UNDERSTANDING THE IMPACTS OF BIOTECHNOLOGY: A SURVEY AMONG THE UNIVERSITY STUDENTS IN CHITTAGONG

By

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A thesis submitted to the Department of Mathematics and Natural Sciences in partial fulfillment of the requirements for the degree of Bachelor of Science in Biotechnology

Department of Mathematics and Natural Sciences

BRAC University

May 2024

DECLARATION

It is hereby declared that

1. The thesis submitted is my original work while completing my degree at BRAC University.

2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.

3. The thesis does not contain material that has been accepted or submitted, for any other degree or diploma at a university or other institution.

4. I have acknowledged all of the main sources of help.

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APPROVAL

The thesis/project titled "Understanding the impacts of biotechnology: A survey among the University students in Chittagong" submitted by Nishat Tasnim (18136071) of Spring has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Science in Biotechnology on May.

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ABSTRACT

Biotechnology, a field of science dealing with modifying living organisms for various purposes, remains a subject of curiosity and uncertainty for many individuals. This study endeavors to shed light on the perceptions and understanding of Genetically Modified Organisms (GMOs) among tertiary-level students in Chattogram, Bangladesh. Through a comprehensive survey conducted among 319 students across diverse academic disciplines in Chattogram, this research seeks to unravel the intricacies of public awareness and attitudes towards biotechnological innovations. For the study 109 Chittagong University (public university), 104 from Asian University for Women, and 106 from the University of Science and Technology (private university) participated in this survey. With due permission and following the standard procedures, the survey was carried out face-to-face in the institutions through a pretested questionnaire. While almost every major student (96.2%) was aware of the term Biotechnology, the study highlighted that the educational majors had a great influence on the participants while responding to the questions, only 57.69% students of Physical Sciences and 71.56% students from other majors reported familiarity with GE/GMOs. Maximum students from all the majors demonstrate a comparatively lower understanding between the difference of hybrid and GM crops. The study showed that a maximum of the participants had good familiarity and knowledge about the biotech products used in the health sectors, whereas a large proportion of the participants from non-biological subjects had either slight familiarity or no familiarity with biotech products of the agriculture and food industry. In cases of the applications of biotechnology in both healthcare, agriculture, and food sectors, they showed agreement, while a good number of participants were neutral about the statements. But when they were asked about the negative impacts of biotechnology on health and the environment, the majority of the respondents were in dilemma while many of them disagreed and few agreed. Overall, the responses were mostly affected by the sources of information related to biotechnology while the scientific articles remain the primary source favored by today's students when seeking information about biotechnology.

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INTRODUCTION

1. Introduction:

Biotechnology, the use of living organisms to develop new products or processes, has become an essential aspect of modern-day life. One of the most controversial aspects of biotechnology is the development and use of genetically modified organisms (GMOs). GMOs are organisms whose genetic material has been altered in such a way which does not occur naturally like mating or natural recombination. It has become a crucial field of study in the modern world. Despite the potential benefits of GMOs to boost agricultural productivity, food security, higher crop yields, resistance to pests, and enhanced nutritional and even medical advancements, they have not gained widespread acceptance in many countries, including Bangladesh. People in Bangladesh have misconceptions and fears regarding GMOs. The misconception and lack of knowledge about GMOs in Bangladesh have led to fears and doubts about their safety and efficacy. This has led to challenges in the country's economic and environmental development, as it hinders the adoption of modern technologies that can drive growth and sustainability

1.1 Biotechnology applications in a variety of industries worldwide

Biotechnology, an inspiration of innovation, transforms industries worldwide. From agriculture to medicine, energy, and conservation, its applications revolutionize solutions to challenges and opportunities. In agriculture, biotech enhances crop traits, boosting yields sustainably against pests and diseases. In medicine, it pioneers personalized treatments and biopharmaceuticals, advancing healthcare with hope against once-incurable diseases. Moreover, biotech addresses energy and environmental needs with biofuels and eco-friendly materials, curbing climate change and ecological harm. In essence, biotechnology's widespread adoption shapes industries globally, unlocking new possibilities for a sustainable, prosperous future.

1.1.1 Biotech Companies: Focus Areas and Achievements :

Now, let's delve into a detailed exploration of specific biotech companies, their focus areas, and notable achievements. These innovative businesses, blending technology and biology, play a crucial role in the biotech field.

Table 1: Biotech Companies and Their Focus Areas

Company	Location	Focus Area	Notable Achievements
Novo Nordisk	Denmark	Diabetes Care, Hemophilia Care, Growth Hormone Therapy	Multiple life-enhancing drugs
Moderna	USA	Messenger Ribonucleic Acids (mRNA)	Developed mRNA-based COVID-19 vaccine
BioNTech	Germany	Tailored Cancer Treatments	Co-developed the first COVID-19 vaccine
Regeneron Pharmaceuticals	USA	Drug Treatments for Various Medical Conditions	Conducts one of the world's largest gene sequencing operations
Vertex Pharmaceuticals	USA	Drug Treatments for Cancer, Cystic Fibrosis, Autoimmune Diseases, Neurological Disorders	Leading in the creation and marketing of treatments
Jazz Pharmaceuticals	Ireland	Drug Products for Narcolepsy, Psychiatry, Pain Management, Oncology	Specializes in drug products addressing multiple conditions
Incyte Corp	USA	Small Molecule Drugs for Oncology	Notable for Jakafi, a treatment for myelofibrosis
Novavax, Inc.	USA	Vaccines for Infectious Diseases	Focus on vaccine development worldwide
Vir Biotech Inc.	USA	Treatments for Infectious Diseases	Sotrovimab for COVID-19 and a robust pipeline of other therapies

Intriguingly, the biotechnology industry comprises a multitude of companies dedicated to the fusion of biology and technology, where their mission is to develop drugs and related products for the treatment of diseases and medical conditions. These visionary enterprises cast their influence over a spectrum of domains, encircling not only pharmaceuticals but also medical devices, diagnostics, biofuels, biomaterials, pollution control, and beyond. This comprehensive reach underscores the universal impact of biotechnology on our modern world.

1.1.2. Global Adoption of GMO Technology: Economic Benefits

Reflecting on the past decade, there has been a significant increase in the utilization of genetically modified organisms (GMOs) in both food and agricultural sectors. The adoption of GM crops has not only led to enhanced crop yields but has also played a pivotal role in the socio-economic advancement of developing nations. Countries such as Brazil, Argentina, India, and China have

emerged as key players in this regard. Despite concerns among the public regarding the use of GMOs in agriculture, developing countries are increasingly embracing them. This trend can be attributed to the potential of these modified plants to increase crop productivity, minimize reliance on harmful chemicals, and enhance the nutritional value of food. Consequently, this transition is not only revolutionizing farming practices but is also positively impacting the livelihoods of individuals within these nations. It is generating novel opportunities for farmers while fostering the growth of the biotechnology industry.

According to a report by the International Service for the Acquisition of Agri-Biotech Applications (ISAAA), countries like the United States, Canada, Brazil, and Argentina have successfully adopted GMO technology, significantly benefiting their economies. For instance, the ISAAA report states that the adoption of genetically modified (GM) crops in the United States resulted in an increase in farm income of $43 billion between 1996 and 2015. Similarly, the report also indicates that the adoption of GM soybeans in Brazil resulted in an increase in production of 48 million tons between 1996 and 2015, contributing to the country's economic growth. (ISAAA, 2021)

Figure 1:

GM HT soybeans: Summary of average gross farm level income impacts 1996–2016 ($/hectare)

Average gross farm income benefit (after deduction of cost of technology) | Aggregate income benefit (million $)

	Average gross farm income benefit (after deduction of cost of technology)	Aggregate income benefit (million $)
1st generation GM HT soybeans		
Romania (to 2006 only)	104	44.6
Â		
Argentina		18,567.3
Â		
Brazil	32	7,220.2
Â		
US	34	13,297.3
Canada	21	200.6
Paraguay		1,199.1
Uruguay	19	183.2
South Africa	9	38.4
Mexico	40	6.1
Bolivia	97	775.6
2ndt generation GM HT soybeans		
US and Canada		
Â		
Intacta soybeans		
Brazil	113	4,207.4
Argentina	64	497.4
Paraguay	122	437.1
Uruguay	62	69.5

Transitioning from the global adoption of GMO technology, let's explore the research by Graham Brookes and Peter Barfoot, highlighting the significant benefits of using genetically modified (GM) crop technology in agriculture. The study found that GM crops have led to increased yields in the US and Canada, by the adoption of the second generation of GM HT and this has resulted in higher average gross farm income benefits , reduced costs, primarily through lower expenditure on weed control (mainly herbicides), and improved environmental sustainability compared to traditional farming methods.

Several countries have experienced significant economic benefits from the adoption of genetically modified herbicide-tolerant (GM HT) soybeans. Argentina, for example, has seen a total income benefit of $18,567.30 million due to both cost savings and second crop gains, similarly Brazil and the US have benefited from cost savings with an aggregate income benefit of $7,220.20 million and $13,297.30 million, and Canada have further increased economic benefits with a total income benefit of $ $662.8 million (Brookes & Barfoot, 2018).

The area of biotechnology is a fantastically revolutionary and rapidly evolving region that has been impacting the global socio-monetary panorama in extensive approaches in recent years. The mega-international locations at the leading edge of biotech studies and improvement including America, China, Japan, and Germany, have invested heavily on this subject. Main to the advent of high-paying jobs and attracting pinnacle skills from around the sector. According to the document by the Biotechnology Innovation Organization (BIO) and the Council of State Bioscience Associations (CSBA), the U.S. bioscience industry employed 2.1 million people across over 127,000 U.S. business establishments in 2021, and has increased employment by 11% since 2018(BIO & CSBA, 2022).This highlights the industry's position in generating exceptional jobs and contributing to the country’s economic increase.

In addition, the report mentions that biotech companies have played a vital role in developing COVID-19 vaccines and therapeutics, with 747 novel compounds currently in development (BIO & CSBA, 2022).This indicates that the biotech industry attracts top talent and fosters innovation. Similarly, the information provided about China's biotech sector also supports the claim. The Made in China 2025 Initiative aimed at developing key industries, including biotech, and China has invested heavily in biotech since 2010 (Dutton, 2022). Transitioning to the global stage of biotech crops, developing countries emerge as key players, planting more biotech crops than their industrial counterparts. The shift is notable, with 24 developing countries accounting for 56% of global biotech hectares in 2019 while 5 industrial countries took the 44% share (ISAAA, 2019).

FIGURE 2.
DISTRIBUTION OF BIOTECH CROPS IN DEVELOPING AND INDUSTRIAL COUNTRIES IN 2019

Source: ISAAA, 2019

Industrial Biotechnology, serving as an economic catalyst, unfolds a myriad of opportunities for Bangladesh also, aligning seamlessly with the nation's economic ambitions. Notable accomplishments by the Bangladesh Council for Scientific and Industrial Research (BCSIR), such as developing virus-free potato seeds and high-quality bananas, exemplify the practical applications of industrial biotechnology (Choudhury & Hossain, 2013).

