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Evaluation of biology textbooks in Jordan regarding the inclusion of bioinformatics, its applications, and related bioethical issues

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Abstract

Bioinformatics is a scientific field that uses computers, software, and computerized databases to analyse and interpret biological data to reach different biological questions. However, bioethical questions encompass a range of ethical, social, legal dilemmas that arise from scientific and technological advances in the fields of biology or medicine as well as their impact on people deeply concerned with it. This research investigates the content of biology textbooks in Jordan, examining how much mention is made about bioinformatics applications and associated bioethical issues. The research is being conducted using a descriptive-analytical approach and utilizes a questionnaire to survey the opinions of science and biology teachers on the importance of integrating bioinformatics applications and ethical issues into biology textbooks. The study sample consists of two groups: biology textbooks for the 11th and 12th grades in Jordan, and supervisors and teachers in the field of science education, randomly selected from various educational regions in Jordan (totalling 419 participants). The results indicate a low inclusion rate of these topics in 12th-grade biology textbooks, which does not align with the global trend of keeping pace with modern biotechnological advancements and their associated ethical considerations. The study recommends that biology curriculum developers in Jordan prioritize integrating bioinformatics applications and bioethical issues into textbooks, linking them to broader themes of science, technology, and society (STS).

Keywords: bioinformatics, bioethical issues, textbook content, teaching strategies, curriculum development



1. Introduction

The era we live in has undoubtedly become the era of science and technology. The rapid and successive scientific developments have brought about profound and immense transformations in the lives of individuals and societies. Scientific applications have permeated various aspects of life to the extent that we can hardly find any aspect of our social, economic, or health lives without seeing the influence of science or technology on it. Therefore, most countries are seeking ways to scientifically prepare their individuals to face this development and the accompanying positives and negatives in people's lives in various aspects. Consequently, educational systems, through educational scientists, have sought to find methods and strategies that can contribute to preparing students to keep pace with these developments and be ready for them in the future. Thus, it was necessary to strive to reach numerous strategies and methods specific to the preparation and construction of curricula offered to students.

In the current digital age, bioinformatics has become an indispensable tool in the study of biological sciences. The World Health Organization indicates that 85% of modern biomedical research primarily relies on the analysis of digital biological data. (WHO, 2022). Therefore, bioinformatics today has become a pivotal tool for understanding complex biological phenomena, particularly in the analysis of genetic information in the genes of living organisms, drug development, understanding microbial interactions, and the response to infectious diseases (Peña-Castillo & Tasan, 2023). Bioinformatics gains special importance in school education because it bridges the gap between theory and practical application. According to the National Science Teaching Association (NSTA, 2021). Integrating bioinformatics into school biology curricula is a strategic step towards achieving scientific education that addresses real-world issues relevant to students' lives. This inclusion helps develop scientific thinking skills, understand technological principles, and reflect on the ethical issues associated with the use of biological data (Campbell et al., 2020).

Bioethics, or the ethics of biology, is a relatively new term referring to the set of rules society establishes to address ethical dilemmas arising from biological revolutions in genetics, biotechnology, and medicine, ensuring human dignity. WHO (2021) highlights that modern advancements in biotechnologies like CRISPR-Cas9 pose unprecedented ethical challenges. Teaching bioethics has been shown to improve students' critical thinking skills by 40% compared to traditional curricula (Brock, 2020). Ethical discussions on topics such as cloning also enhance problem-solving abilities (UNESCO, 2021).

1.1 Research Problem

Through the researcher's review of several previous studies and specialized conferences on the topics of bioinformatics and the ethics associated with it, the researcher concluded the importance of keeping up with vital developments and presenting them to students, linking them to issues of science, technology, and society. Through the researcher's experience in teaching biology and sciences, he felt the students' strong desire to learn everything new, which increases their interest in the subject of biology. From here arose the necessity to conduct this research, which aims to identify the bioinformatics applications that should be included in biology textbooks and to analyze the current high school biology textbooks in light of bioinformatics applications and their ethics. Many previous studies in several countries have shown that the topic of bioinformatics and its ethical issues have not received adequate attention, and even when included in textbooks, it is done in a marginal or brief manner and does not cover important aspects of these topics. Among these studies: Bain et al. (2022), Al-Jaji (2021), and Al-Qarni (2020).

1.2 Research Questions

The current research attempts to address this issue by answering the following main question:
To what extent do biology textbooks in the Hashemite Kingdom of Jordan include bioinformatics applications and their ethical issues within the context of the relationship between science, technology,

and society? This question branches into the following sub-questions:

1. What bioinformatics applications should be integrated into 11th and 12th-grade biology textbooks in Jordan?
2. What bioethical issues are relevant to include?
3. To what extent are bioinformatics topics currently addressed?
4. How do textbooks contribute to ethical discussions in bioinformatics?

1.3 Research Objectives

The research aims to: -

- To identify the key bioinformatics applications suitable for inclusion in secondary-level biology textbooks.
- To determine relevant bioethical issues for integration.
- To evaluate the extent of current bioinformatics content.
- To assess how textbooks address related ethical issues.

