA isolation experiments with Web 2.0 tools like Actionbound can provide pre-service teachers with enjoyable, sensory-rich, enduring, and collaborative learning experiences. Tripepi et al. (2020) devised a PCR analysis laboratory for undergraduate biology students to facilitate the comprehension of the central dogma, a challenging concept in biology education. Other studies (e.g., Hyman et al., 2019; McDonald & Lehman, 2012; Orhan & Şahin, 2018) have also highlighted the benefits of teaching and practicing various DNA technology techniques, including agarose gel electrophoresis, across different student levels and disciplines, such as forensic science. Hands-on experiences with DNA technology tools not only imbue students with a sense of being scientists but also create a meaningful learning environment (Brancaccio-Taras, Mawn et al., 2021; Mierdel & Bogner, 2019). These experiences enhance their critical and quantitative thinking abilities, familiarity with established and emerging DNA technology techniques, and most importantly, their enthusiasm to pursue careers in biotechnology (de Lencastre et al., 2017; Hyman et al., 2019). Consequently, the integration of DNA technology tools is necessary for facilitating the teaching of complex and abstract topics like biotechnology.

Research on Turkish Biology Curriculum, Textbook, and University Placement Exams

The importance of understanding biotechnological developments and methods in biology education is emphasized in the 2011-2016 science and technology human resources strategy and action plan by the Scientific and Technological Research Institution of Türkiye (TUBITAK, 2010) and the biology curricula at the secondary education level proposed by the Ministry of Education in Türkiye (MoNE, 2013, 2018a,b). The 2018 curriculum specifically states that "especially with the new genetic engineering and biotechnology developments,

biology has become a part of our daily lives, increasing the requirements for biology education" (MoNE, 2018a).

Recent studies have analyzed the Turkish Secondary Biology Curriculum in terms of various aspects, including Marzano taxonomy (Çelikkaya et al., 2021), socio-scientific issues (Et & Gömleksiz, 2021), 21st-century skills (Atik & Yetkiner, 2021), environmental issues (Derman & Gürbüz, 2018; Özbuğutu, 2021), reproduction and development topics (Güngör, 2021), plant morphology, anatomy and systematics topics (Çelik, 2019), and virus topic (Takmaz & Yılmaz, 2020) . These studies demonstrate the importance of continuously evaluating and improving the biology curriculum to ensure that it meets the needs of students and keeps up with the latest developments in biotechnology and biology.

The role of textbooks in transforming curriculum objectives into lesson plans and assisting teachers in carrying out these plans has been emphasized in various studies (İrez, 2016; Mahroof & Saeed, 2021; Yu et al., 2022). Additionally, there are several studies analyzing Turkish Biology curricula aligned textbooks in terms of scientific argumentation (Turan, 2019), analogies (Adnan, 2015; Gülcan, 2021), values (Acar & Yaman Kasap, 2020), gene concepts (Yüksel, 2019), history of science stories (Sarıbaş, 2019), energy concept (Aydoğan, 2022), scientific content (Gündüz et al., 2016), and nature of science representations (İrez, 2016).

Since 1974, university placement exams in Türkiye have been updated in different years in areas such as the number of questions, duration, application criteria and times, and content validity for the curriculum. As a result, these exams were named Higher Education Placement Exam (YGS)- Undergraduate Placement Exam (LYS) in 2010 and Basic Proficiency Test (TYT)- Field Proficiency Test (AYT) in 2017. The biology questions in university placement exams must be aligned with the curriculum. However, the fact that the quality of the questions asked is appropriate to the quality of the education provided is as important as the suitability of the subject (Atav & Morgil, 1999). Regarding the biology tests in university placement exams, there are a few studies analyzing the questions in terms of success (e.g., Yilmaz et al., 2019)

Rationale and Research Questions of the Study

While previously mentioned studies have explored various facets of the Turkish curriculum, curricula aligned textbooks, and university placement exams, the present study distinguishes itself through its specific focus and objectives. Firstly, it focuses on the inclusion and treatment of biotechnological techniques within the Turkish biology education framework, a niche that previous studies have not fully addressed. This focus allows for a comprehensive analysis of a critical aspect of biology education. Secondly, the study's emphasis on practical applications is noteworthy, given the hands-on nature of biotechnological techniques and their relevance in real-world contexts, such as the Covid-19 pandemic. This approach acknowledges the importance of preparing students with the skills required to engage with contemporary challenges. Thirdly, by examining the alignment between curricular goals, textbooks, and university placement exams in the context of biotechnology education, the study offers insights into the consistency of educational materials and assessments with intended learning outcomes. This aspect of the research sheds light on whether the educational system effectively equips students with the knowledge and skills needed for the biotechnology field. Lastly, the study's practical orientation sets it apart from more theoretical observational studies. It aims to provide actionable recommendations that can be utilized by curriculum developers, textbook authors, and educators to enhance biotechnology education in the country. This application-focused approach adds a valuable dimension to the research.

Fenwick's framework (1992) identifies three integral components of a curriculum – the written, taught, and tested aspects – which serve as a foundation for curriculum analysis (Ahmad & Mehmood, 2022). This study primarily centers on the written and tested elements of the curriculum, encompassing curricular objectives, aligned textbooks, and standardized university placement exam questions. To evaluate the extent of biotechnological updates within Turkish biology curricula, this study will examine the inclusion of fundamental biotechnological techniques, namely DNA isolation, PCR, and Gel Electrophoresis, within the current 2018 secondary biology curriculum and the 2018 science high school biology curriculum. Additionally, a comparative analysis will be conducted, contrasting these curricula with the preceding secondary biology curriculum from 2013. The selection of the 2013 curriculum for comparison is justified by the fact that, in 2018, biology curricula in Türkiye underwent a division into two separate curricula, one for science high schools and another for other high schools, thus enabling an assessment of the changes between the previous and subsequent curricular approaches. This comparative examination will help address critical questions, including whether the division into science high schools and other high schools has led to a more substantial inclusion of subjects such as biotechnology within the science high school curriculum. Furthermore, it will explore whether, in the context of rapid technological advancements, there have been differential rates of information updates in both programs, shedding light on how each curriculum responds to the evolving field of biotechnology. This comprehensive analysis is expected to provide insights into the alignment between curricular goals, textbooks, and university placement exams in the realm of biology education in Türkiye, as influenced by the 2013 and 2018 curriculum reforms. Towards this end, the main research questions of the present study are:

1. What is the presence and treatment of the basic biotechnological techniques (DNA Isolation, PCR, and Gel Electrophoresis) 2018 secondary biology and 2018 science high school biology curricula, and how these two curricula are different from in 2013 secondary biology curriculum?