1.1.3. Biotechnology for the advancement of developing nations

Biotechnology holds significant promise for communities grappling with environmental challenges and economic constraints. Its potential lies in enhancing agricultural productivity, fortifying crops against environmental stressors, and improving nutritional quality. By leveraging biotechnological innovations, communities can mitigate the impact of adverse conditions such as drought and soil erosion, thereby fostering resilience in farming systems.

In the challenging environment of the Horn of Africa, encompassing Djibouti, Eritrea, Ethiopia, Kenya, and Somalia, approximately 70 million people endure malnutrition, food scarcity, and famine due to inhospitable climates unsuitable for efficient agriculture (FAO, 2000). In African developing countries where agriculture heavily relies on water availability, vulnerability to various challenges like malnutrition, poverty, and vector-borne diseases is high due to weak infrastructures and fragile ecosystems, these African nations lack the economic means and well-defined strategies to effectively address such challenges. However, amidst these adversities, there's a glimmer of hope offered by biotechnology. Collaborative efforts between organizations like the United Nations Development Program and the West African Rice Development Association (WARDA) have resulted in significant breakthroughs. For example, the development of the New Rice for Africa (NERICA) variety through biotechnological advancements has provided tailored solutions for farmers facing resource constraints (AfricaRice. n.d.). This protein-rich rice variety, created by crossing African and Asian species, exhibits resilience to drought and acidic soils, and it offers general resistance to a wide range of African insect pests (Ministry of Foreign Affairs of Japan, n.d.). The adoption of NERICA varieties (NERICA-1 to NERICA-18), particularly NERICA-4, renowned for its resilience to drought and phosphorus deficiency, has lifted approximately 8 million people out of poverty and food insecurity across over 10 Sub-Saharan African countries (AfricaRice, n.d.).

The Philippines has embraced biotechnology to fortify its agricultural sector, notably in the cultivation of papaya, a staple crop crucial for both its economy and nutrition. Managed predominantly by Filipino small-scale farmers, papaya production is locally consumed, enriching the national diet with essential nutrients and antioxidants. However, the industry faced significant challenges from the Papaya Ringspot Virus (PRSV) disease, particularly on Luzon Island. In response, the introduction of genetically modified (GM) papaya varieties, resistant to PRSV, emerged as a promising solution, following the success witnessed in Hawaii. According to the U.S. Agency for International Development (n.d.),it lead to increased yields across approximately 9,000 hectares of cultivated land, collaborating with local entities and Monsanto also the Philippines adopted GM papaya mostly by small-scale farmers with annual production from 77,000 to 132,000 tons, contributing significantly to the nation's economy by US$70 million over a 16-year period, underscoring the economic viability and sustainability of biotechnological interventions in agriculture.

Furthermore, the utilization of biotechnology in these regions extends beyond crop improvement. It includes initiatives such as promoting rural education to raise awareness about the benefits of biotechnology in diversifying agricultural practices, such as fisheries and floriculture. Countries like Kenya, Nigeria, and Bangladesh, which are part of the 149 developing countries, are incorporating biotechnology into these initiatives to address health, basic needs, and daily life usage, thereby contributing to the reduction of financial crises, global poverty, and hunger in regions like South Asia, particularly in Pakistan (Usman, n.d.).

Additionally, the production of high-quality tissue culture-reared plantlets and the emergence of rural biotech industries contribute to income generation, particularly for women. Moreover, biotechnology facilitates the production of genetically modified organisms (GMOs) for food production and alternative products like biodiesel, biofertilizers, and biopesticides, offering sustainable solutions to enhance agricultural productivity and economic development in arid and semi-arid regions of Africa (DaSilva, Baydoun, & Badran, 2002).

Plant biotechnology plays a pivotal role in addressing global challenges such as hunger and food insecurity. In Kenya, for instance, the adoption of tissue culture techniques for cultivating disease-free banana plantlets has proven instrumental in increasing yields. This approach not only boosts

productivity but also safeguards farm household incomes, particularly in regions where traditional cash crops like coffee are facing challenges (Kabunga, Dubois, & Qaim, 2011). Similarly, cassava clones sourced from the International Institute of Tropical Agriculture in Nigeria exemplify the transformative potential of plant biotechnology (Fukuda et al., 2010). These disease-free plantlets, propagated through biotechnological methods, serve as a starting point for enhancing crop productivity. Through the implementation of effective crop protection techniques, the productivity of cassava crops is maintained, contributing to food security and economic stability (FAO, 2001).

In terms of public health and biotechnology, the Serum Institute of India (SII) stands as a beacon of innovation and progress. Since the 1970s, when it introduced its first DTP vaccine, SII has been instrumental in shaping the landscape of global immunization efforts. Emerging from India, a country with diverse healthcare challenges, SII has demonstrated remarkable prowess in vaccine development and production. Today, its vaccines reach one in every three children worldwide, a testament to the transformative impact of biotechnological advancements on public health outcomes (Dhodi, 2013). Through relentless research and unwavering commitment to quality, SII has not only changed its own fate but has also elevated India's stature as a frontrunner in the field of biotechnology and vaccine manufacturing.

1.2. Biotechnological research and developments in Bangladesh

In the heart of Asia lies Bangladesh, a country that, despite its modest dimensions, houses an extraordinarily dense population, nearly 130 million strong, within an expanse of 55,598 square miles, rooted in agriculture, with 80% of its population tied to its harvests for sustenance(Church of Bangladesh, n.d.).Bangladesh faces with the pressing need to confront difficulties such as climate change-induced disasters amid its growing economic landscape . In this environment, the inspiration of biotechnology illuminates the path forward, offering a crucial instrument to strengthen crop resilience against the harshness of a changing climate. This part embarks on a journey through the strides of biotechnological research and development within the borders of Bangladesh, unraveling the intricate tapestry intertwined by key institutions.

1.2.1 Bangladesh Council of Scientific and Industrial Research (BCSIR): The Bangladesh Council of Scientific and Industrial Research (BCSIR), founded in 1973, plays a crucial role in propelling the rapid growth of biotechnology in Bangladesh (BCIR, 2018). This institution stands

as a formidable player, providing crucial support to scientists and researchers dedicated to advancing biotechnological progress. BCSIR's contributions extend across various domains, notably in environmental sustainability and agriculture. It also working on assessing the effect of exogenous allantoin to improve the salt tolerance of Oryza sativa and Solanum tuberosum (BCSIR, 2023).

Within the realm of environmental sustainability, BCSIR has developed bioremediation techniques combating pollution effects, alongside efforts to create crops resilient to water-scarce environments (BCSIR, 2021). The institution's involvement extends to therapeutic solutions and vaccines for prevalent diseases like dengue fever, showcasing a comprehensive approach to public health. In summary, BCSIR's inception has played a pivotal role in propelling biotechnological research and development, fostering cutting-edge solutions with the potential to elevate agriculture, environmental integrity, and public health.

1.2.2 National Institute of Biotechnology (NIB): Established in 1999, the National Institute of Biotechnology (NIB) in Bangladesh is a key player in biotechnology research. It focuses on agricultural advancements, including genetically modified crops resistant to pests, drought, and soil salinity, through local and global collaborations. NIB's endeavors extend to vaccine and medicinal treatments for prevalent diseases, exemplified by its pursuit of a dengue infection with green Nano biotechnology (Zohra et al., 2022). Simultaneously, the institute actively engages in expedited screenings for contagious illnesses, enhancing disease identification and supervision. Beyond health, NIB tackles ecological predicaments, developing bioremediation techniques for contaminated sites and crafting crops suited to water-scarce habitats (Azubuike, Chikere, & Okpokwasili, 2016). To prevent and control contamination of the food chain by heavy metals and trace elements in agricultural lands they are working on microbial bioremediation of heavy metal.-pollution (NIB, 2015), especially from heavy metals, can seriously harm our health, causing diseases like cancer and even death. These toxic metals build up in the environment, especially in agricultural areas, where they can get into the food we eat. In places like Bangladesh, where there are a lot of industries, pollution is a big problem. To tackle this issue, scientists are looking into microbial bioremediation, which is a method using microorganisms to clean up the environment from these harmful metals. They are also developing of cost-effective rice nitrogen biofertilizer for sustainable agriculture, which is the replacement of chemical urea fertilizer (NIB 2023).

NIB's research initiatives cover a spectrum of topics crucial for Bangladesh's development. These include enhancing the productivity, nutritional quality, and shelf life of food products, developing crops resistant to stress, and promoting the use of underutilized crops. Additionally, the institute actively engages in waste reduction, bioremediation, and the use of biocontrol agents for pest management(SAARC Secretariat, n.d.). for example, they are working on the development and production of eco-friendly enzymes for use in the leather industry (NIB 2023). These efforts contribute to sustainable agricultural practices and environmental conservation.

1.2.3. International Rice Research Institute (IRRI): The International Rice Research Institute (IRRI) is actively engaged in enhancing rice varieties, particularly those resilient to salinity and flooding. For instance, IRRI's efforts include the development of rice varieties with increased iron, zinc, and provitamin A content, aiming to address micronutrient deficiencies (International Rice Research Institute, n.d.). These fortified rice varieties serve as valuable supplements to existing strategies aimed at mitigating such deficiencies. Additionally, IRRI is dedicated to the creation of short-duration cold-tolerant rice varieties tailored for the Haor areas of Bangladesh, contributing to agricultural resilience and productivity in this region(International Rice Research Institute, n.d.).

1.2.4. Economic Impact: The economic benefits of biotechnological interventions in Bangladesh are evident in various sectors, including agriculture and pharmaceuticals. For instance, the country aims to.of bt cotton Dr. Mohammad Abdur Razzaque, Bangladesh's agriculture minister, expressed optimism about bt cotton cultivation which can meet 20 percent of its yearly demand through domestic cultivation, also field experiments conducted by CDB revealed that farmers could potentially earn an additional $900 per hectare from cultivating Bt cotton compared to traditional varieties (Ahmad, 2023). Furthermore, the introduction of Bt cotton cultivation holds promise for boosting cotton production domestically, potentially reducing lead time and production costs for the textile industry. According to The Daily Star, in the pharmaceutical sector, the local market size of the industry has shown remarkable growth, reaching TK 25,000 crore ($3 billion) in 2019, compared to TK 18,755.6 crore in 2017 and around TK 9,390 crore in 2012. Additionally, Bangladesh is on track to becoming a $6 billion pharma market by 2025, as reported by an Irish market research firm. This growth reflects the increasing self-sufficiency in manufacturing pharmaceutical ingredients within the country. According to Bangladesh Bureau of Statistics, the pharmaceutical industry contributes around 1.83% of the total GDP of Bangladesh.

Moreover, the successful cultivation of genetically modified crops like Bt brinjal demonstrates the economic benefits of biotechnology in agriculture. Increased marketable yields, reduced pesticide application, and economic gains signify the potential of biotechnological advancements to transform agricultural landscapes and enhance farmer livelihoods. Overall, these examples highlight the significant economic advantages of embracing biotechnology in Bangladesh, both in terms of agricultural productivity and pharmaceutical manufacturing self-sufficiency.

1.2.5. Forensic and Bioinformatics Contributions: Bangladesh's foray into forensic science, exemplified by the National Forensic DNA Profiling Laboratory, showcases the nation's capabilities in utilizing biotechnology for legal and investigative purposes. Moreover, the integration of bioinformatics technology underscores Bangladesh's commitment to advancing research capabilities, as seen in the sequencing of the jute genome and the genome of the fungus *macrophomina phaseolina*. These endeavors highlight collaborative efforts between academia, private entities, and government institutions (Majumder et al., 2018) (Islam et al., 2012).