1.4 Research Significance

The importance of this study is evident in the following aspects:

1. This research aligns with global educational trends that emphasize the necessity of teaching science with up-to-date topics and contemporary scientific issues that impact individuals and societies, while stimulating critical thinking in line with their values. Given the rapid developments in biotechnology and bioinformatics, it has become imperative to expand traditional curricula to include modern topics that reflect current scientific realities (Campbell, Ledbetter, & Hoopes, 2020).
2. The study will benefit those responsible for developing biology textbooks at this educational level by demonstrating the need to keep pace with scientific and technological progress through the integration of bioinformatics applications and their associated ethical values into biology curricula, while connecting them to societal contexts.
3. Additionally, both teachers and supervisors can benefit from this study, as it provides them with a reference framework for key bioinformatics applications and related ethical values that should be introduced to students.

1.5 Study Limitations

1. **Human Limitations:** The study sample was confined to biology supervisors and teachers.
2. **Geographical Limitations:** The research was limited to the Hashemite Kingdom of Jordan.
3. **Temporal Limitations:** The study focused on the first semester of the 2023/2024 academic year.
4. **Content Limitations:** The analysis was restricted to 11th and 12th grade biology textbooks for both first and second semesters.

1.6 Research Terminology

First: Bioinformatics

“Bioinformatics is an interdisciplinary field that integrates biology, computer science, and mathematics to analyze and interpret biological data, particularly genomic and proteomic data, using advanced computational tools and algorithms.” (Aufreiter, 2021).

Second: Bioethics

“Bioethics is the study of ethical issues arising from advances in medical and biological sciences, emphasizing principles such as respect, justice, non-maleficence, and autonomy.” (Beauchamp & Childress, 2019, p. 2)

2. Theoretical Framework and Review of Literature

2.1 Bioinformatics

Bioinformatics is the science that uses computers, software, and computerized databases to analyze and interpret data with the aim of solving, explaining, and interpreting many biological questions. This science deals with the massive biological data resulting from large-scale biological projects, such as genomics and proteomics. (Al-Zuhairi, 2013, p.1).

2.1.1 Objectives of Bioinformatics

One of the main goals of bioinformatics in the field of research is to understand how genes and proteins work within living organisms and to interpret their complex biochemical interactions (Baek et al., 2021). Simulation and computational modelling tools help in building accurate representations of these processes. Bioinformatics uses gene analysis techniques for strains with the aim of comparing living organisms, providing a deeper understanding of biological evolution (Altschul et al., 2020). It contributes to understanding the molecular structures and biological functions of living organisms. (Al-Azwani, I., & Al-Jardani, S. 2023). Another of its goals is to design computer systems that assist in analyzing patients' genetic profiles to provide individualized treatments for each patient. (Qasim.M., et al.2022. And the use of computer simulations to reduce the time and costs of drug discovery. (Abu-Doleh, A., & Al-Hadidi, K. 2023).

2.1.2 Applications of Bioinformatics

There are many applications of bioinformatics that have enabled scientists to handle and process vast amounts of data, reducing efforts and risks while increasing the accuracy of results. Some of these applications include molecular medicine, diagnostic medicine, preventive medicine, gene therapy, drug development, microbiome genomics applications, waste cleanup, climate change studies, alternative energy sources, biotechnology, antibiotic resistance, forensic microbiology, bioweapons creation, evolutionary studies, crop improvement, pest resistance, food quality enhancement, and developing drought-resistant varieties. Veterinary sciences (O P & Rani, 2011, p 107-108)

In academic and research contexts, bioinformatics has become indispensable. For instance, it can assist in analyzing amino acid and protein sequences, identifying gene expression patterns, and locating proteins within cells. In the field of forensic science, bioinformatics-based tools are increasingly accepted in courts and forensic agencies to determine crimes or verify parentage (Al-Khafaji & Ibrahim, 2012, p.7).

One notable example of bioinformatics applications is the use of whole genome sequencing for diagnosing genetic diseases and cancers. A study by Al-Mulla et al. (2023) in the *Arab Journal of Genomics* reported that full genome analysis contributed to diagnosing 65% of previously undiagnosed cases in Saudi hospitals. In the area of drug discovery and design, molecular docking simulations are used to predict the efficacy of drugs targeting specific proteins. According to research by Abu-Doleh and Al-Hadidi (2023), two promising drug compounds for diabetes treatment were identified using artificial intelligence algorithms at Jordan University of Science and Technology.

2.1.3 Bioinformatics Centers and Conferences Worldwide

Bioinformatics has witnessed significant growth over recent decades, driven by advances in genome sequencing, big data analysis, and artificial intelligence applications. As a result, many countries have established specialized research centers and organized symposia and workshops to promote research and collaboration in this evolving field. Examples of such countries include:

- *United States of America*

The United States is a global leader in bioinformatics, hosting numerous pioneering research centers and academic initiatives. Notably, the National Institutes of Health (NIH), particularly the National Human

Genome Research Institute (NHGRI), has supported bioinformatics research through its Computational Genomics Program (NHGRI, 2023). In addition, the National Center for Biotechnology Information (NCBI) offers vital biological databases such as GenBank (NCBI, 2023). The U.S. also emphasizes international engagement by hosting major conferences such as the Intelligent Systems for Molecular Biology (ISMB), organized by the International Society for Computational Biology (ISCB, 2023).