2. What is the presence and treatment of basic biotechnological techniques (DNA Isolation, PCR, and Gel Electrophoresis) in curricula aligned textbooks adopted by the Ministry of National Education?

3. What is the presence and treatment of basic biotechnological techniques (DNA Isolation, PCR, and Gel Electrophoresis) in the university placement exams from 2016 to 2022?

Methods

Study Method and Documents

The study is a qualitative case study. The study treated biology curricula, textbooks and university placement questions as distinct cases. Document analysis is used in the study to examine the presence and treatment of biotechnological techniques in the Turkish high school biology curricula (2013 and 2018), curricula aligned textbooks, and university placement exams (2016 to 2022). Document analysis is a research method that is especially appropriate for qualitative case studies, which yield detailed descriptions of a single phenomenon, event, organization, or program (Bowen, 2009; Stake, 1995; Yin, 2003). By comparing it with content analysis, document analysis aims to investigate the features that distinguish a specific text or document (Yıldırım & Şimşek, 2013). This process is necessary for in-depth content analysis, just like any other analysis approach, to produce underlying meanings and create empirical information (Corbin & Strauss, 2013).

The present study analyzed several documents to investigate the presence and treatment of biotechnological techniques in the Turkish high school biology curricula, curricula aligned textbooks, and university placement exams. The documents analyzed in the study include:

1. Turkish National Biology Curriculum published in 2013 and 2018 for 9th to 12th grades. The study compared the two different curricula dated 2018, one for science high schools and the other for the rest, to investigate similarities and differences between the two curricula. The 2013-dated curriculum was also included in the study to reveal the current situation more clearly. Given that the study considered the presence and treatment of biotechnological methods and decided to use acquisitions related to these methods as inclusion criteria, a comprehensive review of units, subjects, achievements, and explanations across all three programs revealed that pertinent acquisitions were exclusively found in the 10th and 12th grades. Consequently, the study will exclusively focus on the acquisitions at these two grade levels as they pertain to biotechnological methods.

2. Upon conducting an extensive review of biology textbooks aligned with both the 2013 and 2018 curricula, the researchers noted that titles addressing biotechnological techniques were discernible in merely two of the 12nd grade biology textbooks aligned with BC and SBC. Consequently, these two specific biology textbooks were chosen as the primary materials for this study, with the aim of examining the presence and treatment of the aforementioned techniques. The first textbook in question is the Secondary School 12th grade Biology textbook (EBA, 2018a), which received official textbook approval from the Ministry of National Education's Board of Education on May 28, 2018, under the document number 78. The second selected textbook is the Secondary Science High School 12th grade Biology Textbook (EBA, 2018b), which obtained textbook approval from the Ministry of National Education's Board of Education on April 18, 2019, with document number 8. It is worth noting that these textbooks were procured from The Educational Informatics Network (EBA) materials website (https://ogmmateryal.eba.gov.tr/etkilesimli-kitaplar/biyoloji) specifically for the purpose of this study.

3. Since the students, who are subject to the secondary school biology curriculum adopted in 2013 took the university placement exams for the first time in 2016, university placement exams from 2016 to the present were included in the study (OSYM-YGS, 2016; OSYM-LYS,2016; OSYM-YGS,2017; OSYM-LYS,2017; OSYM-AYT,2018; OSYM-TYT,2018; OSYM-AYT,2019; OSYM-TYT, 2019; OSYM-AYT, 2020; OSYM-TYT, 2020; OSYM-AYT, 2021; OSYM-TYT, 2021; OSYM-AYT, 2022; OSYM-TYT, 2022). The study retrieved the exam questions from The Measuring, Selection and Placement Center's website (e.g., https://www.osym.gov.tr/TR,23824/2022-yks-tyt-ayt-ve-ydt-temel-soru-kitapciklari-ve-cevap-anahtarlari.html). The inclusion of university placement exams in the study aimed to investigate the presence and treatment of biotechnological techniques in the exams and their alignment with the high school biology curricula and textbooks.

Data Analysis

In the present study, the documents were analyzed using a three-phase approach that involved reviewing, reading, and interpretation while incorporating aspects of content analysis and thematic analysis (Bowen, 2009). The study followed Bowen's (2009) recommendations for document evaluation and scrutinized the papers with a critical eye to determine their significance and relevance to the topics under investigation. To ensure the reliability of the analysis, two researchers who were experts in biology education independently analyzed the achievements of the curriculum, the textbooks, and the university exam questions held between 2016-2022 regarding the existence of biotechnological techniques. The researchers then came together to identify similarities and differences in their analysis.

Analysis of Curricula

The present study primarily examined the Secondary Education Biology Curriculum (MoNE, 2013), the Secondary Education Biology Curriculum (MoNE, 2018a), and the Science High School Biology Curriculum (MoNE, 2018b). To avoid confusion, the study referred to the secondary education biology curriculum as SBC with the publication years BC-2013 and BC-2018, and the science

high school biology curriculum as SBC-2018. The BC-2018 and SBC-2018 curricula, which started to be implemented in 2018 in Türkiye, consist of two phases: Basic Level (9th and 10th grades) and Advanced Level (11th and 12th Grades). The study found that only the 10th and 12th grade curricula are likely to include biotechnological methods and techniques. Therefore, only acquisitions and explanations of these two grades were examined and presented the findings.

Analysis of Biology Curricula aligned Textbooks

The study considered two textbooks: the 12th-grade Biology Textbook aligned with BC-2018 (EBA, 2018a) and the 12th-grade Biology Textbook aligned with SBC-2018 (EBA, 2018b). Initially, the textbooks were sourced from the EBA platform, revealing that only the 12th-grade Biology textbooks contained information related to biotechnological techniques. Subsequently, the study employed the 'Chairman of the Board of Education and Training' framework, abbreviated as CBET (CBET, 2019), to assess the relevant sections of these textbooks. CBET provides a set of criteria and explanations for evaluating educational materials and draft textbooks. Specifically, the study focused on the Scientific Adequacy of the Content Aspect within the CBET framework, which comprises five primary aspects and various sub-criteria. These five main aspects encompass (2.1) content, (2.2) knowledge accuracy, (2.3) learning, teaching, measurement, and evaluation, (2.4) language, expression, and style, and (2.5) copyright and evaluation. The sub-criteria relevant to each aspect are elaborated upon in the findings section. The evaluation process involved selecting sections of the textbooks that contained information regarding biotechnological methods and scrutinizing their adherence to the criteria delineated in the foundational elements of the CBET framework.

Analysis of University Placement Exam Questions

The university placement exams held between 2016 and 2022 were analyzed by matching the objectives in the biology curricula to the biology questions in those tests. The study analyzed whether there were questions on genetic engineering, biotechnology, and biotechnological methods. The study labeled the university placement exams as Year-ExamType (such as 2022-AYT and 2022-TYT; 2016-LYS and 2016-YGS) while presenting the findings.