1.2.6. Plant Biotechnology and Tissue Culture: The history of plant biotechnology in Bangladesh traces back to the late 1970s, marked by endeavors in tissue culture. Academic institutions, research organizations, and NGOs have collectively contributed to the development of in vitro regeneration protocols. Commercial utilization of these protocols holds significant promise for agricultural productivity and economic growth in Bangladesh.

1.2.7. Innovations in Pharmaceuticals: In line with Bangladesh's efforts, various pharmaceutical companies worldwide have made significant contributions to biotechnological research. Below is a summary of their focus areas and notable achievements, highlighting their dedication to advancing healthcare and scientific knowledge.

Table 2 : Contributions from Pharmaceutical Companies in Biotechnology

Pharmaceutical Company	Biotechnology Research Involvement
Opsonin Pharma	• Mentioned that they have a Biotech Division and conduct research on recombinant DNA technology (product: **Acerux Cream, Gemifloxacin)**.
Eskayef Pharma	• Mentioned that they have a Biotech Division and conduct research on biologics, • Eskayef Bangladesh Limited has tried to produce drugs that can treat Covid-19, including the generic Remdesivir, which is used for treating Covid-19 patients. They also mention the preparation to produce the Japanese drug Avigan, which is also used to treat Covid-19.
Beximco Pharma	• Engaged in research on biologics, biosimilars, and is involved in biotechnology research. Mentioned that they have conduct research on biologics, has an agreement that particularly target-specific high-value **monoclonal antibodies**, in Bangladesh.
Incepta Pharma	• Develops biosimilars and is engaged in biotechnology research. Mentioned that they have a dedicated Biotech Division, which is working on Developing glycosylated biomolecules, including monoclonal antibodies and insulin analogues. • They also have a research collaboration with the International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b) to develop a new generation of low-cost vaccines for infectious diseases.
ACI Pharma	• Engaged in research on biologics and biosimilars, and is involved in biotechnology research. Mentioned that they have a Biotech Division and conduct research on recombinant DNA technology (Product: **Glarine Recogen etc.),** • Has a biotech division that is involved in research on genetically modified crops and seed production, as well as the production of biofertilizers, biopesticides, and biocontrol agents for agriculture.
Square Pharma	• Conducts research on biologics and biosimilars, and is involved in biotechnology research. Mentioned that they have a Biotech Division and conduct research on recombinant DNA technology (product: **Darboren**). • (BCSIR) & Square Pharmaceuticals Ltd. has collaborated to develop new pharmaceuticals and biotechnology-based products. Together, they have conducted research on natural products, such as medicinal plants, for the development of new drugs.
Beacon Pharma	• Development of biosimilars, recombinant proteins, monoclonal antibodies, (product: **Caviral (Entecavir 0.5mg))** and vaccines for various diseases such as cancer, hepatitis B, and COVID-19. • A dedicated plant has been established to produce antibiotics, following strict FDA Good Manufacturing Practice regulations. Specifically, it focuses on cephalosporins, a potent antibiotic group effective against diverse bacteria.

1.2.8 Medical biotechnology: Esteemed institutes such as the Institute of Public Health (IPH) and the International Centre for Diarrheal Disease Research, Bangladesh (icddr'b) spearhead medical biotechnological research, emphasizing vaccines and disease management. Initiatives led by the Director General of Health Office underscore a national commitment to medical biotechnology, covering stem cell research, DNA-based diagnostics, and pharmacogenomics (Choudhury & Hossain, 2013). In Bangladesh, the landscape of DNA-based diagnostics is evolving, with notable institutions like DNA Solution Ltd. pioneering molecular diagnostic services. Additionally, other institutions in the medical sector are making significant contributions. For instance, the Bangladesh Council of Scientific and Industrial Research (BCSIR) is actively involved in various projects, including the development and characterization of neutralizing antibodies against SARS-CoV-2 infection (BSCIR 2023). According to DNA Solution Ltd. (n.d.),it is the first Molecular Diagnostic Lab of its kind, epitomizes Bangladesh's endeavor towards cutting-edge medical technologies. In addition to DNA Solution Ltd., other prominent institutions are contributing to DNA-based diagnostics in Bangladesh. For instance, Epidemiology, Disease Control, and Research (IEDCR) is renowned for its utilization of Real-time PCR (Polymerase Chain Reaction) technology. They employ Real-time PCR as a key tool in the detection and characterization of pathogens responsible for infectious diseases, including viral outbreaks such as dengue fever and influenza. Such initiatives hold promise for advancing healthcare practices in Bangladesh by tailoring treatments to individual genetic profiles.

1.2.9. Agriculture biotechnology: Traditional methods like breeding and marker-assisted selection, combined with cutting-edge genetic engineering, are instrumental in ensuring the resilience and productivity of crops. A key focus of modern agriculture is the development of stress-tolerant crop varieties, capable of withstanding environmental challenges like floods, droughts, and soil salinity exacerbated by climate change. Institutions such as the International Rice Research Institute (IRRI) and the Cereal Systems Initiative for South Asia (CSISA) are leading efforts in this domain. For instance, IRRI focuses on improving rice varieties including those resilient to salinity and flooding while CSISA promotes the adoption of stress-tolerant varieties in South Asia. Collaborative efforts among research institutions, development organizations, and governments such as initiatives like USAID's Feed the Future program support country-driven approaches to address poverty, hunger, and undernutrition, fostering partnerships

with organizations like IRRI, CGIAR, and CSISA (Feed the Future Bangladesh, 2022) . The CSISA-BD initiative commenced its activities within the agricultural domain under the 'Feed the Future' . Primarily centered on rice-centric agricultural practices, the project additionally encourages the growth of grains like wheat and maize during arid periods. Furthermore, it supports the method of rice-fish co-cultivation, wherein fish rearing is integrated with rice cultivation practices (Ahmed, Akhter & Hernandez, 2016).Through these partnerships, the agriculture sector aims to ensure sustainable growth and food security in the face of climate change challenges.

1.2.10. Environmental biotechnology: Bangladesh, amidst its environmental challenges, relies on biotechnology as a vital tool. Microorganisms play a pivotal role in waste processing, detoxification, and the development of biofuels, bolstering environmental preservation efforts (Diba et al., 2021).Several institutions in Bangladesh are actively engaged in plant and environmental biotechnology, contributing significantly to research and development efforts in these fields (Table 3).SUST is also leading efforts in two significant projects. According to the Sylhet Agricultural University (n.d.), One involves the Bioconversion of organic municipal solid wastes into bioresources through the production of industrially important recombinant enzymes and biodiesel, funded by IDCOL and the World Bank. Another project focuses on the development of an Environmentally Friendly Biological Solar System for Renewable Electricity Production. The ongoing research landscape, spanning animal and plant biotechnology, underscores Bangladesh's resolve to bridge the gap with developed nations in this crucial domain.

Furthermore, the National Institute of Biotechnology (NIB) is actively engaged in the development and production of eco-friendly enzymes tailored for application in the leather industry. By replacing conventional chemical-based processes with environmentally sustainable enzyme-based alternatives, this initiative seeks to minimize environmental pollution and foster sustainable practices within the leather manufacturing sector, thus reducing its overall environmental footprint (NIB 2023).

Simultaneously, the Bangladesh Council of Scientific and Industrial Research (BCSIR) has initiated a comprehensive project focusing on the assessment of macro and microplastic pollution in Bangladesh. This undertaking involves examining the impact of plastics on the environment and exploring potential recycling methods to mitigate their adverse effects. Through this project,

BCSIR aims to evaluate the extent of plastic pollution in Bangladesh and develop effective strategies for recycling, thereby contributing to environmental conservation efforts and the preservation of marine ecosystems (BCSIR 2023).

Table 3 : Environment Biotechnology Activities in Bangladesh (SAARC Secretariat, n.d.)

Institution	Full Name	Biotech Activities
BRRI	Bangladesh Rice Research Institute	Plant Biotech
BARI	Bangladesh Agricultural Research Institute	Plant Biotech
BJRI	Bangladesh Jute Research Institute	Plant Biotech
BSRI	Bangladesh Sugarcane Research Institute	Plant Biotech
BLRI	Bangladesh Livestock Research Institute	Fisheries Biotech
BTRI	Bangladesh Tea Research Institute	Plant Tissue Biotech
BFRI	Bangladesh Fisheries Research Institute	Plant Tissue Biotech
BAEC	Bangladesh Atomic Energy Commission	Plant Biotech, Environmental Biotech, Insect Biotech
NIB	National Institute of Biotechnology	Plant, Animal, Fisheries, Environmental, Microbial, Molecular Biotech
BINA	Bangladesh Institute of Nuclear Agriculture	Plant, Industrial, Environmental Biotech

In the policy landscape, the commitment of the Bangladesh government to the biotechnological movement is evident in the revised national Biotechnology Policy 2012 (Attaché Report (GAIN), 2016). The formation of committees like the National Taskforce on Biotechnology of Bangladesh (NTBB) and the National Executive Committee of Biotechnology (NECB) reflects a strategic commitment to policy formulation and implementation. A proactive stance in disseminating knowledge and sensitizing stakeholders through workshops underscores the government's determination to propel Bangladesh into the modern era of biotechnology.

In conclusion, Bangladesh's biotechnological trajectory unveils a rich tapestry of scientific progress. As the nation strides forward, the confluence of academia, industry, and research promises sustainable agriculture, environmental preservation, and heightened advancements in healthcare.

1. 3. Biotechnological Problems: The major issues concerning Biotechnology

In the realm of biotechnology, the landscape is rife with both promise and ethical considerations. As we delve into the issues surrounding this field, it becomes imperative to navigate the complex web of scientific advancements, societal implications, and ethical quandaries. Think about a farmer growing special crops with new features, making them resistant to pests. Now, imagine a company gets hold of how these crops are made. Who decides what happens with this info? What if big companies use it to control the farming market? This is a privacy concern with genetic info, but for crops. It's a big deal in our farming world today. Just like this, there are several other issues linked to biotechnology (United Nations Conference on Trade and Development, 2002). Let's explore some more of these topics.

If its categorized, they can be divided into:

1. **Biotechnological Accessibility:**
    - How can we ensure reasonable access to biotechnological advancements, particularly in developing regions?
    - Are there mechanisms in place to prevent technological disparities, fostering a global benefit from biotechnological breakthroughs?
2. **Long-Term Impacts on Biodiversity:**
    - What potential consequences might arise from the integration of genetically modified organisms into diverse ecosystems over extended periods?
    - Are there strategies to monitor and mitigate unintended consequences on biodiversity resulting from the widespread application of biotechnology?
3. **Informed Consent and Genetic Manipulation:**
    - How can we guarantee informed consent when it comes to genetic manipulations, especially considering the difficulties and implications involved?
    - Are there established frameworks to address the ethical dilemmas surrounding altering an individual's genetic makeup and the potential long-term consequences?
4. **Societal Perception and Education:**
    - How do societal perceptions influence the ethical considerations associated with biotechnology, and how can education play a role in shaping informed opinions?