- *Scotland (United Kingdom)*

Scotland is renowned for its excellence in life sciences and bioinformatics. A key institution is the Roslin Bioinformatics Institute (RBI) at the University of Edinburgh, which focuses on genomic analysis and artificial intelligence applications in biology (RBI, 2023).

- *Germany*

Germany has been proactive in advancing biological and bioinformatics sciences. One of its major achievements is the establishment of the European Bioinformatics Institute (EMBL-EBI) in Heidelberg, which is considered one of the leading global centers in bioinformatics development (EMBL-EBI, 2023).

- *Jordan*

The rapid progress in life sciences, research, and healthcare has led to growing demand for bioinformatics expertise. Despite its importance, bioinformatics remains underrepresented in Jordan. There are currently no institutions exclusively dedicated to bioinformatics in the country. However, at least four centers incorporate bioinformatics as a core component of their research and educational programs. One of the key institutions is the Princess Haya Biotechnology Center (PHBC), established in 2013 at Jordan University of Science and Technology (JUST), which aims to support biotechnology research at both national and regional levels (Princess Haya Biotechnology Center, 2013).

Several bioinformatics-related conferences and workshops have also been held in Jordan. Notable examples include: The First German Jordanian Conference on Molecular Genetics of Human Diseases (2015), organized by Philadelphia University (Jordan) in collaboration with the Institute of Human Genetics and Genomics at the University of Tübingen (Germany). The International Conference on Medical Bioinformatics Ethics, organized by the Faculty of Pharmacy at Jordan University of Science and Technology (Baker & Nuser, 2019).

2.2 Bioinformatics in the Classroom

Access to biological data also presents new opportunities for science education at the secondary level by introducing students and their teachers to the field of bioinformatics. Despite the growing awareness of bioinformatics and the vast volumes of biological data produced through emerging research technologies, many teachers remain uncertain about how to relate these developments to the science taught in the classroom. Bioinformatics and large-scale biological data are also largely absent from biology curricula (Wood & Gebhardt, 2013, p.1).

Bioinformatics represents a convergence between natural sciences and modern technology. Teaching this field helps students acquire essential skills to understand and apply modern biotechnology in solving scientific problems, and to learn how computational tools and software can be used to analyze biological data. A study published in *BMC Bioinformatics* (2020) indicated that incorporating bioinformatics into education can motivate students to recognize the connections between traditional sciences like biology and chemistry, and emerging technologies such as artificial intelligence and data science. Teaching practical applications of bioinformatics also enables students to understand how to analyze genetic and proteomic data using computational tools. A study by Smith et al. (2021) demonstrated that students who learned bioinformatics applications developed a deeper understanding of molecular biology compared to those who studied the subject theoretically only.

2.2.1 Bioethical Issues

2.2.1.1 Concept and Importance

Bioethical issues refer to biological questions and dilemmas raised by modern applications, often controversial and widely debated. Perspectives on these issues vary depending on religious, cultural, legal standards, and the prevailing values of society. Some experts have worked to define and categorize these issues (Al-Khathami, 2016, p. 315).

Bioethics is a branch of ethics that addresses moral issues related to life and biological sciences, including genetic research, biological evolution, ethical concerns in healthcare and drug trials, embryo technology, genetic modification, and more (Yeshineh, 2022). The ethical consequences of these advancements can lead to social and communal tensions, especially in a world marked by inequality and rapid demographic change. Developing effective policies, laws, and regulations to address these developments—while considering their diverse social, cultural, political, and historical contexts and the ethical dilemmas they raise—is a challenging task. In pluralistic societies, public opinion must also be taken into account (Köhler et al., 2021).

The goal of bioethics is to define the necessary principles to guide scientific progress in ways that preserve human dignity. These ethical frameworks establish guidelines to empower individuals to make informed choices as free and responsible beings in the face of rapid scientific advancement. As a result of such progress, various legal and ethical challenges have emerged that relate to fundamental human rights as enshrined in international human rights declarations (Saleh, 2011, p. 248). Moreover, “bioethics seeks to balance scientific advancement with religious and social values in Arab societies” (ALECSO, 2021).