Trustworthiness and Credibility

To enhance the trustworthiness and credibility of this study, several key factors have been carefully considered. Firstly, two experts (one is a professor of biology education and the other has a PhD in biology education) experienced in biotechnology education conducted the analysis. In addition, the documents examined in this research, including the curricula, textbooks, and university placement exam questions, are all official and authoritative sources retrieved from their official websites. Secondly, a clear and concise labeling system has been employed throughout the research process. This labeling system ensures that each document, curriculum, textbook, or exam question, is appropriately categorized and easily identifiable. This consistency in labeling contributes to the study's reliability as it minimizes the risk of confusion or misclassification. Moreover, the criteria used to analyze the textbooks (CBET) for evaluating the content of textbooks is based on well-established educational criteria. This framework is recognized for its trustworthiness in assessing educational materials, further bolstering the study's credibility.

Findings

The presence and treatment of Biotechnological Methods in BC and SBC

The present study found that in the 2013 Grade 10 Biology Curriculum, the acquisitions related to Modern Genetic Applications were in the 2nd unit, "General Principles of Heredity." However, no topics, acquisitions, or explanations emphasized biotechnological methods under this objective. With the curriculum amendment in 2018, these acquisitions were transferred to the 1st unit of 12th grade, "From Genes to Proteins." As a result, there have been no topics, concepts, acquisitions, or explanations related to biotechnological methods or techniques in the 10th-grade BC and SBC since 2018. However, the Science High School Biology Curriculum (SBC-2018) includes acquisitions related to biotechnological methods and techniques. A comparison of acquisitions in BC-2018 and SBC-2018 is presented in Table 1.

As seen in Table 1, the acquisition explanations in italics in SBC-2018 include "PCR" and "gel electrophoresis" concepts. Also, different suggestions were made to teachers in terms of applications. It is noteworthy that there is no explanation or application suggestion for DNA isolation in the acquisitions or explanations of BC-2018 and SBC-2018. However, the cloning of a gene into a plasmid using recombinant DNA techniques (in explanation 12.1.2.3.d) naturally include DNA isolation as a step. So, one needs to understand DNA isolation to acquire this learning outcome. These findings indicate that biotechnology methods and techniques are included in the SBC-2018 for the first time with the separation of the common biology curriculum and the science high school biology curriculum with the curriculum update in 2013.

The presence and treatment of Biotechnological Methods in Curricula aligned Textbooks

BC-2018 aligned Grade 12 Textbook

As explained in the first section of the findings, it is evident that the 12th grade BC-2018 textbook does not include any acquisitions or explanations related to biotechnological techniques. However, the BC-2018 aligned 12th grade textbook (EBA, 2018a) examination showed that biotechnological methods such as PCR and Electrophoresis are included in this textbook as definitions and short explanations. This finding indicates that the

textbook authors realized the necessity of explaining these techniques and included them in the content. Furthermore, the keywords of BC-2018 include "DNA fingerprinting". To explain DNA fingerprinting, it is necessary to explain biotechnological methods, but the methods in the textbook are mentioned after the topic of gene cloning and are not associated with other topics of genetic engineering and biotechnology applications. This can make it challenging to understand gene cloning without knowing the techniques that form its basis. It is also worth noting that the BC-2018 aligned Biology Textbook, available on EBA, does not have a QR code containing visuals, animations, etc., related to these topics. This can limit the students' ability to access additional resources and information related to biotechnological techniques and DNA fingerprinting. When the "DNA Fingerprinting" text on page 63 of the 12th-grade biology textbook is examined in detail within the framework of the criteria, the following points seem to draw attention.

CBET criteria: 2.1.1. content should be understandable. 2.1.1.4. There should be no ambiguity in the content.

Based on the findings, it is evident that the definition of DNA fingerprint in the 12th-grade Biology textbook creates an ambiguous situation regarding whether or not book authors should take DNA fingerprinting as a technique. The definition in the textbook says, "The banded structures formed on the gel by meaningless base sequences that repeat in the DNA base sequence of a living thing are called DNA fingerprint." However, the authors explained the process of obtaining DNA fingerprints by mentioning restriction enzymes, PCR, and Electrophoresis after the definition. This can create confusion about whether DNA fingerprinting is a technique or just the formation of bands on the gel. It is important to note that DNA fingerprinting is the process of determining an individual's DNA characteristics, and the formation of bands on the gel results from the techniques used during the process. Additionally, DNA fingerprinting is not revealing the whole sequence, but revealing the differences in certain DNA regions between individuals, as in fingerprints. Therefore, it is necessary to mention DNA fingerprinting as a technique including multiple steps and the DNA fingerprints as results of the process to overcome the ambiguity in the content.

Thus, to improve the content's understandability and eliminate ambiguity, the textbook's authors should clarify that DNA fingerprinting is a technique that involves multiple steps, including the use of restriction enzymes, PCR, and Electrophoresis, and that the formation of bands on the gel is the result of this process. This will help students better understand the concept of DNA fingerprinting and its application in forensic science.

CBET criterion 2.1.1.3. Content should be presented in such detail and structure that a student can read, understand, and learn without the help of others.

Table 1. Comparison of BC-2018 and SBC-2018 in terms of acquisitions related to biotechnological techniques

Biology Curriculum Name	BC-2018	SBC-2018
Unit	12.1. From Genes to Proteins	
Topic	12.1.2. Genetic Code and Protein Synthesis	
Key Concepts	antibiotic, anticodon, bioethics, biosecurity, biotechnology, DNA fingerprinting, gene therapy, genetic code, genetic counseling, genetical engineering, insulin, cloning, code, codon, stem cell, model organism, RNA polymerase, protein synthesis, transcription, translation, artificial tissue/organ	
Acquisitions/ Explanations	12.1.2.3. Explains the applications of genetic engineering and biotechnology. a. Gene technologies, DNA fingerprint analysis, stem cell technologies, and their usage areas are researched, and the results are shared. b. The characteristics of model organisms are discussed. c. Examples of the use of model organisms in genetic and biotechnological research are given.	12.1.2.3. Explains the applications of genetic engineering and biotechnology. a. Gene technologies, DNA fingerprint analysis, stem cell technologies, and their usage areas are researched, and the results are shared. *b. Examines the gel electrophoresis technique and explains the separation of DNA fragments of different sizes in gel electrophoresis by using visual elements, graphic organizers, e-learning objects, and applications.* *c. replication of genes is studied using the polymerase chain reaction (PCR).* d. The cloning of a gene into a plasmid using recombinant DNA techniques is investigated. 12.1.2.4. Gives examples of synthetic biology applications. 12.1.2.4./12.1.2.5. Evaluates the impact of genetic engineering and biotechnology applications on human life. a. vaccines, antibiotics, insulin, interferon production, cancer treatment, and gene therapy applications are briefly explained. b. Possible consequences of cloning studies and genetic modification of organisms are indicated. Ian Wilmut's studies on cloning are mentioned. c. Biosafety and bioethics issues are discussed. ç. It is emphasized that the socioeconomic and cultural context influences the development of biology. d. Ethical and security dimensions of biotechnological developments, such as developing biological weapons, protecting personal DNA information, and stem cell therapy, are examined. e. Practice related to obtaining bioproducts (chitosan, cellulose, bioplastics, etc.) from waste biological materials is ensured.