- Are there ongoing initiatives to bridge the knowledge gap, ensuring that the public is well-informed about the science and ethics of biotechnological advancements?

5. **Global Governance and Regulatory Frameworks:**
    - What steps are being taken at the international level to establish robust governance and regulatory frameworks for the responsible use of biotechnology?
    - How can collaborative efforts among nations facilitate the development of universally accepted guidelines to address the global implications of biotechnological practices?

1.3.1. Environmental Risks: Within the domain of biotechnology, there are more growing concern about how genetically modified (GM) crops might impact the environment. A key issue is the potential transfer of modified genes to other plants through pollination, raising uncertainties about long-term effects, worries include the development of resistant "super-weeds," a decline in crop genetic diversity, and possible ecosystem destabilization (United Nations Conference on Trade and Development, 2002). This concern extends to crops modified with Bacillus thuringiensis (Bt), where toxins are produced directly. Environmentalists are worried that genetically modified crops, like those engineered with Bt technology, might unintentionally harm harmless insects, but when scientists study these crops in controlled laboratories, especially when looking at their impact on monarch butterflies, the results are not clear (United Nations Conference on Trade and Development, 2002). This shows that what happens in a lab might be different from what occurs in the real world, raising concerns about the potential effects of these crops on insects outside of controlled environments. It's crucial to recognize that ecological impacts may vary by ecosystem, emphasizing the need for a nuanced approach in understanding the environmental consequences of GM crops in different contexts.

Consider the case of Bt cotton, a product of genetic modification designed to produce a toxin from Bacillus thuringiensis (Bt), offering resistance against specific pests. The clear advantage lies in reduced reliance on chemical pesticides and increased crop yields. However, over time, an unexpected issue arose: the targeted pest, the cotton bollworm, developed resistance to the Bt toxin. This resistance triggered a comeback of pest populations, forcing farmers to adopt additional pest control measures. This real-world situation underscores the crucial need for continuous

monitoring and adaptability in biotechnological applications to effectively tackle unforeseen challenges.

1.3.2. Genetic Risks : Another concern is about health risks tied to altered food products. This worry intensifies when genes from non-traditional sources enter crops, potentially introducing unfamiliar allergens into our food chain. A notable case involved a Brazil nut gene in soybeans for animal feed, causing allergies, however, supporters of genetic engineering argue that these concerns highlight the importance of rigorous safety testing, which prevents such modified crops from being used commercially(United Nations Conference on Trade and Development, 2002). To address worries about health, scientists emphasize simple testing methods for new allergens, based on characteristics of known allergens(United Nations Conference on Trade and Development, 2002). Some people are concerned that introducing specific genes into crops could lead to the production of harmful substances, but others argue that adding well-defined genes simplifies the testing for toxicity compared to traditional methods(United Nations Conference on Trade and Development, 2002). Another concern is the use of antibiotic resistance genes as "markers" in genetic modification, raising fears about the transfer of resistance through food, despite these concerns, current evidence suggests that this isn't a significant problem(United Nations Conference on Trade and Development, 2002). Importantly, scientists have ways to remove these "marker" genes before the crops reach commercial use, reducing the risks associated with antibiotic resistance.

1.3.3. Challenges in Bangladesh: Amidst global concerns about health risks linked to modified food, such as allergens and antibiotic resistance, Bangladesh faces notable hurdles in advancing biotechnology. Challenges span scientific, economic, and societal fronts, including a shortage of skilled professionals, limited funding, infrastructure gaps, and regulatory deficiencies. Moreover, according to Shaikh Mizan's work, "Medical Biotechnology: Problems and Prospects in Bangladesh" (2013), issues like lack of commitment, corruption, and irresponsibility in politics and bureaucracy hinder progress. Overcoming these obstacles is crucial for nurturing biotechnology's growth in the country.

Despite the intricate challenges, the field of biotechnology beckons with immense promise. From unraveling genetic complexities to reshaping the environmental and agricultural landscape, the

transformative potential is boundless. As we navigate these scientific frontiers, recalibrating public perceptions is imperative to foster an environment conducive to the growth and realization of biotechnology's limitless potential.

1.4. Biotechnology-Based Government Initiatives and Regulatory Frameworks: Catalysts for Economic Development

In the ever-changing landscape of biotechnology, there's a growing acknowledgment of its pivotal role in driving economic progress. This shift from traditional biotech to the broader notion of the bioeconomy highlights the complex relationship between technological advancement, economic principles, and government actions. Across the globe, governments strategically implement initiatives and strong regulations to maximize the benefits of biotechnological progress. This segment delves into the crucial role of government intervention in guiding biotechnology toward economic success, highlighting universal challenges and the varied approaches taken by different nations.

1.4.1. Genetic Modification in Europe's Bio economy: Navigating Sustainable Paths

Emerging from the European Union in 2005, the bio economy concept has played a pivotal role in shaping the intersection of food security, economic development, and sustainability in Almería (McCormick & Kautto, 2013). This strategic approach focuses on generating bioproducts and bioenergy from non-food or feed biomass, strategically reducing reliance on fossil fuels and mitigating the carbon footprint.

As we delve into a more granular exploration of genetic modification projects contributing to the European bio economy, the following table encapsulates key initiatives, their associated products, and the pivotal players involved.

Table 4: Key Genetic Modification Projects Contributing to Biotechnological Advancements and the Bio economy in Europe

Project Name	Product Name	Details	Location	Initiative	Key Players
Insect-Resistant Maize in Spain	GM Maize	Enhanced pest resistance, increased yields	Spain	Agricultural Advancement	Institute for Sustainable Agriculture (CSIC),

Project Name	Product Name	Details	Location	Initiative	Key Players
					Syngenta (García et al., 2023)
Industrial Microbial Engineering	Engineered Microorganisms	Production of bio-based materials and biofuels	Germany, Netherlands, France	Industrial Biotechnology	BASF, Novozymes, DSM (Zhou et al., 2022)
Insulin Production via GMO	Genetically Modified Bacteria	Insulin production for medical use	UK, Denmark, Switzerland	Pharmaceutical Innovation	Novo Nordisk
Bioeconomy Enabling Project in Finland	Biomass Utilization	Sustainable biomass utilization for economic growth	Finland	Bioeconomy Development	VTT Technical Research Centre of Finland, UPM Biofuels (Heikki Vappula, 2014)

Concluding this thorough examination of genetic modification projects reveals their role as intricate threads woven into the fabric of the European bioeconomy. The collaborative efforts, innovations, and economic outcomes highlighted in Table 1 illustrate the dynamic landscape of biotechnological advancements across diverse sectors.

The European Union is deeply committed to fostering a sustainable bioeconomy, showcasing its dedication through key programs like Horizon 2020 and the Bioeconomy Strategy. Which articulates a commitment to smart, sustainable, and inclusive growth (McCormick & Kautto, 2013). This comprehensive strategy spans overarching goals in employment, research and development investment, climate change and energy, education, and poverty reduction. These goals collectively underscore the comprehensive nature of the strategy and its alignment with the unfolding bioeconomic landscape. These initiatives prioritize research and innovation, particularly in biotechnology-based projects. The EU's GMO regulations further underscore a careful and thorough approach, emphasizing the safe and responsible use of biotechnology within the bioeconomy (McCormick & Kautto, 2013). A closer examination of the current state of the European bioeconomy unveils a market valued at approximately €2.4 billion, spanning diverse sectors such as agriculture, food and beverage, agro-industrial products, fisheries, aquaculture, forestry, biochemicals, enzymes, biopharmaceuticals, biofuels, and bioenergy(Scarlat et al., 2015). This

expansive market employs approximately 22 million people, leveraging around 2 billion tons of biomass. In line with the Europe 2020 Strategy for smart, sustainable, and inclusive growth, the bioeconomy sector emerges as a cornerstone. The strategy's five headline targets, covering employment, research and development investment, climate change and energy objectives, education, and poverty reduction, collectively guide Europe toward a bio-based future(Scarlat et al., 2015). The focus on innovation, sustainable development, and job creation within the bioeconomy sector aligns with the overarching vision of achieving a competitive, resource-efficient, and low-carbon economy by 2050 (Scarlat et al., 2015). These insights offer a comprehensive understanding of Europe's bioeconomic landscape, laying the groundwork for further exploration and strategic development in the field of genetic modification and its potential contributions to economic advancement within the bioeconomy.

1.4.2. Germany: A Vanguard of Sustainable Bioeconomic Strategies

In the realm of economic development, genetically modified organisms (GMOs) play a pivotal role, fostering sustainability and innovation within the bioeconomy. This section delves into Germany's noteworthy position as a proponent of bioeconomic strategies, examining its commitment to integrating GMOs into the National Bioeconomy Strategy.

Germany's bioeconomy is a strong example of how businesses and technology work hand-in-hand. The private sector, especially industrial biotechnology, plays a big part. The government also helps by speeding up progress and bringing biotech into important areas like farming, forestry, and fisheries(Duque-Acevedo et al., 2020). This shows how crucial the German bioeconomy is for a sustainable future. In this future, GMOs help a lot by boosting the economy. They make things more resilient, efficient, and environmentally friendly.

The ensuing table offers a concise overview of companies, research institutions, and regions actively contributing to the realization of Germany's robust bioeconomic model.

Table 5 : Companies, Research Institutions, and Regions Implementing Sustainable Bioeconomic Strategies:

Project/Initiative	Location	Key Players	Overview & Focus	Biotechnological Development	Economic Outcomes
BioEconomy Cluster in North Rhine-Westphalia ("Bioeconomy in North Rhine-Westphalia," n.d.)	North Rhine-Westphalia	- Covestro (Polymer Manufacturer)	Collaborative hub for sustainable bioeconomic initiatives. Focus on bio-based materials and sustainable production processes.	Drives innovation, advances biotechnological solutions.	Growth of bio-based industries, increased regional economic resilience.
Fraunhofer Center for Chemical-Biotechnological Processes (CBP)	Germany	- Research & Industry Collaborations	Advances sustainable processes for bio-based chemicals and materials. Biorefinery concepts, biomass utilization, innovative processes.	Influences biotechnological development, fosters growth in bio-based industries.	Contributes to the bioeconomy, creates avenues for sustainable economic growth.
Circular Economy Initiatives in Baden-Württemberg	Baden-Württemberg	- EnBW (Energy Provider)	Embraces circular economy principles, reducing waste. Sustainable practices aligned with bioeconomic goals.	Promotes eco-friendly technologies, encourages biotechnological solutions.	Development of circular value chains, resource conservation, and sustainable economic practices.
Leuna BioRefinery (State Strategy for a Sustainable Bioeconomy Baden-Württemberg, 2019)	Saxony-Anhalt	- Various Technologies Integration	Flagship project converting biomass into bio-based products. Integration of biocatalysis and chemical processes.	Drives innovations in bio-refinery technologies, supports biotechnological advancements.	Promotes sustainable practices, creates economic opportunities, reduces reliance on fossil resources.

As we conclude this exploration into Germany's bioeconomic landscape, the intricate connection of these endeavors to the broader national strategy becomes evident. Examining the impact of these

projects provides a comprehensive understanding of how they align with and reinforce the principles outlined in Germany's National Bioeconomy Strategy.