2.2.1.2 National and International Efforts in the Field of Bioethical Issues

One of the foremost guiding principles governing bioethics is the respect for human dignity, which takes precedence over the principle of scientific freedom. Accordingly, international declarations and legal frameworks consistently affirm the supremacy of this principle. In Islam, the sanctity of human dignity is explicitly emphasized in the Qur’an:

“We have certainly honoured the children of Adam and carried them on the land and sea and provided for them of the good things and preferred them over much of what We have created, with [definite] preference.”(Al-Isra:70)

“And whoever saves one life—it is as if he had saved all of mankind.” (Al-Ma’idah: 32)

In line with these values, both Islamic and Western countries have enacted laws and ethical codes that underscore the imperative of protecting human dignity. These frameworks prohibit any inhumane practices that may diminish a person’s humanity or their freedom to choose how they live. To support these principles, many countries have organized conferences, symposia, and workshops dedicated to bioethics.

2.3 Legislative and Legal Efforts

- **National legislation and policies** have been developed to create a balance between scientific advancement and the safeguarding of human dignity and rights. For instance, in the aftermath of the atrocities of World War II, the Nuremberg Code (1947) was introduced as the first document to regulate ethical research involving human subjects. It emerged from the trials of medical war crimes. (U.S. National Library of Medicine, 2022)
- **United States of America:** In the 1970s, the U.S. established the National Commission for the Protection of Human Subjects of Biomedical and Behavioural Research under the National Research Act of 1974. One of its key mandates was to conduct a comprehensive study of the ethical, social,

and legal implications of advancements in biomedical and behavioural research and technologies (Köhler et al., 2021). Additional regulatory frameworks include:

- The Health Insurance Portability and Accountability Act (HIPAA, 1996), which protects patient data.
- Ethical guidelines for genomic research issued by the National Institutes of Health (NIH). (Department of Health & Human Services, 2021)
- **Canada** enacted the Canadian Public Health Act (2022), which governs the use of health data and outlines ethical conditions for conducting research involving Indigenous populations. (Government of Canada, 2022)
- **European Union:** Adopted the General Data Protection Regulation (GDPR, 2018), along with the Oviedo Convention on Human Rights and Biomedicine (1997). (Council of Europe, 2019)
- **Arab Countries:** Some Arab nations have contributed to the formulation of bioethical legislation. Examples include:
 - Article 32 of the Saudi Health Law (2021), which pertains to medical research ethics. (Ministry of Health Saudi Arabia, 2021)
 - The Ethical Regulations for Health Research (2019) and the Center for Medical Ethics at King Faisal Specialist Hospital. (Saudi Food and Drug Authority, 2020).

2.4 Events and Conferences

Several international and regional events have been held to address emerging bioethical challenges. Notable examples include:

- **The World Conference on Medical Ethics and the Davos Forum on Technological Ethics (2023):** Organized by the World Medical Association (WMA) in Berlin, this conference focused on the ethical challenges of gene therapies. (World Medical Association, 2023, pp. 15–17)
- **The First International Conference on Bioethics in the Sultanate of Oman (March 8–10, 2015)** and the subsequent Second International Conference on Bioethics, both of which emphasized the role of bioethics in regional scientific development. (Al Shabiba Newspaper, 2020)
- **Qatar Annual Conference on Medical Ethics:** Organized by Sidra Medicine since 2010, this conference highlights bioethical issues within the context of Islamic values and jurisprudence. (Sidra Medicine, 2023)

2.5 The Ethics of Bioinformatics Issues Between Teacher and Student

Science teachers bear a significant responsibility in training learners to make informed decisions and act responsibly regarding controversial bioinformatics applications and ethical dilemmas. This can be achieved not merely by mentioning such topics in passing, but by meaningfully integrating them into the curriculum (Abu Fouda, 2010, p. 47). The role of the science teacher is to present the humane and ethical face of science and its applications, thereby enhancing students' scientific literacy. Perhaps most importantly, teachers serve as facilitators of moral and ethical reflection, promoting an appreciation of science as a tool to serve humanity—without violating cultural or religious beliefs.

The roles of the science teacher in addressing bioethical issues can be summarized as follows:

- **Facilitating Ethical Dialogue:** Teachers help students engage in discussions about complex ethical questions—such as genetic engineering or the distribution of healthcare—by leading dialogues that promote scientific reasoning and critical thinking (Meilaender, 2020).
- **Providing Ethical Frameworks:** Teachers can introduce foundational ethical theories, such as the four core principles of biomedical ethics—autonomy, beneficence, non-maleficence, and justice—to help interpret and analyze ethical issues (Beauchamp & Childress, 2019).
- **Linking Theory to Real-World Practice:** Educators help students understand ethical challenges

through the use of real-life case studies. For example, the ethical controversy surrounding the global distribution of COVID-19 vaccines provides a practical and timely context for analysis (WHO, 2021).

- **Enhancing Analytical Skills:** Teachers guide students in evaluating ethical arguments using structured tools such as cost–benefit analysis and risk–benefit assessments (Jennings, 2021).

Furthermore, **ethics in science teaching** refers to the professional standards of conduct that science teachers should uphold while planning, delivering, and assessing science lessons, and in their interactions with students, colleagues, supervisors, and administrators. These professional ethics encompass all duties and responsibilities expected of a teacher both inside and outside the classroom. As one of the most critical components of the educational process, the teacher’s effectiveness and competence are fundamental to the success of science education (Al-Shahri, 2009, p. 76).