"DNA fingerprint" subtitle in the 12th-grade Biology textbook presents many new concepts with only their definitions and expects students to understand them with that one-sentence definition. Additionally, too many new concepts are given in one page of information, which can make it challenging for students to comprehend the material. For example, in the DNA Fingerprinting subtitle, the authors presented DNA fingerprint, PCR, and Electrophoresis; however, they mentioned Electrophoresis as a method without a definition and with an image of an electrophoresis device. This can create confusion for students who are not familiar with the technique.

Furthermore, the statement regarding DNA fingerprint says, "While determining DNA fingerprint, DNA is first cut with restriction enzymes and then amplified with PCR." However, DNA fingerprints can be determined by two recently preferred methods: Restriction Fragment Length Polymorphism (RFLP) using restriction enzymes and PCR-based methods. These two approaches are presented one after the other in the text, making it difficult to understand without additional explanation.

CBET criterion 2.1.3.2. Content should be based on accurate, valid, and reliable sources.

Examining the DNA fingerprint subtitle regarding this criterion showed that some parts of the text were reduced to keep it short, which shifted the meaning. For example, the X-Ray film image on page 63 is directly described as a DNA fingerprint.

CBET criterion 2.2.1. There should be no lack of information or information errors.

2.2.1.2. The content should not contain date, name, definition, unit, symbol, formula, equation, concept, term, law, theory, principle, statistical data, abbreviation, writing, translation, pronunciation, video, subtitle etc. errors.

The content states, "This method is used to determine plant and animal breeds in paternity cases." However, DNA fingerprinting involves multiple techniques, such as DNA isolation, PCR, and Electrophoresis.

CBET criteria 2.2.4. There should be no information and expression that may lead to misconceptions.

2.2.4.1. Definitions, explanations, examples, demonstrations, and activities should be unambiguous in a way that does not lead to discussion.

The definition of DNA fingerprint in the textbook as "banded structures formed by base sequences on a gel" is unclear. It is just a step in the process of determining individual-specific DNA profiles. The definition and demonstration of DNA fingerprinting are open to discussion and have the potential to create misconceptions regarding biotechnological methods.

CBET criteria 2.2.7. The visual design and content visuals should not contain scientific errors.

2.2.7.2. All the elements used in the visuals must be authentic and error-free.

The explanation of Image 1.51. (See Figure 1) page 63 of the 12th Grade Biology Textbook says, “DNA fingerprint”. However, it is an X-Ray film image of DNA fingerprints showing the result of the DNA Fingerprinting process. In other words, it is DNA fingerprint band pattern, gel electrophoresis image. The differences in the bands on the gel reveal the differences in DNA. Thus, it is an incomplete image and does not show the gel obtained due to Electrophoresis. In addition, the starting part of the gel (wells) is not visible, so it is unclear which individuals or species they are. There are no standards against which the bands are compared and no column with the negative. What the columns and bands tell is an incomplete image for those who knows the subject and incomprehensible for those who is not entirely familiar with the subject.

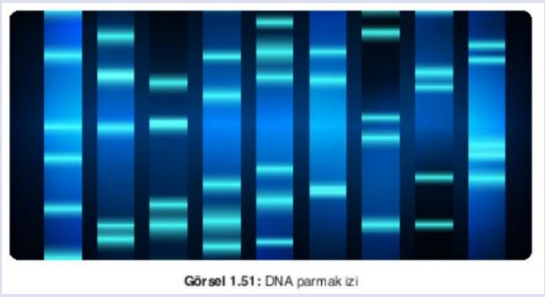

Figure 1. DNA fingerprinting image on 12th Grade Biology Textbook (Unit 1, page 63)

SBC-2018 aligned Grade 12 Textbook

As explained in the first section of findings, 12th grade SBC-2018 includes acquisitions and explanations related to PCR and Gel electrophoresis. The PCR and gel electrophoresis techniques in Unit 1 of the SBC-2018 aligned Grade 12 textbook (EBA, 2018b, pages 39-43) are given in order. Still, there is no section describing DNA isolation as a biotechnological technique. The theoretical explanations of the techniques and visuals explaining PCR and Gel electrophoresis are correct and understandable. The fact that they were given before the subtitle of gene cloning is thought to facilitate understanding this topic. However, the relationship between the techniques is not fully explained.

Contrary to BC-2018 aligned 12th-grade Biology textbook, DNA fingerprinting has been tried to be explained as a method in SBC-2018 aligned Grade 12th textbook. The PCR technique has been included as the most frequently used one of these techniques in recent years. In addition, Gel Electrophoresis is included as a technique by step-by-step preparation processes.

The findings below present the examination of images in terms of CBET criteria.

CBET criterion 2.2.7. The visual design and content visuals should not contain scientific errors.

2.2.7.2. All the elements used in the visuals must be authentic and error-free.

In the 12th grade Science High School Biology Textbook, a gel image is given as a DNA fingerprint analysis image (page 39, image 1.51). The gel image here depicts a hand holding a pencil and examining whole DNA sequencing (see Figure 2). For those who do not know,

gels don't mean anything, but for those who know, they provide insufficient data. The other visuals (1.54, 1.55, and 1.56) (EBA, 2018b) on page 42 under the title "Gel Electrophoresis Technique" are given as DNA fingerprints, not gel electrophoresis images. Regarding Figure 3, at first glance, it can be thought that the first two of the gel images may have even been made to determine whether there is genomic DNA as a result of DNA isolation. Although the third is an image is clearer, the information here needs to be specified next to these images. The explanation of visuals in the book may lead to misconceptions (See Figure 3).

DNA isolation is also not included in this book. PCR and Gel Electrophoresis techniques are included theoretically. No suggestions or activities such as experiments, animations, simulations, etc., can contribute to understanding these abstract techniques. The book's introduction states, "It shows the QR code that can be accessed to additional resources such as pictures, videos, animations, questions, and solutions by scanning with a QR code reader." Such a QR code is found on page 39, next to the DNA fingerprint topic. The result is unsuccessful when this QR code is tried to be read with a QR code reader. The warning is a proof that students cannot easily use this part of the book. The information about this QR code requires access to the book via the web.