1.4.3.Almería's Sustainable Agro-Industrial Transition: A Model of Integrated Bioeconomy

The transition of Almería from traditional farming to a significant vegetable exporter within the European Union (EU) reflects the EU's visionary bioeconomy agenda initiated in 2005 (Egea et al., 2018). At the core of Almería's agricultural practices lies a dedication to sustainability, with precision farming emerging as a key strategy to optimize resource usage and reduce reliance on fossil fuels.

Ongoing efforts in Almería strive to integrate its thriving agro-industrial complex into a fully sustainable bio economy model. Biomass plays a central role in this endeavor, driving the production of bioproducts and bioenergy while promoting the adoption of circular economic principles (Egea et al., 2018). Technological advancements within Almería's facilities, particularly in enhancing quality control within biorefineries and identifying valuable compounds in agricultural waste biomass, contribute significantly to the region's economic prosperity(Egea et al., 2018).

In Almería's agro-industrial complex, sustainability is paramount, achieved through precision farming, biomass utilization, and strategic waste reduction. Precision farming optimizes resource usage, including water and fertilizers, while innovative approaches to biomass utilization for compost production and animal feed minimize waste and maximize economic value(Egea et al., 2018). Advanced analytical techniques ensure efficient biomass valorization, reinforcing the region's commitment to waste reduction. Technology plays a key role in quality control within biorefineries and the identification of high-value compounds in waste biomass, aligning with the EU's vision for sustainable production (Egea et al., 2018). This holistic approach underscores Almería's evolution towards sustainability and its seamless integration into the circular economy, highlighting the potential for genetic modification to further enhance economic development within the bioeconomic landscape.

1.4.4. Specific case studies within Almería's agro-industrial complex:

Over the past four decades, Almería's agro-industrial complex has transformed from traditional agriculture to becoming the EU's primary vegetable exporter. Spanning a radial distance of 65km, the region boasts approximately 30,000 hectares of polyethylene greenhouses, comprising half of Spain's total greenhouse area. In 2015, fruit and vegetable production surpassed 3.2 million tonnes, valued at over EUR 2.2 billion, with 70% destined for international markets, reaching over 500 million consumers. Despite occupying only 0.02% of the EU's agricultural land, Almería's productivity surpasses the EU average by 30-fold, contributing 0.6% to the EU28's total agricultural output (Egea et al., 2018). This success is attributed to concerted efforts in agronomic science and technological innovation, fostered by collaborations among stakeholders including farmers, plant breeders, agronomists, industry partners, financial institutions, and academia.

1.4.5. India's Trajectory: Biotechnological Strategies for Economic Prosperity

In India, biotechnology serves as a key driver for economic growth, with the Department of Biotechnology (DBT) playing a pivotal role in shaping policies. The National Biotechnology Development Strategy (NBDS) guides initiatives across agriculture, healthcare, and industrial sectors(Huda, 2018). Despite some opposition, India's commitment to establishing a robust regulatory framework is evident in the proposed Biotechnology Regulatory Authority of India (BRAI) Bill (Huda, 2018) . Biotechnology parks, incubation centers, and financial incentives further stimulate research and development activities, showcasing India's dedication to fostering innovation in biotechnology. The government's diverse range of initiatives and regulations underscores its proactive approach to driving economic development in the biotechnology sector, with the DBT leading policy formulation and implementation. Initiatives like the NBDS provide a strategic roadmap for biotechnological advancements, while support for startups and technology transfer through biotechnology parks and incubation centers reinforces India's commitment to biotechnological growth (Huda, 2018). Financial incentives, including tax benefits and grants, highlight the government's efforts to incentivize research and development within the biotechnology sector.

Now, let's delve into a detailed examination of the impact of biotechnological strategies in key sectors with the following table

Table 6 : Biotech Impact on Indian Sectors

Sector	Biotechnological Strategy	Economic Impact	Key Players	Overview & Focus	Biotechnological Development
Agriculture	Adoption of Bt cotton (GM crops)	Increased yields, reduced pest-related losses, improved farmer income	Monsanto, Mahyco, Bioseed	Genetic modification for pest resistance, improved crop traits	Development of genetically modified crops for enhanced agriculture (Shukla et al., 2018)
Healthcare	Development of affordable vaccines	Improved public health, reduced economic burden of disease treatment	Serum Institute, Bharat Biotech	Vaccine research and production for prevalent diseases	Affordable vaccine development, disease prevention strategies. (Chavda et al., 2022)
Energy	Research in biofuels	Alternative and sustainable energy sources, reduced dependence on traditional fuels	Indian Oil, BPCL, Praj Industries	Biofuel production from renewable sources	Exploration of biofuel technologies for sustainable energy (Green Car Congress, 2023)

In summary, India's commitment to biotechnological strategies, as exemplified by initiatives like the National Biotechnology Development Strategy, has yielded tangible economic benefits. From enhanced agricultural practices to improved healthcare solutions and the pursuit of sustainable energy alternatives, key players in various sectors have played crucial roles in driving progress.

1.4.6. Global Bioeconomic Strategies: A Tapestry of Innovation and Sustainability

In the ever-evolving landscape of biotechnology, nations worldwide are strategically positioning themselves to capitalize on the economic and societal benefits offered by advancements in this field. South Korea emerges as a key player in advancing biotechnology research and development (R&D), with the Ministry of Science and Technology spearheading crucial initiatives , in contrast, the UK has significantly invested in industrial biotechnology, allocating GBP 11 million and GBP 4.5 million to leverage its economic and societal benefits while tackling pressing challenges and Britain's strategic investments emphasize the importance of addressing societal issues and bolstering industrial competitiveness (Wei et al., 2022).

A global outlook underscores the interconnectedness of policy objectives in driving bioeconomic advancements, offering a guiding framework for life sciences and biotechnology applications to propel the bioeconomy towards sustainable development goals.

1.5 Nationwide surveys to analyze public perception of biotechnological products and innovations

Understanding public perceptions of biotechnological products and innovations is crucial in today's advancing world. Nationwide surveys offer valuable insights into societal attitudes and concerns regarding these advancements. This section explores the findings of such surveys, synthesizing data from various sources to provide a comprehensive understanding of public viewpoints on biotechnology. Genetic engineering techniques have been predicted as an opportunity to improve food production to fulfill consumer preferences for improved quality and diversity. Although genetic modification technology holds the promise to increase food security in developing countries, negative public acceptance can affect its adoption.

Acceptance or rejection of biotechnological products, particularly genetically modified (GM) products, varies among individuals due to differing opinions influenced by various factors in different countries. Numerous studies have been conducted across different regions to gauge public perceptions towards this technology.

For instance, in poor countries when the knowledge and willingness to use genetically modified crops was assessed such as, among the people of **Uganda**, respondents believed GM crops grew faster and yielded more, though concerns about taste, nutrition, and risks like pest resistance and soil depletion were noted. Limited knowledge on harmful effects was evident, with concerns about health impacts and soil fertility and factors influencing knowledge included age, education, occupation, financial constraints, socio-cultural preferences, existing policies, and climate change, also this lack of knowledge was linked to limited willingness to use GM crops, with concerns about costs and perceived risks (Mustafa et al. 2023).

In today's world, genetically modified (GM) products are becoming increasingly accepted in developing countries as well. Therefore, it's crucial to comprehend the perceptions of people in these regions regarding GMOs. Numerous studies have been carried out in various developing

countries to explore this topic, such as a thorough study conducted in **Kenya** used a diverse approach involving multiple disciplines and sectors to explore public opinions on GMOs. It also examined the effects and risks associated with the GMO ban from 2012 to 2022 and evaluated how well the Biosafety Act and Cartagena Protocol on biosafety were being implemented. The study gathered information through organized survey interviews. Most knew about GMOs and believed they could help with food security and many respondents saw potential in GMOs for enhancing food security through benefits like increased crop resilience and higher yields, yet concerns lingered regarding their safety and ethical implications, including perceived differences from traditional foods and potential harm to health and the environment (Kunyanga, Mugiira, & Muchiri, 2024).

In another study focused on **China**, researchers delved into how people view GM food and what influences their opinions, and they discovered that various factors such as age, location, education, and income sway attitudes, with older individuals and those with higher incomes often expressing opposition to GM foods. Public perceptions are often shaped by media reports, internet rumors, and a lack of scientific understanding, highlighting the importance of providing balanced education and clear communication on the topic and despite government reassurances about the safety of GM foods, only a small percentage of respondents actually trust official statements, revealing a significant gap in public trust, additionally, there is limited awareness of which GM crops are approved for consumption, with many respondents expressing support for stricter government oversight or even a complete ban on GM foods (Cui & Shoemaker, 2018) . Similarly, another study conducted in Jiangsu province, China, researchers examined factors influencing consumer acceptance of genetically modified foods (GMFs). Their findings, based on a representative sample of 1167 urban residents from six cities across three economic regions, shed light on consumer preferences regarding GMFs. Interestingly, the study revealed a preference among consumers for indirectly ingesting GMFs, particularly in the form of pest-resistant or herbicide-resistant GM crops or those derived from a different plant species and furthermore, the researchers found that consumer attitudes toward GMFs were more closely associated with the purpose of consumption rather than the function or source of the transcribed gene (Zhang, Chen, Hu, Chen, & Zhan, 2016). This suggests a potential lack of understanding among urban consumers regarding genetic engineering and biotechnology, leading to neutrality or indifference toward GMFs. The

study highlights the need for balanced education and clear communication regarding GM foods to address misconceptions and enhance consumer confidence

In a study conducted in **Turkey**, researchers explored the understanding of GMOs among nursing students, a group presumed to possess a relatively higher level of scientific knowledge. However, their understanding was limited. When asked about the most commonly cultivated GMO, only a third correctly identified soy and cotton and many mistakenly thought other crops like tomatoes and peppers were more common, these students also expressed significant caution about GMOs, believing them to be risky for all living things , although knowing that GMOs are widely used and possibly present in products they buy most felt uninformed about the topic, with many believing society lacked adequate knowledge about GMOs (Turker et al., 2013).

In **India**, concerns about the ethics, potential risks to human health and the environment, and the need to carefully weigh socio-economic benefits regarding GM technology have been raised (Bawa & Anilakumar, 2013). In a study conducted in India, researchers delved into the awareness and attitudes towards biotechnology in the agriculture sector, specifically focusing on genetically modified organisms (GMOs) among farmers and consumers. Surveying 500 consumers in each of five cities across different states, totaling 2500 respondents, alongside qualitative insights from focus group discussions. The study revealed a concerning lack of awareness regarding GMOs as many respondents had never heard of GM foods despite their relatively educated backgrounds, their sources of information on GMOs were predominantly media and friends concerns about GM foods were prevalent among participants, ranging from worries about long term health effects to ethical considerations, also many expressed a preference for natural foods with minimal chemical inputs, doubting technology's ability to anticipate consequences adequately (Gene Campaign, n.d.), In conclusion, the study underscored a significant lack of information and consumer skepticism towards GMOs in India. Consumers relied heavily on the government for protection of their interests and cultural practices, signaling a crucial need for clear communication and education on GMOs.