The main challenges to integrating bioinformatics more broadly into education can be summarized into three general categories: the required infrastructure and logistical considerations; teacher knowledge of bioinformatics and ongoing professional development; and the expansive nature of bioinformatics itself, coupled with the diversity of student populations and educational objectives (Cummings & Temple, 2010).

A teacher’s success in teaching ethics in general—and bioethics in particular—requires adherence to the ethical standards and professional codes of teaching. Students often learn more through observing the behaviour of those around them than through direct instruction or advice. Therefore, it is imperative that the teacher serves as a role model, embodying the very values and ethical principles they seek to impart

3. Review of Related Studies

The researcher reviewed several prior studies that addressed the topics of bioinformatics applications and related bioethical issues, selecting several for inclusion in this study:

A study by **Al-Jaji (2022)** aimed to assess the level of awareness of bioethical issues among science teachers and supervisors in Sana’a, Yemen. The researcher adopted the descriptive methodology and conducted the study on a sample of 64 science teachers and supervisors. She developed a measurement tool composed of 18 scenarios distributed across nine bioethical issues. The study’s findings indicated a below-acceptable level of awareness among participants regarding bioethical issues. Additionally, the study revealed statistically significant differences in awareness levels in favor of teachers over supervisors, based on professional rank. However, no statistically significant differences were found based on gender or academic qualification.

Another study by **Al-Rifai and others (2022)** sought to develop a learning unit based on the Next Generation Science Standards (NGSS) aimed at fostering bioethics within high school biology education. The study was conducted on a sample of 28 male and female 12th-grade students. The researchers developed a bioethics knowledge test, and the results demonstrated that the post-test mean scores were higher than the pre-test mean scores for the experimental group. Furthermore, there were statistically significant differences between the mean scores of the experimental and control groups, indicating the effectiveness of teaching nucleic acids and bioethics to the experimental group

A study by **Al-Jaji (2021)** aimed to investigate the extent to which bioethical issues are included in high school biology textbooks in the Republic of Yemen. The study sample consisted of all biology textbooks prescribed at the secondary level. The researcher employed a descriptive methodology using content analysis. The study tool consisted of a checklist encompassing nine bioethical issues. The results revealed that bioethical issues were **not** included in the biology textbooks for grades 10 and 11. However, the grade 12 biology textbook **did** include some bioethical content. The study concluded that, overall, there is a clear deficiency in the integration of bioethical issues in Yemeni secondary-

level biology textbooks, indicating a lack of alignment between the science curriculum and modern technological developments in the field of biology.

The study by **Ahmed et al. (2020)** aimed to develop the grade 12 biology curriculum in light of bioinformatics. The researchers adopted a descriptive methodology. To achieve the study objectives, a survey was developed to identify relevant areas and applications of bioinformatics that should be addressed in the grade 12 biology curriculum. Two sets of standards were also developed: one for the curriculum objectives and one for the content, both aligned with bioinformatics principles and applications. The results indicated that the current curriculum objectives and content **poorly reflect** the standards and indicators related to bioinformatics and its applications.

A study conducted by **Martins et al. (2020)** sought to evaluate the educational impact on high school students of a series of instructional activities developed to teach basic bioinformatics skills—specifically, analyzing bacterial genome sequences and identifying coding genes using specially designed assessment tools. The central research question driving this investigation was: Are there significant changes in students' scientific and digital knowledge, interest, and attitudes toward gene regulation, genomics, and evolution after participating in bioinformatics-based activities? The study sample consisted of 387 high school students and 11 teachers from five public and private schools. The results showed that only a modest percentage of students had heard of bioinformatics in the pre-test (40.1% in the experimental group, 24.2% in the control group). In the post-test, the percentage of students who reported having heard of bioinformatics increased significantly in both the experimental and control groups, reaching **99.0%**. Overall, students expressed a positive attitude toward integrating bioinformatics-based approaches into their learning experiences, affirming the added value of such methods in science education.

A study conducted by **Widodo, Lukiati, and Amin (2017)** aimed to evaluate the need for bioinformatics-based educational materials within the *plant metabolism* course, using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). Data were collected through questionnaires distributed to students enrolled in the plant metabolism course in the Department of Biology at the University of Malang, in addition to an analysis of the course syllabus. The learning outcomes of the course revealed that bioinformatics content had not yet been integrated. All respondents reported that textbooks on plant metabolism do not include bioinformatics content and fail to explain the metabolic pathways of chemical compounds from local Indonesian plants. Participants believed that bioinformatics could provide explanations and analysis of secondary metabolic processes and facilitate the discussion of potential medicinal compounds derived from local plants. The development of instructional materials incorporating bioinformatics in the context of plant metabolism is deemed essential to improving students' understanding of the subject matter.