The presence and treatment of Biotechnological Methods in University Placement Exam Questions

University placement exams in Türkiye are standard exams for all senior high school students who are about to graduate and willing to continue their education at universities. The findings of the present research on whether there were questions on genetic engineering, biotechnology, and molecular biology in the university placement exams held from 2016 to 2022 are given in Table 2 below.

As indicated in Table 2, it is seen that there were questions in the AYT exams of 2018 and 2019 and one question in the 2016 LYS exams. In Question 40 of AYT-2019, while it is stated that genetic engineering is used for artificial selection, the question focuses on artificial selection. The AYT-2018 question asks about the characteristics of transgenic organisms, and the 2016-LYS2 question asks about the characteristics of model organisms. These questions do not include biotechnological techniques or require knowledge of those techniques for selecting the right option.

Upon comparing the results of document analysis from various sources, the findings indicated that the SBC-2018 included explanations of the PCR and Electrophoresis techniques. These techniques are also defined in the subject expressions of BC-aligned textbooks and included in the subject content of BC-2018. However, university placement exams do not feature any questions related to these biotechnological techniques.

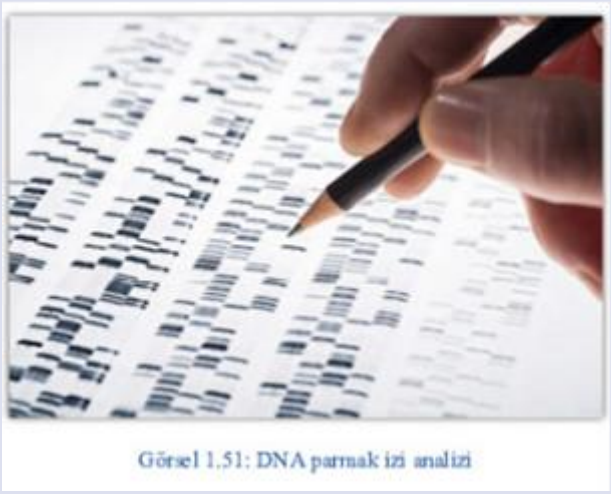

Figure 2. DNA fingerprint analysis image on SBC-2018 aligned 12th Grade Biology Textbook (Unit 1, page 39)

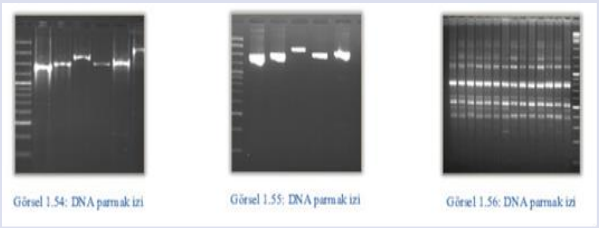

Figure 3. DNA fingerprint images on SBC-2018 aligned 12th Grade Biology Textbook (Unit 1, page 42)

Table 2. The presence and treatment of Biotechnological Methods in University Placement Exam Questions from 2016 to 2022

Year-Exam Type	Question Status (Yes/No)	Question number and explanation
2016-LYS2	Yes	Question 21: Characteristics of model organisms
2016-YGS	No	
2017-LYS2	No	
2017-YGS	No	
2018-AYT	Yes	Question 36: Characteristics of a transgenic organism
2018-TYT	No	
2019-AYT	Yes	Question 40: The use of genetic engineering applications in artificial selection.
2019-TYT	No	
2020-AYT	No	
2020-TYT	No	
2021-AYT	No	
2021-TYT	No	
2022-AYT	No	
2022-TYT	No	

Results and Discussion

The present study aimed to examine the presence and treatment of biotechnological techniques (DNA Isolation, PCR, and Gel Electrophoresis) in the Turkish high school biology curricula (2013 and 2018), curricula aligned textbooks, and university placement exams (2016 to 2022). The following sections present the results obtained from the study findings.

Results and Discussion related to BC-2018 and SBC-2018

The Turkish High School Biology Curriculum highlights the significance of genetic engineering and biotechnology in its specific objectives. The study's examination of the Grade 10 Biology Curriculum in 2013 revealed that the content related to Modern Genetic Applications was situated within the 2nd unit, titled "General Principles of Heredity." However, a notable observation was that there were no topics, acquisitions, or explanations that emphasized biotechnological methods within this specific curriculum. Subsequently, with the curriculum revision in 2018, these genetic acquisitions were transferred to the 1st unit of the 12th-grade curriculum, titled "From Genes to Proteins". This curriculum update might create a situation where biotechnology subjects are solely the responsibility of science field students. As a result, students who opt-out of the science field may have to seek information about these topics outside of the biology lessons, from sources like media (Fonseca et al., 2012; Özgen et al., 2007; Tanır, 2005). But young people today will be future adults who may face problems related to DNA or need help making decisions about genetic counseling and cancer diagnosis (Bouakaze et al., 2010). Hence, it is essential to educate all students, not just those in the science field, about biotechnology and genetic engineering. Educating students accurately and entirely through informative activities can help them make informed decisions about biotechnological products and applications (Akman, 2007; Kolonkaya, 1990). Additionally, the ability of non-scientists to have basic scientific knowledge is crucial in solving socio-scientific problems.

Based on the research findings, a comparison was made between Grade 12 BC-2018 and SBC-2018 in terms of the learning outcomes of Unit 1 (From Genes to Proteins), where SBC-2018 included explanations of PCR and Electrophoresis techniques. However, while the explanation for "PCR" in SBC-2018 was found to be open to different applications besides theoretical knowledge, the explanations for "PCR" and "electrophoresis" were not as detailed. This curriculum recommends incorporating visual aids, graphic organizers, e-learning objects, and applications to teach the "gel electrophoresis technique" to help students better understand the technique and its applications. Moreover, while the curricula provide suitable conceptual knowledge of these techniques regarding DNA isolation, neither curriculum explains this concept. This absence is thought to be concerning, given that the 1998 Biology Curriculum (MoNE, 1998) included "Isolation of DNA from Living Cells and Transfer of DNA to cells" as a learning outcome. Including the subject of DNA isolation as a content in biology textbooks can provide more clarity on the accuracy of the textbook in terms of reaching the achievement of understanding DNA isolation. It may be acceptable not to include DNA isolation in the 12th-grade curricula if DNA-related applications are covered in 10th-grade subjects or in the form of applications in the "DNA and Genetic Code" Unit in the 8th-grade Science Curriculum. This approach would ensure that students have a solid understanding of DNA-related concepts and techniques before entering the 12th grade. It is worth adding that the 2018 biology curriculum for 12th-grade students does not cover topics related to DNA isolation, PCR, and gel electrophoresis methods, but the 12th-grade biology textbook briefly mentions these methods under the topic of "DNA fingerprinting". However, it is unclear whether the information provided is sufficient, and it may lead to misconceptions.