The findings from surveys conducted among consumers in **Thailand** published in ISAAA website, provides valuable insights into public perceptions and attitudes towards biotechnology. Thailand's consumers demonstrate a moderate to high level of interest in biotechnology, coupled with

moderate concern about related issues, despite this concern they perceive the risks associated with biotechnology to be relatively low while acknowledging its high potential benefits According to the survey consumers in Thailand trust various stakeholders in biotechnology for public health and safety, but assign risk assessment to agri-biotech companies, regulators, and university scientists also they believe in science's role in agriculture but have moderate factual knowledge about biotech, signaling a need for more education. Attitudes towards biotech vary with widespread support for labeling GM foods, consumers rely on various sources for biotech information perceiving it as useful and scientific and moral concerns significantly influence their views. (ISAAA, n.d.). These insights reveal the nuanced perspectives and attitudes of Thai consumers towards biotechnology, suggesting areas for further exploration and engagement.

While it's understandable that developing countries may have misconceptions about GMO acceptance, it's disheartening to see misunderstandings persist in developed nations as well. Such as, a study involving **Polish** students revealed low levels of knowledge about genetic modification, with the majority feeling uninformed or uncertain about the topic, they held predominantly negative views of GMOs in food production, considering them to be potentially dangerous and unhealthy while many participants expressed doubts about the reliability of studies on GMO health effects and found media reports on GMOs untrustworthy (Jurkiewicz et al., 2014).

In **New Jersey**, Vecchione and colleagues conducted a study among adult supermarket shoppers to explore the relationship between GMO awareness, attitudes, and purchasing behaviors. They found that consumers with greater knowledge about GMOs tended to have more positive attitudes toward non-GMO products and were slightly more inclined to purchase them. However, this correlation was modest. Additionally, there was a weak positive association between GMO knowledge and education level (Vecchione, Feldman, & Wunderlich, 2014). Overall, the findings suggest that awareness of GMOs may influence preferences for non-GMO alternatives, but the impact on purchasing decisions is relatively modest.

European consumers generally hold more negative perceptions and are less inclined to purchase GM foods compared to their North American counterparts. Eurobarometer studies conducted by the European Commission reveal that while Europeans exhibit positive attitudes towards technological advancements overall, they harbor more skepticism towards specific applications

such as GM foods. This sentiment varies across different countries, with Spain and Portugal showing higher levels of approval due to Bt maize cultivation, while countries with GM bans such as **Austria, Germany**, and **France** tend to display lower approval rates (Gaskell et al., 2010).

Farmers in various regions worldwide widely embrace genetically modified (GM) products due to firsthand experiences witnessing their benefits. These advantages include boosted crop yields and enhanced resistance to pests, thanks to GM technology. In countries where farmers have the liberty to select their agricultural methods, GM plants have outpaced conventional varieties. Adoption rates for biotech maize, cotton, and soybean exceed 90% in the **United States**, as well as in **Brazil** and **Argentina** for soybeans, in **India** and **China** for cotton, and in **Canada** for oilseed rape (Lucht, 2015). Notably, transgenic herbicide-tolerant sugar beets saw rapid adoption in the U.S., reaching 95% within two years of limited seed availability in 2009. This surge was propelled by benefits such as easier weed control, reduced herbicide use, time savings, and increased profits, prompting many farmers to switch to biotech varieties. Similarly, transgenic papaya trees resistant to papaya ringspot-virus (PRSV) were introduced in Hawaii in 1998, effectively saving the papaya industry from collapse during a severe PRSV outbreak. Within a short time, approximately 90% of papaya farmers embraced these resistant varieties, thereby securing the Hawaii papaya industry from extinction (Smyth, Phillips, & Castle, 2014). A meta-analysis conducted by Klümper and Qaim in 2014, which reviewed 147 agronomical studies on GM crops, revealed significant benefits. These included a 68% increase in farmer profits, a 22% rise in crop yields, and a 39% decrease in pesticide expenses. Notably, these advantages were more pronounced in developing nations. Despite the higher costs associated with GM seeds, farmers still experienced financial gains from biotech crops. Additionally, farmers noted non-monetary benefits such as time savings and ease of use.

Based on the comparative analysis of existing investigations, it is important to propose recommendations for future research to address existing gaps and improve the understanding of public perceptions of GMOs worldwide. These recommendations may include employing rigorous methodologies with large, representative samples, conducting longitudinal studies to track changes in public perceptions over time, and undertaking cross-cultural studies to compare attitudes across diverse regions and cultures. Additionally, qualitative research approaches such as in-depth

interviews and ethnographic studies can offer deeper insights into the underlying motivations and beliefs driving public perceptions of GMOs.

In summary, this analysis underscores the intricate interplay of societal, cultural, and economic factors in shaping public attitudes towards biotechnological innovations, particularly genetically modified products. Despite a moderate level of awareness and knowledge regarding modern biotechnology globally, perceptions of risk and benefit vary significantly across different regions and demographics. The findings highlight the importance of comprehensive, context-specific approaches to understanding and addressing public concerns and promoting informed decision-making in the field of biotechnology. Moving forward, continued research and dialogue are imperative to navigate the complexities surrounding biotechnological advancements and to ensure their responsible and equitable integration into society.

1.6. Background surveys on biotechnology and GMOs conducted previously in Bangladesh

In Bangladesh, a country deeply reliant on agriculture, the integration of biotechnology, particularly Genetically Modified Organisms (GMOs), has generated significant interest and debate. After an extended period, on October 30th, 2013, the government officially endorsed the cultivation of genetically modified (GM) crops, marking Bangladesh as the pioneering nation in South Asia to engage in such agricultural practices (Daily Star. 2013). In 2013, Bangladesh introduced the world's initial biofortified zinc-rich rice variety, BRRI dhan-62, with a micronutrient content of 19 mg/kg. Since then, researchers in the country, notably at BRRI and Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), have developed a total of six zinc-rich rice varieties, with the highest zinc content documented (Daily Star, 2017).

Amidst these developments, public perceptions play a crucial role in shaping attitudes towards GMOs. Gender, occupation, income, education, and field of study significantly influence these perceptions. Some individuals hold positive views, while others express concerns. Addressing misconceptions and uncertainties surrounding GMOs is essential for effective promotion and acceptance in Bangladesh. The media serves as a key source of information on biotechnological products which impacts public opinions and the younger generation particularly professionals with master's and Ph.D. degrees holds a more favorable view towards GMOs , this positive

perception among the youth suggests a growing acceptance and understanding of GMO technology in the country but the females and those in business-related fields are less likely to possess extensive knowledge and positive attitudes towards it (Das & Sumit, 2022). Despite the optimism about biotechnological products improving quality of life, concerns about consumption levels pose safety challenges in Bangladesh. The age and educational background of has a notable impact on their perspective regarding biotechnological products, and Industry personnel in Bangladesh who are highly involved in biotech product development do not hold a good awareness about the biotech products. (Abdullah, Afrad, Bhuiyan, et al., 2018). These findings align with similar studies conducted globally, emphasizing the importance of transparency and accountability in the dissemination of information regarding GM foods.

Occupation and gender further illuminate the dynamics of GMO perception in Bangladesh. Compared to other nations, Bangladeshi consumers and stakeholders exhibit limited understanding and perception of GM foods and one of the reasons of it is the lack of clear regulations on food labeling in Bangladesh, thus this absence of clear guidelines results in consumer confusion about the origin and production methods of everyday food c products(Ahmed AU et al., 2021).

In a comprehensive national survey conducted by Nasiruddin and Nasim (2007), the state of biotechnology, genetic engineering, and genetically modified organisms (LMOs) in Bangladesh was assessed. Furthermore, examining demographic factors sheds light on the nuanced attitudes towards GMOs. It shows that while research and development efforts are underway in biotechnology, the main focus is on specific areas within this field which includes improving plant tissue culture methods, growing important plants in labs, and studying different crop varieties at a molecular level. Despite these focused efforts & having skilled experts in universities and research centers, challenges exist due to limited resources available in the private sector, NGOs, and international organizations, which can impact the overall progress and effectiveness of biotechnological research and development in Bangladesh.

Moving from public perceptions to regulatory frameworks, it's evident that governmental policies and regulatory measures also shape the landscape of GMOs in Bangladesh. Notably, biosafety measures, as outlined in the Cartagena Protocol on Biosafety, are adhered to by universities and research institutes through their Institutional Biosafety Committee (IBC) (Nasiruddin & Nasim,

2007). Moreover, the government demonstrates strong support for agricultural biotechnology, particularly in the development of transgenic crops. Initial regulatory approval has been granted for crops such as Golden Rice, Bt brinjal (eggplant), and virus-resistant potato, signaling a proactive stance towards biotechnological advancements. However, challenges persist in formulating and implementing biosafety regulations, highlighting the need for increased awareness and capacity building in biotechnology and biosafety.

In conclusion, while Bangladesh shows promise in integrating GMOs into its agricultural landscape, addressing public perceptions, enhancing regulatory frameworks, and bolstering research and development efforts are essential for sustainable adoption. Overcoming challenges such as consumer confusion and resource constraints is crucial to realizing the full potential of biotechnology in Bangladesh's agricultural sector.

1.7 Rational of the current study:

Biotechnology, a dynamic field intersecting healthcare, agriculture, and industry, holds immense potential for societal advancement. Despite its centuries-old roots, there exists a significant gap in public awareness. This study is motivated by the need to bridge this gap, focusing on the diverse perspectives of tertiary-level students across varied educational backgrounds and age groups. By delving into their viewpoints and knowledge regarding Genetically Modified Organisms (GMOs), the research aims to contribute valuable insights to the evolving landscape of biotechnology education and perception in Bangladesh. The outcomes will not only enrich academic understanding but also inform strategies for enhancing awareness and fostering a nuanced understanding of biotechnology among the upcoming generation.

The questionnaire utilized in this study aims to collect essential data regarding participants' backgrounds and their perceptions of biotechnology and genetically modified organisms (GMOs). It begins with basic demographic information such as name, gender, educational background, and major subject. Moving forward, the survey assesses participants' understanding of biotechnology and GMOs, including their ability to distinguish between hybrid and genetically modified crops. This foundational knowledge aids in shaping the subsequent questions to ensure clarity and comprehension. Participants are then prompted to evaluate their familiarity with key

biotechnological products, such as vaccines, antibiotics, insulin, Bt brinjal, and golden rice. These questions are designed to measure participants' familiarity with common biotechnology products and innovations. Furthermore, the questionnaire delves into participants' perspectives on GMO-related statements, covering various aspects including food security, nutritional enhancement, pesticide reduction, medical applications, health risks, and environmental impact. Responses are assessed on a scale of 1 to 4 where 1 represents "Strongly Agree" and 4 represents "Strongly Disagree," to capture the spectrum of opinions (Prokop et al., 2007). In conclusion, participants are queried about their primary sources of information regarding biotechnology and GMOs, as well as the frequency of their exposure to such information through scientific articles, electronic media, printed media, and social media. This holistic approach aims to gather diverse viewpoints on biotechnology and GMOs in a concise yet comprehensive manner.

1.8 Objectives of the survey

- Evaluate students' understanding and opinions about biotechnology and GMOs.
- Identify challenges and factors influencing their perception and acceptance of GMOs.
- Investigate potential misconceptions or misinformation about GMOs prevalent among students.