A study by **Abu Zaid (2015)** sought to develop a training program for pre-service science teachers specializing in biological sciences, in light of emerging fields such as bioinformatics and bioethics. The goal was to enhance integrated science process skills and scientific values as key learning outcomes of the proposed program. The researcher adopted a combined descriptive-analytical and quasi-experimental methodology, applying the study to a sample consisting of selected life science teacher preparation courses and students from the Faculty of Education. The results revealed that the subjects of bioinformatics and bioethics were absent from the course content. Furthermore, the study found statistically significant differences between pre- and post-test scores among participants in both the scientific values scale and the integrated science process skills scale, indicating the effectiveness of the proposed program in achieving its objectives.

4. Research Methodology

The study adopted a **descriptive-analytical research methodology**, which is based on portraying the phenomenon as it exists in reality by observing the actual status of the research problem, uncovering its dimensions, and identifying the relationships among its elements. In addition to description, the

descriptive method involves analysis, interpretation, comparison, and evaluation in order to arrive at meaningful assessments and gain insight into the phenomenon under study (Al-Azzawi, 2008, p. 97).

The research population and sample consisted of two categories:

- **First Category:** The biology textbooks for Grades 11 and 12, including both the first and second semester books, first edition (2022–2023), issued by the National Center for Curriculum Development under the Ministry of Education in the Hashemite Kingdom of Jordan in 2022. These textbooks also constituted the sample for content analysis in this study.
- **Second Category:** This included the entire population of biology supervisors and teachers (both male and female) across all educational regions in Jordan. A random sample was selected from two governorates: Irbid and Mafraq, comprising a total of 419 participants, including supervisors and teachers of biology. These samples were considered representative of the original population, given their comparable demographic and professional characteristics.

The researchers employed two main tools:

1. A **questionnaire** to survey the opinions of professionals in the field of science education regarding the importance of integrating bioinformatics applications and related ethical issues into the content of biology textbooks.
2. A **content analysis card** developed to evaluate biology textbooks according to bioinformatics applications and their associated ethical dimensions.

A finalized list of bioinformatics applications and ethical issues was then presented in the form of a survey to supervisors and teachers in the science education field, with the aim of determining the perceived importance of incorporating these topics into the biology textbook content.

4.1 Content Analysis Procedures

The content of the biology textbooks was analyzed using the prepared tool, following these steps:

1. **Identifying the Unit of Analysis:** The analysis sample consisted of all topics included in the biology textbooks for the secondary education stage (Grade 12).
2. **Defining the Analysis Units:** The researchers selected the topic as the unit of analysis. Accordingly, the units of analysis in this study were defined as all topics presented in each chapter of the analyzed biology textbooks (Tuaima, 2004, p. 133).
3. **Defining Analysis Domains:** The analysis domains for this study were determined based on the bioinformatics applications and associated ethical issues included in the analysis tool.
4. **Ensuring Tool Reliability:** The researcher used the analysis tool to analyze the textbooks under study. The sample was sent to other specialized analysts, and the reliability coefficient was calculated using the Holsti inter-rater reliability formula to measure the agreement between their analyses.

Table (1) presents the number of topics included in each textbook:

Table (1): Content of 11th and 12th Grade Biology Textbooks

12th Grade Biology Textbooks	Unit	Number of Topics	Number of Pages
First Semester	Chemistry of Life	14	53
	Cell Cycle and Protein Synthesis	11	38
Second Semester	Genetics	26	68
	Biodiversity and Conservation	6	30
Total		57	189

11th Grade Biology Textbooks	Unit	Number of Topics	Number of Pages
First Semester	Regulation and Homeostasis	13	31
	Digestion, Transport, and Gas Exchange	9	30
	Excretion and Reproduction	12	35
	Immunity and Antibiotics	6	20
Second Semester	Biotechnology	8	33
	Biological Processes in Plants	12	38
	Ecosystems	10	43
Total		70	230

5. Research Results and Discussion

5.1 Results Related to the First Question

What are the bioinformatics applications that should be included in biology textbooks for the 11th and 12th grades?

To answer this question, the results of the survey of the opinions of those working in the field of science teaching about the importance of including bioinformatics applications in biology textbooks were analyzed. The number of responses from the sample members was 348 supervisors and teachers, males and females. The frequency, percentages, and relative weights of the opinions on each application were calculated, as shown in Table (2).

Table (2): Results of the Survey of Science Teachers and Supervisors on the Importance of Including Bioinformatics Applications in Biology Textbooks.