In conclusion, the research suggests that while the curricula provide adequate conceptual knowledge of PCR and Electrophoresis techniques, more detailed explanations and visual aids are necessary for students to comprehend these techniques fully. Moreover, the absence of DNA isolation in the curricula is concerning, and it may be acceptable not to include it in the 12th-grade curriculum if adequately addressed in earlier grades.

Results and Discussion related to Biology Curricula aligned Textbooks

The SBC-2018 curriculum explicitly includes PCR and gel electrophoresis as part of the learning outcomes, and the biology textbook for 12th-grade students explains these methods theoretically and includes explanatory visuals. However, the suggested e-learning objects are not utilized in the curriculum, and the QR code application provided in the textbook does not work. This lack of support may make it challenging for students to understand the theoretical concepts presented in the book and associate them with related concepts (Acarlı, 2016)

Moreover, both textbooks lack an explanation of DNA isolation, and it is important to explain DNA isolation, PCR, and gel electrophoresis together. The connections between these methods and their applications in genetic engineering and biotechnology should also be emphasized, including gene cloning, GMO, and DNA fingerprinting. However, there are deficiencies in the visuals used to explain DNA fingerprinting in both books, and providing gel electrophoresis images in this way may cause misconceptions.

The biology textbook, aligned with BC-2018 includes techniques as definitions, while the SBC-2018-aligned textbook includes them as a section with figures. Although the SBC-2018-aligned textbook also has shortcomings, it seems possible to teach the methods with the support of teachers. However, teachers tend to rely on school

textbooks as their primary source of information and may not actively search for more specialized sources due to time constraints (Fonseca et al., 2012). Therefore, textbooks should include relevant applications in detail, and the presence of technological applications linked to the book should be supported. However, the problems in their use should be corrected. These technological applications can be very convenient tools for virtual laboratories.

In summary, the 12th-grade biology curriculum should cover DNA isolation, PCR, and gel electrophoresis together, along with their applications in genetic engineering and biotechnology. Textbooks should include relevant applications in detail, and the presence of technological applications linked to the book should be supported. Finally, practical teaching and activities are essential for biotechnology education, and websites and scientific studies should be recommended to improve the quality of education.

The lack of activities in the textbook is also a concern, as practical teaching is essential for biotechnology education. Experiments or interactive activities are needed, as the adequacy of theoretical biotechnology teaching is considerably lower than that of practical teaching (Altun et al. 2011; Sıcaker & Öz Aydın, 2015). Teachers also state that practical studies on biotechnology are insufficient compared to other biology subjects (Steele & Aubusson, 2004). Researchers suggest increasing studies on applications in biotechnology education (Nordqvist & Aronsson, 2019). In this field, websites and scientific studies share experiments and applications that can be a resource for teachers, students, and interested parties. For example, teaching biotechnology with analogies can be done with web-based training and laboratory exercises (Kirkpatrick et al., 2002; Fırat & Köksal, 2019). Researchers have shown that "The Journey of a Gene" module helps teachers increase their time on genetic engineering education and improve their knowledge (Troupe et al., 2018). In applied biotechnology education with science teachers, it is stated that innovative teaching approaches effectively improve teachers' laboratory experiences and significantly affect biotechnology knowledge and awareness (Orhan & Şahin, 2018). These studies present laboratory teaching examples (DNA isolation, PCR, Electrophoresis, etc.) enriched with innovative teaching approaches for biotechnology education. Educational websites (http://learn.genetics.utah.edu; http://genetiksifre.org) provide teaching examples of DNA isolation, PCR, and gel Electrophoresis, which can be applied quickly and do not require laboratory and unique experimental materials. Therefore, it would be helpful to recommend such applications in textbooks and disseminate them to improve biotechnology education.

Results and Discussion related to the University Placement Exam Questions

An analysis of university placement exams between 2016 and 2022 found that although genetic engineering and biotechnology questions were included in 2016, 2018, and 2019, these questions did not require knowledge of the relevant methods. The absence of questions related to methods in university placement exams poses a significant challenge to both teaching and learning new and complex biotechnology methods (Chen & Raffan, 1999; Orhan & Şahin, 2018). It also raises concerns about the alignment between curriculum objectives and assessment practices and may inadvertently discourage educators from teaching any topic (Smith, 1991; Wiggins, 1993). Studies conducted in Australia have shown that biology teachers tend to avoid teaching biotechnology as they perceive that students taking this course may be disadvantaged in university placement exams (Steele & Aubusson, 2004). The perception that students might be disadvantaged in exams can lead to a superficial treatment of topics (Black & Wiliam, 1998). A similar situation may also exist regarding biotechnology education in Türkiye.

Conclusion

Coming back to the study's question whether we are keeping with the pace of biotechnology, the present study's findings highlighted significant shortcomings in our education systems regarding biotechnology. Biotechnological methods are not consistently integrated into biology curricula, and textbooks, especially in science high schools, often provide inadequate and scientifically erroneous information. It is to say that we are struggling to keep up with the pace of biotechnology in terms of curricula, aligned-textbooks and university entrance exams.

Implications

To ensure students' readiness for future challenges related to pandemics and GMO issues, it is imperative to elevate science literacy and modernize biology curricula by integrating these topics. The 2013 curriculum can serve as a blueprint for curriculum updates, particularly in the 10th-grade basic biology course. The research findings underscore the need for meticulous curriculum design, with a particular concern being the absence of DNA isolation in the 12th-grade curriculum. Therefore, it is recommended to shift genetic application topics to earlier grades. For instance, DNA isolation, a relatively straightforward technique, can be introduced in the 8th-grade "DNA and Genetic Code" unit. Additionally, PCR and gel electrophoresis can be incorporated into the 12th-grade BC-2018 curriculum to align it with the biology curricula of BC and SBC, ensuring broader accessibility for high school students. While SBC does provide a foundational understanding of PCR and electrophoresis, there is room for improvement in terms of the depth of explanations and the inclusion of visual aids. To enhance students' comprehension of these techniques and their practical applications, it is advisable to develop more comprehensive explanations and incorporate visual aids, graphic organizers, e-learning resources, and practical experiments. These enhancements can significantly

contribute to a more robust learning experience and a better grasp of essential biotechnological techniques. Given the significance of basic molecular methods of DNA technology in contemporary health applications, it is recommended to integrate these methods into health science courses.