METHODOLOGY

2. Methodology

2.1 Questionnaire preparation

In the quantitative research, for this study, we adopted a cross-sectional survey research design, which according to Lavrakas (2008), aims to collect quantitative and qualitative data to make inferences about a population at one point in time. This methodology facilitated the integration of a comprehensive array of closed-ended questions, coupled with Likert scale inquiries, while adhering to ethical and biosafety regulations and precisely crafted to explore multiple dimensions of participants' viewpoints on GMOs. By employing a blend of structured and scaled responses, the questionnaire aimed to enhance the granularity and scope of the data analysis. The questionnaire development process drew inspiration from the study conducted by Marina Casanoves, Ángel González, Zoel Salvadó, Juan Haro, and Maite Novo, titled "Knowledge and Attitudes Towards Biotechnology of Elementary Education Preservice Teachers: The first Spanish experience," published in the International Journal of Science Education in 2015. To ensure impartial analysis, the questionnaire was crafted in a manner accessible to all participants, irrespective of their academic backgrounds. The survey comprised five closed-ended questions and five Likert scale questions to assess students' understanding and opinions on GMOs. By employing closed-ended questions as a means of data collection, an enrichment of analysis on various perspectives was achieved, including students' awareness of biotechnology, familiarity with genetic engineering, beliefs about hybrid crops, and frequency of exposure to biotechnology-related information. As close-ended questions are less demanding since they only need to select from provided options, it’s easier for those with limited communication skills the respondents can respond swiftly, and choosing from predefined options is simpler and more efficient, enhancing respondents' willingness to complete the questionnaire (Hyman & Sierra, 2016; NMSU Business Outlook, p. 14). Similarly, Likert scale questions is easy to administer and understand, making them suitable for both researchers and participants allowing for a nuanced examination of attitudes towards GMOs, including opinions on the usefulness of GM technology, the safety of GMOs, the environmental impact of genetic engineering, and other relevant aspects with the measurement of attitudes and perceptions on a continuum, providing more nuanced information compared to simple yes/no questions.

2.2 Participants

The survey conducted was thoughtfully crafted to gather comprehensive insights of students from universities in Chattogram, representing diverse academic backgrounds. In this study, 319 students from diverse academic backgrounds across three different institutions from Chattogram collaborated. These students were thoughtfully organized into four distinct groups, each representing a different field of study: Biotechnology, Biochemistry, and Molecular Biology; Other Biological Sciences; Physical Sciences; and Other Subjects. The universities mentioned above are chosen for having all these groups. Noteworthy is the composition of our participant pool, with 109 students from Chittagong University (public university), 104 from Asian University for Women, and 106 from the University of Science and Technology (private university) contributing to the scope and depth of our study.

2.3 Data collection

A convince and simple random sampling was chosen for the study because it's easy and saves time. It helped to find participants from different departments in the universities without too much trouble, considering the limited time and resources. Additionally, simple random sampling was employed to ensure that each participant had an equal chance of being selected, thus enhancing the representativeness of the sample. However, it's important to acknowledge that convenience sampling may introduce bias, as participants who are more accessible or willing to participate may be overrepresented in the sample. Similarly, while simple random sampling aims to reduce bias, it may not always capture the full diversity of the population, especially in large and heterogeneous settings

To begin the proceeding, the registrars of the concerned universities were contacted seeking permission to survey their respective campuses through email. Then the universities were visited and a formal request letter was presented to avail the permission. With the permission, different departments were visited to contact the faculty members. The detail was described to them explaining about the study and its objectives. With their permission, two or three classes of different years from the department were visited. The students were consulted to make them

understand about the study and the questionnaire. Then, the printed questionnaires were distributed among the students. After that, the questionnaires were collected from the participants and compiled in different folders based on the visited departments and universities .

2.4 Statistical Analysis and Test Selection

There were both virtual and in-person meetings for discussions among the researchers and the supervisors. The collected data was input and analyzed using Statistical Product and Service Solutions (SPSS)19.0. software. Microsoft Excel was used to create the graphical presentation of the data. After all the data was collected and analyzed carefully, the next step was to choose the right tests for analysis. These tests needed to match up with the research goals and fit well with the types of data collected. It was important to select tests that were robust and aligned with the study's objectives. The Likert scale was key in gauging participants' attitudes, while the Compare Means Test (including t-tests or ANOVA) was used to analyze differences among groups, especially for normally distributed data. Lastly, chi-square tests were used to explore associations or differences in categorical data.

2.4.1.Likert scale

A Likert scale item commonly asks participants to express their level of agreement with a statement about their attitudes or behaviors. The Likert scale utilized in this study was adapted from the methodology employed by Ghasemi, S., Karami, E., and Azadi, H. (2013) in their research titled "Knowledge, attitudes and behavioral intentions of agricultural professionals toward genetically manipulated (GM) foods: A case study in Southwest Iran," published in Science and Engineering Ethics. This scale served as a framework for assessing respondents' perceptions and attitudes regarding genetically modified (GM) foods. In this analysis participants typically choose from response options ranging from "strongly disagree" to "strongly agree." Likert scales offer several advantages in survey research. Firstly, they provide a structured format for participants to express their opinions or attitudes on a topic, allowing for standardized data collection. This uniformity facilitates comparability across respondents and enhances the reliability of the findings. Additionally, Likert scales offer flexibility in response options, ranging

from strongly agree to strongly disagree, which enables nuanced measurement of attitudes or perceptions. Moreover, Likert scales are easy to administer and analyze, making them suitable for both large-scale surveys and small-scale studies. In this study, the Likert scale is used to gauge respondents' perceptions and opinions on various aspects related to genetically modified organisms (GMOs), including their familiarity with different biotechnological products and their views on GMO-related statements.

2.4.2. Chi-Square Tests

The chi-square test methodology utilized in this study was inspired by the work Turker, Turker, Koçak, Aydin, Istanbuluoglu, Yıldıran, Turk, and Kilic (2013), who utilized Pearson's chi-square test to compare answer frequencies across various groups. In this article, chi-square tests were used to explore associations or differences in categorical data .Such as , examined the connection between students' academic departments and how often they come across information related to biotechnology and genetically modified organisms (GMOs) in scientific articles or intricate interaction between respondents' academic affiliations and their perspectives on the safety of Genetically Modified Organisms (GMOs). P values of <0.05 were considered statistically significant. The chi-square test is specifically designed for situations involving multiple tests and at least two discrete outcomes, such as response and non-response. One of the key advantages of the chi-square test lies in its ability to easily accommodate multiple test groups and outcomes, provided that these groups are clearly distinguishable from one another. Ensuring the distinctiveness of the groups being compared is paramount when utilizing this test.((Berry & Linoff, 1997; Halkidi, Batistakis, & Vazirgiannis, 2001)). It helps determine if there's a connection between different categories in the data. By analyzing this, one can figure out if any differences between the categories are just random or if they actually mean something. The chi-square analysis yielded compelling results, with both Pearson and Likelihood Ratio chi-square statistics demonstrating statistical significance.

2.4.3. Compare Means Test

Comparison of means test was conducted to gauge the level of association with GMO related concepts among students from different departments. Additionally, the standard deviation was considered, which measures the consistency of responses within each department. A lower standard deviation indicates a higher consistency in familiarity levels among students within that department, while a higher standard deviation suggests more variability in responses. By incorporating both mean scores and standard deviations, a comprehensive understanding of the familiarity landscape regarding biotechnological concepts among students from diverse academic backgrounds was gained. This statistical analysis allowed exploration of whether there are significant differences in the mean values of the variable under study across different groups. The mean, a fundamental statistic, serves as the average value of the variable within each group, providing insight into the typical value within the group. Accompanying the mean is the standard deviation, which signifies the dispersion or spread of the data points around the mean within each group. A higher standard deviation indicates greater variability in the data, whereas a lower standard deviation suggests more consistency among the data points. Additionally, the variance, which is the square of the standard deviation, quantifies the average squared difference of each data point from the mean within each group. This measure offers further insight into the spread of the data and complements our understanding of variability within each group. By considering these statistical metrics alongside the results of the Comparison of Means Test, a comprehensive understanding of the association between the studied concepts and the diversity among students from different departments is obtained

RESULT

3. Results

3.1 Sociodemographic Data

The interview was sought from undergraduate students from 109 Chittagong University (public university), 104 from Asian University for Women, and 106 from the University of Science and Technology (private university). The total response in the study was 319 among which 219 females, 100 males participated in the survey. The study was conducted in 3 universities of which 2 were private and 1 was public university. The participation was 210 from private universities and 109 from public university.

Table :7 Diversity in Academic Backgrounds, Departments, and Gender Distribution Among Survey Participants

Gender	**Number of Participants**	**Percentage (%)**
Male	100	31.3
Female	219	68.7
Medium	**Number of Participants**	**Percentage (%)**
Bangla	203	63.6
English version	59	18.5
English	57	17.9
Year	**Number of Participants**	**Percentage (%)**
1st	12	3.8
2nd	89	27.9
3rd	150	47.0
4th	68	21.3
Academic Background	**Number of Participants**	**Percentage (%)**
Biotechnology, Biochemistry, Molecular Biology	103	32.3
Other biological sciences	55	17.2
Physical sciences	52	16.3
Other subjects	109	34.2
Total	**319**	**100.0**

3.2 Awareness and Familiarity with Biotechnology and GMOs among University Students

In the study regarding awareness of biotechnology among 319 individuals, the results showed that 96.2% of respondents stated they have heard about biotechnology, making it the most common response. Only 1.6% reported they have not heard about biotechnology, while 2.2% were uncertain and selected "Not sure." These findings indicate a significant level of awareness regarding biotechnology within the surveyed population, with a minority remaining either uninformed or uncertain about the concept (fig:3).