No.	Application	Important (%)	Somewhat Important (%)	Not Important (%)	Cannot Judge (%)	Weighted Average (%)
1	Human Genome Project Concept	98%	0.5%	1%	0.5%	98%
2	Proteome Project Concept	97%	2%	1%	0%	98%
3	Early Diagnosis of Diseases and Identification of Their Genes	98%	2%	0%	0%	99%
4	Nucleotide Variation	98%	1%	1%	0%	99%
5	Genetic Maps	100%	0%	0%	0%	100%
6	Reducing the Occurrence of Heritable Mutations	93%	4%	2%	1%	95%
7	Preventive Medicine	89%	6%	2%	3%	92%
8	Diagnostic Medicine	81%	6%	1%	1%	88%
9	Molecular Medicine	95%	3%	2%	0%	97%
10	Gene Therapy	98%	1%	1%	0%	99%
11	Immunoinformatics (Computational Immunology)	87%	8%	3%	2%	88%
12	Development of Antibiotics	89%	6%	2%	3%	92%
13	Providing Genomic Databases for Pathogens to Enhance Drug and Vaccine Development	85%	11%	3%	1%	91%
14	Analysis of Patient Genetic Records	90%	7%	2%	1%	93%
15	Rapid Identification of Genetic Diseases Through Biological Databases	81%	6%	1%	1%	88%

16	Predicting Drug Side Effects	95%	3%	2%	0%	97%
17	Drug Design	61%	25%	12%	2%	73%
18	Drug Banks	65%	22%	11%	2%	76%
19	Personalized Medicine	92%	5%	1%	1%	95%
20	Three-Dimensional Molecular Analysis Using Computers for Treatment Development	90%	2%	3%	0%	93%
21	Modifying Current Evolutionary Theory	93%	5%	3%	0%	95%
22	Updating Evolutionary and Taxonomic Studies of Living Organisms	98%	1%	1%	0%	99%
23	Understanding Evolution Through Mutations in Nucleotide and Protein Sequences	97%	2%	1%	0%	98%
24	Classification of Living Organisms Through Nucleotide and Protein Sequence Analysis	80%	10%	10%	0%	82%
25	Identifying Genetic Similarities Between Species and Individuals	85%	8%	5%	2%	89%
26	Microbial Genome Project Concept	90%	5%	5%	0%	92%
27	Human Microbiome	88%	5%	7%	0%	90%
28	Role of Microbial Genomics in Biotechnology	70%	12%	15%	3%	76%
29	Role of Microbial Genomics in Alternative Energy Production	67%	11%	13%	9%	73%
30	Role of Microbial Genomics in Environmental Cleanup and Waste Management	88%	5%	7%	0%	90%
31	Role of Microbial Genomics in Climate Change Studies	68%	10%	15%	7%	73%
32	Role of Microbial Genomics in Ozone Layer Protection	64%	9%	18%	9%	69%
33	Genetic Improvement of Crop and Food Quality	71%	10%	11%	8%	76%
34	Improving Disease Resistance and Environmental Adaptation in Crops and Livestock	92%	1%	7%	0%	93%
35	Environmental Quality (Eco-Friendly Pesticides and Herbicides)	97%	2%	1%	0%	98%
36	Prevention and Genetic Treatment of Crop and Livestock Diseases	88%	3%	9%	0%	90%
37	Production of Hybrid Crop Varieties	94%	4%	3%	0%	96%
38	Sustainable Organic Agriculture	81%	6%	1%	1%	88%
39	Analysis of Crop Genomic Data	95%	3%	2%	0%	97%
40	Control Over the Use of Biological and Genetic Databases	61%	25%	12%	2%	73%

41	Use of Biological Information in Forensic Science	67%	11%	13%	9%	73%
42	Protection and Awareness of Biological Warfare	88%	5%	7%	0%	90%

It is evident that all the applications examined in this research are considered important for inclusion in the content of biology textbooks, according to the perspectives of science educators. All participants agreed on the importance of integrating these applications into biology textbooks, with 89% of supervisors and teachers affirming the necessity of incorporating these applications. This represents a high percentage, as shown in Table (2).

The table also reveals that some applications were deemed more critical for inclusion in biology textbooks by supervisors and teachers. These include: The Human Genome Project , Genetic Mapping , Genetic Fingerprinting, Cloning ,Nucleotide Variation.

These applications were highlighted due to their strong connection to issues of science, technology, and society (STS), which directly impact human life. On the other hand, comparative biology and molecular medicine were considered less important. This may be attributed to their highly specialized nature, which may not directly affect human life or society in a tangible way.

The findings of this study align with the results and recommendations of several previous studies, including Ibrahim (2021) Ahmed, Darwish, and Abdel Wahab (2020), Al-Qarni (2020). These studies similarly emphasized the importance of integrating bioinformatics applications and ethical considerations into biology curricula to enhance students' understanding of modern biological sciences and their societal implications

Key Findings

- Over 90% of educators deemed foundational topics (e.g., Human Genome Project, genetic mapping) “essential.”
- Advanced applications (e.g., climate change bioinformatics) received lower priority (73%).

5.2 Results Related to the Second Question

What are the bioethical issues that should be included in biology textbooks for the 11th and 12th grades?

To answer this question, the results of the survey of the opinions of those working in the field of science teaching about the importance of including bioethical issues in biology textbooks were analyzed. The frequency, percentages, and relative weights of the opinions on each issue were calculated, as shown in Table (3)

Table (3): Results of the Survey of Science Teachers and Supervisors on the Importance of Including Bioethical Issues in Biology Textbooks.