Turning to textbooks, it is essential to elucidate the interconnected nature of DNA isolation, PCR, and gel electrophoresis as methods employed to address real-world scientific challenges. While the SBC-2018 curriculum already includes PCR and gel electrophoresis in its learning outcomes, and the corresponding textbook provides theoretical explanations and visuals, there are challenges, including underutilized e-learning resources and malfunctioning QR code applications. To bridge this gap, educators should explore and integrate effective e-learning materials into their teaching methodologies. Additionally, rectifying technical issues, such as non-functional QR codes, is pivotal for ensuring a seamless learning experience. Furthermore, the BC-2018-aligned textbook should be enriched to adequately cover these methods. Notably, both the BC-2018 and SBC-2018 textbooks lack an explanation of DNA isolation, a fundamental component of biotechnology. The research underscores the importance of teaching DNA isolation, PCR, and gel electrophoresis as an integrated package, along with their practical applications in genetic engineering and biotechnology. It is essential to adopt a comprehensive approach that connects these methods with their real-world applications, including gene cloning, GMOs, and DNA fingerprinting, within the biology education framework. Additionally, addressing deficiencies in visuals, particularly those related to DNA fingerprinting, is crucial to prevent student misconceptions.

The research underscores the need for practical teaching and hands-on activities in biotechnology education. The dearth of experiments and interactive activities in textbooks is a significant concern since theoretical instruction alone often falls short. To remedy this, educators should incorporate practical experiments and interactive activities that provide students with a tangible understanding of biotechnological techniques. Furthermore, leveraging educational websites and scientific studies that share experiments and applications can further enrich the learning experience in biotechnology.

The study also emphasizes the importance of incentivizing and supporting educators in delivering comprehensive and effective biotechnology education. This may involve revising assessment practices to better reflect the significance of methodological knowledge in biotechnology. To promote the teaching and learning of these topics, it could be beneficial to include questions related to current issues like Covid-19, which involves biotechnological techniques, in standard exams. This approach can serve as motivation for students to learn and for teachers to provide more thorough instruction.

It's worth noting that the study's conclusions are based on data available up to 2022 university placement exams in Türkiye. Given the dynamic nature of educational systems, which include updates to curricula and policy changes, certain aspects of biotechnology education may have evolved since that time. Researchers should consider conducting periodic updates to capture ongoing changes. Additionally, the study primarily relies on document analysis and does not incorporate the perspectives of key stakeholders, such as educators, students, and curriculum developers. Gathering insights from these individuals could enhance our understanding of the challenges and opportunities within biotechnology education. The analysis of university placement exams was conducted within a specific timeframe (2016 to 2022), allowing for an assessment of recent trends. However, this timeframe may not fully capture long-term shifts in assessment practices. Furthermore, the study's focus was exclusively on biology-related placement exams, without considering other science-related disciplines. It's essential to keep these limitations in mind when applying the findings to a broader assessment context.

Despite these constraints, the study provides valuable information and insights into the current state of biotechnology education in Türkiye. Future research endeavors in this field may address these limitations and provide a more comprehensive understanding of biotechnology education, its influence on students' learning outcomes, and its implications for future career opportunities.

Genişletilmiş Özet

Giriş

Biyoteknoloji endüstride ihtiyaç duyulan becerilerin veya gelecekte gerekecek olan becerilerin hepsini kapsayabilecek tek bir öğretim programı yoktur ve biyoteknoloji, müfredatların uyum sağlayamayacağı kadar hızla ilerlemektedir. Ancak öğretim programlarının ve ders kitaplarının bilim eğitimindeki önemi, biyoteknoloji eğitimindeki eksikliklerin başlıca nedenlerinden birinin de biyoteknolojinin öğretim programlarına yeterince dahil edilmemesi olduğu göz önüne alındığında, biyoteknoloji eğitiminin lise düzeyindeki ilerlemesini değerlendirmenin mümkün yollarından biri de, biyoteknolojik tekniklerin biyoloji öğretim programları, programla uyumlu ders kitapları ve üniversite yerleştirme sınavlarında varlığını ve ele alınışını ayrıntılı bir şekilde incelemektir. Bu tür bir inceleme, eğitimcilerin ders kitapları ile müfredat arasındaki uyumu sağlayarak, öğretim, değerlendirme ve değerlendirme konularında tutarlılığı artırmalarına yardımcı olma potansiyeline sahiptir. Eğitim materyallerini güncel biyoteknoloji gelişmeleriyle uyumlu hale getirmek, öğrencileri alanın dinamik taleplerine hazırlar. Bu çalışma, temel biyoteknolojik tekniklerin (DNA izolasyonu, PCR ve Jel Elektroforezi) belirtilen dokümanlardaki varlığını ve işlenişini inceleyerek, bu alandaki hızlı gelişmelere uygunluğunu değerlendirmeyi amaçlamaktadır. Bu analizin, biyoteknoloji alanında pek çok konunun

anlaşılmasında karşılaşılan zorlukları ve COVID-19 pandemisi gibi olaylar ışığında eğitim sistemlerimizin bu zorluklarla başa çıkma ve fırsatları değerlendirme yeteneğini belirlememize yardımcı olacağı düşünülmektedir.

Yöntem

Buna göre, bu çalışma biyoteknolojik tekniklerin (DNA izolasyonu, PCR ve Jel Elektroforez) 2013 ve 2018 yıllarında yürürlüğe giren Türkiye Ortaöğretim Biyoloji öğretim programları, biyoloji ders kitapları ve 2016-2022 yılları arasında yapılan üniversite yerleştirme sınavlarındaki durumunu incelemeyi amaçlamaktadır. Çalışma, nitel durum çalışması araştırma yaklaşımı izlenen bir doküman incelemesi çalışması olarak tasarlanmıştır. İncelenen dokümanlar, içerik analizi ve tematik analizin özelliklerini bir araya getirerek, inceleme, okuma ve yorumlamayı içeren üç aşamalı bir yaklaşım kullanılarak analiz edilmiştir.

Sonuç

Çeşitli kaynaklardan doküman analizi sonuçları karşılaştırıldığında SBC-2018'in PCR ve Elektroforez teknikleri ile ilgili açıklamalara yer verdiği görülmüştür. Bu teknikler BC-2018 ders kitaplarının konu anlatımlarında da tanımlanmış ve BC-2018 konu içeriğinde yer almıştır. DNA izolasyonu program kazanımlarında ve kitaplarda yer almamaktadır. Ancak üniversite yerleştirme sınavlarında bu biyoteknolojik tekniklerle ilgili herhangi bir soru yer almamaktadır. Biyoteknolojinin hızına ayak uydurup uydurmadığımızı sorgulayan, mevcut çalışmanın bulguları eğitim sistemlerimizde biyoteknoloji ile ilgili önemli eksiklikleri vurgulamaktadır. Biyoteknolojik yöntemler biyoloji öğretim programlarına tutarlı bir şekilde entegre edilmemekte ve özellikle fen liselerinde ders kitapları sıklıkla yetersiz ve bilimsel olarak yanlış bilgi sunmaktadır. Sonuç olarak, öğretim programları, uyumlu ders kitapları ve üniversite giriş sınavları açısından biyoteknolojinin hızına ayak uydurma konusunda zorlandığımızı söylemek mümkündür.