No.	Bioethical Issue	Important (%)	Somewhat Important (%)	Not Important (%)	Cannot Judge (%)	Weighted Average (%)
1	Human Cloning	97%	2%	1%	0%	98%
2	Genetic Engineering	98%	1%	1%	0%	99%
3	Privacy of Genetic Information	80%	4%	16%	9%	82%
4	Gene Therapy	94%	4%	3%	0%	96%
5	Artificial Insemination Methods	71%	11%	18%	7%	77%
6	Gender Selection	64%	9%	26%	11%	69%
7	Human Genetic Enhancement	71%	11%	18%	7%	77%

8	Stem Cell Research	90%	5%	5%	0%	92%
9	Hormonal Therapy	67%	11%	22%	6%	73%
10	Anti-Aging Research	64%	14%	13%	9%	67%
11	Evolutionary Biology Ethics	85%	3%	12%	0%	86%
12	Alternative Medicine	81%	13%	5%	1%	88%
13	Genetically Modified Foods	92%	1%	7%	0%	93%
14	Ownership of Biological Data and Resources	71%	11%	18%	7%	77%
15	Fair Use of Data	90%	5%	5%	0%	92%
16	Animal Testing	85%	3%	12%	0%	86%
17	Biological Warfare	88%	5%	7%	0%	90%
18	Environmental Ethics	97%	2%	1%	0%	98%

The results of the table indicate that all the issues under investigation were significant in terms of their inclusion in the content of the 12th-grade biology textbook, according to the perspectives of those working in the field of science education. All of them agreed on the importance of incorporating these issues into biology textbooks, with the relative weight of supervisors and teachers who affirmed the importance of including these issues in biology textbooks in the Hashemite Kingdom of Jordan reaching 85%, which is a high percentage. The table also reveals that some issues were deemed more important by the professionals, such as genetic engineering, gene therapy, and human cloning. The least important issues were anti-aging and gender selection. This may be due to the fact that these issues are directly connected to human life and have a significant impact on society. The least important issues, anti-aging and gender selection, may be attributed to the professionals' belief that these issues are not of great importance and do not directly affect human life and societal values. These results confirm the researcher's assumption regarding the importance of including these issues in the content of 12th-grade biology textbooks.

Key Findings

- High consensus on core issues (e.g., cloning, gene therapy).
- Emerging topics (e.g., bioweapons) received moderate attention.

5.3 Results Related to the Third Question

To what extent do biology textbooks include bioinformatics applications?

To answer this question, the content of biology textbooks for the 11th and 12th grades in Jordan was analyzed in light of their inclusion of bioinformatics applications. The results of the analysis are shown in Table (4).

Table (4): Results of the Content Analysis of Biology Textbooks in Light of Their Inclusion of Bioinformatics Applications.

Textbook	Percentage of Applications	Percentage of Topics	Percentage of Pages
12th Grade (First Semester)	2.4%	4%	1.1%
12th Grade (Second Semester)	12%	3.1%	7.1%
Total (12th Grade)	14.4%	3.5%	4.2%
11th Grade (First Semester)	0%	0%	0%
11th Grade (Second Semester)	7%	4.3%	4%
Total (11th Grade)	7%	4.3%	4%

Through these results, the researcher concluded that the percentage of bioinformatics applications included in biology books for the twelfth and twelfth grades was low, and the percentage of topics and the number of pages that contained these applications were also low.

Key Findings

- Only 14.4% of bioinformatics applications were covered in 12th-grade textbooks.
- 11th-grade textbooks lacked any bioinformatics content.

5.4 Results Related to the Fourth Question

To what extent do biology textbooks include bioethical issues?

To answer this question, the content of biology textbooks for the 11th and 12th grades in Jordan was analyzed in light of their inclusion of bioethical issues. The results of the analysis are shown in Table (5).

Table (5): Results of the Content Analysis of Biology Textbooks in Light of Their Inclusion of Bioethical Issues.

Textbook	Percentage of Issues	Percentage of Topics	Percentage of Pages
12th Grade (First Semester)	0%	0%	0%
12th Grade (Second Semester)	11%	6.3%	2%
Total (12th Grade)	11%	3.5%	1%
11th Grade (First Semester)	0%	0%	0%
11th Grade (Second Semester)	0%	0%	0%
Total (11th Grade)	0%	0%	0%

The number of topics that included these issues in all books was two out of (57) topics, in both the biology books for the first and second semesters, at a rate of (3.5%). These two issues were included in the biology book for the second semester, and their rate was (6.3%) of the total topics in it. No ethical issue was mentioned in the biology book for the eleventh grade for the first and second semesters.

Key Findings

- Minimal coverage of bioethics, limited to genetic engineering.
- No ethical discussions in 11th-grade textbooks.

6. Conclusion

The study concluded that the percentage of bioinformatics applications and ethical issues included in the 12th-grade biology textbooks is low and does not align with the trend of keeping up with the latest biotechnological developments and their associated ethics. The researcher recommended that biology curriculum planners and developers in Jordan should pay attention to including bioinformatics applications and ethical issues related to science, technology, and society in biology textbooks.

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