Tartışma

Araştırma bulgularına dayalı olarak 2018 Fen Lisesi Biyoloji Öğretim Programı'nda PCR ve Elektroforez teknikleri açıklamalarının teorik bilginin yanı sıra farklı uygulamalara açık olduğu görülürken, "PCR" ve "elektroforez" açıklamaları bu kadar detaylı olmadığı görülmüştür. Bu öğretim programı, öğrencilerin tekniği ve uygulamalarını daha iyi anlamalarına yardımcı olmak için "jel elektroforez tekniğini" öğretmek için görsel yardımcıların, grafik düzenleyicilerin, e-öğrenme nesnelerinin ve uygulamaların dahil edilmesini önermektedir. Ayrıca, öğretim programı DNA izolasyonu ile ilgili bu tekniklerin uygun kavramsal bilgisini sağlarken, hiçbir program bu kavramı açıklamamaktadır. 1998 Biyoloji Öğretim Programı'nda (MEB, 1997) "Canlı Hücrelerden DNA İzolasyonu ve DNA'nın Hücrelere Transferi" konusuna öğrenme çıktısı olarak yer verildiği düşünüldüğünde, bu eksikliğin endişe verici olduğu düşünülmektedir. Ek olarak, 2018 Fen Lisesi Biyoloji Öğretim Programı'nda kazanımlar arasında açıkça PCR ve jel elektroforezi yer almakta olup, 12. sınıf biyoloji ders kitabında bu yöntemlerin teorik olarak anlatıldığı ve açıklayıcı görseller yer aldığı görülmüştür. Ancak önerilen e-öğrenme nesneleri öğretim programında kullanılmamakta ve ders kitabında yer alan QR kod uygulaması çalışmamaktadır. Bu destek eksikliğinin, öğrencilerin kitapta sunulan teorik kavramları anlamalarını ve bunları ilgili kavramlarla ilişkilendirmelerini zorlaştırabildiği düşünülmektedir. 2016-2022 yılları arasındaki üniversite yerleştirme sınavlarının analizi, 2016, 2018 ve 2019'da genetik mühendisliği ve biyoteknoloji sorularının yer almasına rağmen, bu soruların ilgili yöntemler hakkında bilgi gerektirmediğini ortaya koymuştur. Üniversite yerleştirme sınavlarında yöntemlere ilişkin soruların bulunmaması, yeni ve karmaşık biyoteknolojik yöntemlerin hem öğretilmesi hem de öğrenilmesi açısından önemli bir zorluk teşkil ettiği düşünülmektedir.

Öneriler

Öğrencilerin salgın hastalıklar ve GDO sorunlarıyla ilgili gelecekteki zorluklara hazır olmalarını sağlamak için, bilim okuryazarlığını özelde biyoteknoloji okuryazarlığını artırmak ve bu konuları entegre ederek biyoloji öğretim programını güncellemek önemlidir. 2013 öğretim programı, özellikle 10. sınıf temel biyoloji dersinde yapılabilecek güncellemeler için bir taslak görevi yapabilecek nitelikte görünmektedir. Araştırma bulguları, titiz bir öğretim programı tasarımına olan ihtiyacın altını çizmektedir; özellikle 12. sınıf öğretim programında DNA izolasyonunun bulunmaması önemli bir noktadır. Bu nedenle daha basit olarak nitelendirilebilecek bu konuların daha önceki sınıflarda ele alınması önerilmektedir. Örneğin 8.sınıf "DNA ve Genetik Kod" ünitesinde nispeten basit bir teknik olan DNA izolasyonuna yer verilebilir. Programda öğrencilerin bu teknikleri ve pratik uygulamalarını anlamalarını geliştirmek için, daha kapsamlı açıklamalar geliştirilmesi ve görsel yardımların, grafik düzenleyicilerin, e-öğrenme kaynaklarının ve pratik deneylerin dahil edilmesi tavsiye edilmektedir. Bu geliştirmeler, daha sağlam bir öğrenme deneyimine ve temel biyoteknolojik tekniklerin daha iyi anlaşılmasına önemli ölçüde katkıda bulunabilecektir. DNA teknolojisinin temel moleküler yöntemlerinin çağdaş sağlık uygulamalarındaki önemi dikkate alındığında, bu yöntemlerin sağlık bilimleri derslerine entegre edilmesi önerilmektedir. Ders kitaplarıyla ilgili olarak araştırma DNA izolasyonu, PCR ve jel elektroforezinin entegre bir paket olarak öğretilmesinin ve bunların genetik mühendisliği ve biyoteknolojideki pratik uygulamalarının öneminin altını çizmektedir. FBP-2018 öğretim programı, öğrenme çıktılarında PCR ve jel elektroforezini içeriyor ve ilgili ders kitabı teorik açıklamalar ve görseller sağlıyor olsa da yeterince kullanılmayan e-öğrenme kaynakları ve arızalı QR kod uygulamaları gibi zorluklar da mevcuttur. Bu boşluğu kapatmak için eğitimciler etkili e-öğrenme materyallerini keşfetmeli ve kendi öğretim yöntemlerine

entegre etmelidir. Ek olarak, işlevsel olmayan QR kodları gibi teknik sorunların düzeltilmesi, kusursuz bir öğrenme deneyimi sağlamak için çok önemlidir. Ayrıca BP-2018 uyumlu ders kitabının bu yöntemleri yeterince kapsayacak şekilde zenginleştirilmesi gerekmektedir. Biyoloji eğitimi çerçevesinde bu yöntemleri gen klonlama, GDO'lar ve DNA parmak izi dahil olmak üzere gerçek dünyadaki uygulamalarla birleştiren kapsamlı bir yaklaşımın benimsenmesi önemlidir. Ayrıca görsellerdeki, özellikle DNA parmak izine ilişkin eksikliklerin giderilmesi, öğrencilerin kavram yanılgılarının önlenmesi açısından önemlidir. Bu konuların öğretilmesini ve öğrenilmesini teşvik etmek amacıyla üniversiteye giriş sınavı gibi standart sınavlarda biyoteknolojik teknikleri içeren Covid-19 gibi güncel konulara ilişkin soruların yer alması yararlı olabilir. Bu yaklaşım, öğrencilerin öğrenmesi ve öğretmenlerin daha kapsamlı öğretim sağlaması için motivasyon görevi görebilir.

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