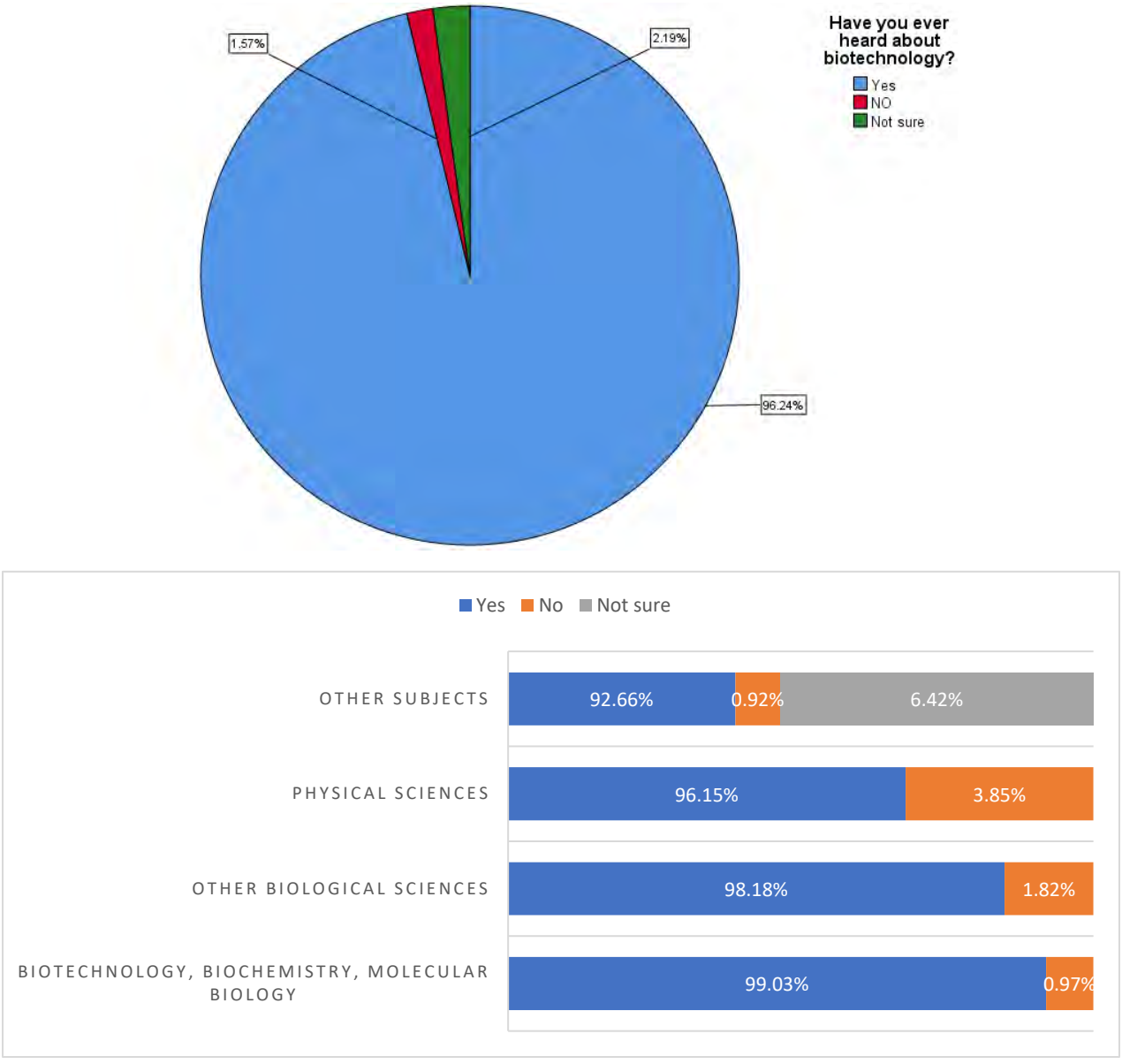

Figure 3: Participant's familiarity with the word biotechnology.

The figure 3 , also displays the number of students familiar with biotechnology across different academic majors. Among those majoring in Biotechnology, Biochemistry, and Molecular Biology, nearly all students (99.03%) were aware of biotechnology. Similarly, a high level of familiarity which is 98.18% was observed among students in Other Biological Sciences and in 98.15% students were aware in the Physical Sciences department. Even in Other Subjects, which include diverse academic disciplines, the majority of students which is 92.66% showed awareness. These findings indicate widespread understanding of biotechnology across various majors, with only a small proportion expressing uncertainty or unfamiliarity.

3.3 Exploring Familiarity with Genetic Engineering and GMOs Across Departments

To assess potential variances in familiarity with Genetic Engineering (GE) and Genetically Modified Organisms (GMOs) across academic departments comparison of means test was conducted. The goal was to gauge the level of associate with these concepts among students from different departments. The analysis aimed to reveal any differences in knowledge among these departments.

The statistical analysis method compared the average familiarity levels across departments, represented by the mean score, enabling the identification of any significant variations in knowledge. Lower mean scores imply higher familiarity with GE and GMOs. Additionally, the standard deviation is considered, measuring the consistency of responses within each department. A lower standard deviation indicates higher consistency in familiarity levels among students within that department, while a higher standard deviation suggests more variability in responses. By incorporating both mean scores and standard deviations, a comprehensive understanding of the familiarity landscape regarding biotechnological concepts among students from diverse academic backgrounds are gained.

3.3.1 Findings: The analysis underscores significant variations in familiarity with GE and GMOs across different academic departments. While some departments demonstrate a strong awareness of these concepts, others exhibit lower levels of familiarity. From the analysis, it's apparent that departments like "Biotechnology" and "Bioinformatics" exhibit high familiarity with GE/GMOs. This conclusion is supported by their larger sample sizes and robust mean scores (both at 1.0000), which indicate a strong understanding of the concepts among participants.

Additionally, these departments, including "Bioinformatics," "Biotechnology," and "Genetic Engineering," demonstrate high consistency in responses, as indicated by a standard deviation of 0.00000, suggesting a uniform level of understanding within these department (Table-8).

Table 8: Comparison of means test result

Are you familiar with Genetic Engineering (GE)/ Genetically Modified Organisms (GMOs)?			
department	Mean	N	Std. Deviation
Bangladesh studies	2.0000	2	.00000
Banking and insurance	1.1200	25	.43970
BBA	1.6071	28	.87514
Bioinformatics	1.0000	34	.00000
Biotechnology	1.0000	28	.00000
BOTANY	1.0625	16	.25000
Chemistry	1.5000	6	.83666
CSE	1.8500	20	.81273
CSE	1.5500	20	.82558
Dramatics	1.0000	1	.
Economics	1.3000	20	.47016
English	1.6429	14	.92878
Environmental science	1.5000	2	.70711
genetic engineering	1.0000	9	.00000
Genetic engineering	1.0000	32	.00000
Pharmacy	1.4500	20	.75915
Physics	1.1250	8	.35355
Public health	1.6000	20	.94032
Science	1.0000	3	.00000
Social science	1.6667	9	.86603
Soil science	1.0000	2	.00000
Total	1.3072	319	.64888

In contrast, departments such as "Dramatics," "Environmental Science," "Science," and "Soil Science" show limited familiarity, likely due to their notably low sample sizes (Table-8). These findings underscore the importance of tailoring educational initiatives and communication strategies related to biotechnology concepts. Bridging the knowledge gap is paramount, especially as biotechnology continues to play a pivotal role in diverse fields. Moreover, these results highlight the need for cross-disciplinary engagement to ensure students across various departments are well-informed about these critical concepts.

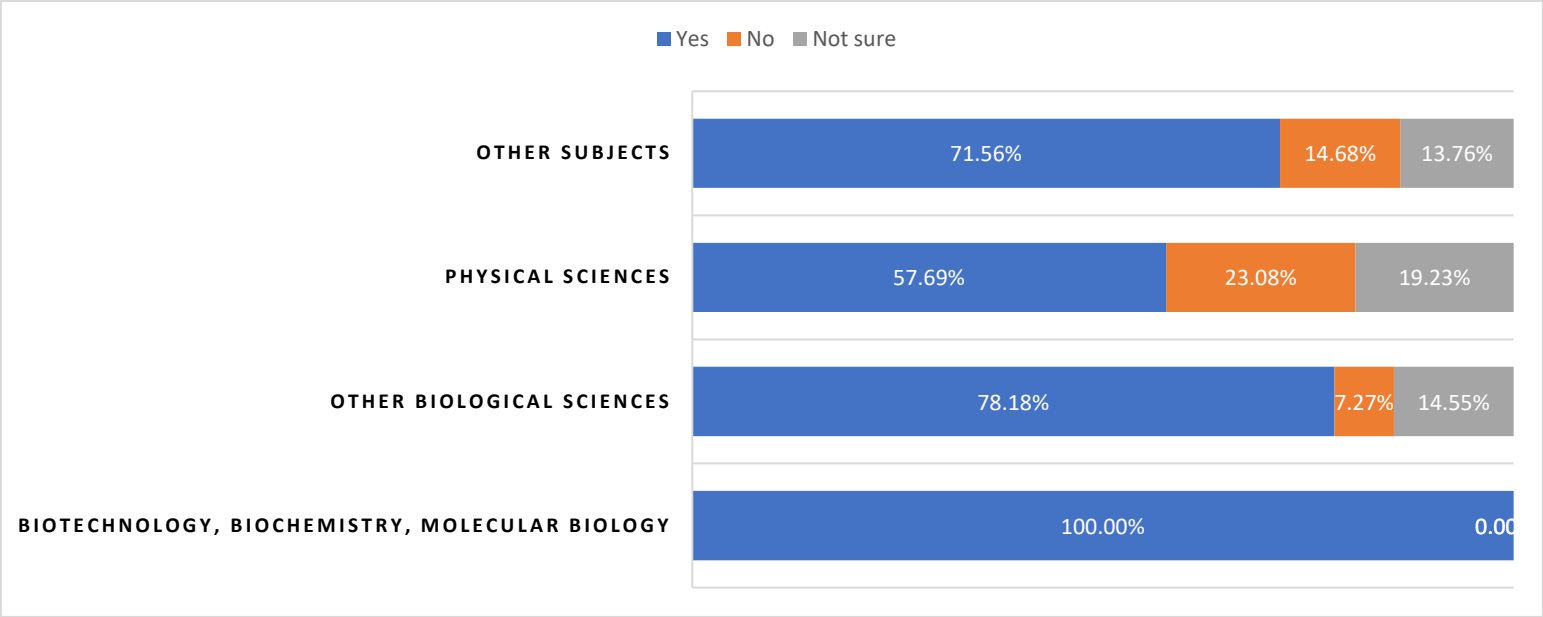

Figure 4: Participant's familiarity with GE/GMO

Figure 4 illustrates the percentages of students familiar with Genetic Engineering (GE) and Genetically Modified Organisms (GMOs) across various academic majors. Each row represents a different major, while columns display the percentage of students who responded 'Yes', 'No', or 'Not sure' to the question.

3.3.2 Biotechnology, Biochemistry, Molecular Biology: All students in this major showed familiarity with Genetic Engineering (GE) and Genetically Modified Organisms (GMOs). This means every respondent from this major responded affirmatively to being familiar with GE/GMOs.

3.3.3 Other biological sciences: In this survey, the familiarity level with the terms GE/GMOs dropped to 78.18% of students compared to the previous one. In addition, some students (7%) of this discipline agreed that they were not familiar, and 14.55% were unsure. This suggests that a majority of students in this major are familiar with GE/GMOs, but there is also a notable proportion who are unfamiliar and unsure.

3.3.4 Physical sciences: Among students in this major, 57.69% indicated they were familiar with GE/GMOs, 23.08% reported they were not familiar, and 19.23% were unsure. This indicates a lower level of familiarity compared to the previous majors, with a significant proportion of students expressing uncertainty

3.3.5 Other subjects: In this major, 71.56% of students reported familiarity with GE/GMOs, 14.68% indicated they were not familiar, and 13.76% were unsure. This suggests a relatively high level of familiarity among students, but still a considerable proportion expressing uncertainty.

3.4 Comparing Perspectives: An Analysis of Majors and Their Opinions on Hybrid vs. GM Crops

While both hybrid crops and genetically modified organisms (GMOs) are innovations in agricultural biotechnology, they are distinct in their methodologies and outcomes. Hybrid crops are the result of cross-breeding different varieties of the same species to produce offspring with desirable traits, such as increased yield or disease resistance. On the other hand, GMOs are created by inserting genes from one organism into the DNA of another organism to impart specific characteristics or traits. This genetic modification can involve genes from unrelated species, offering the potential to introduce traits that are not naturally occurring in the target organism. The survey included a question: "Are hybrid crops the same as genetically modified crops?" This aimed to gauge participants' understanding of the distinction between these two agricultural biotechnologies, specifically focusing on their knowledge of GMOs.

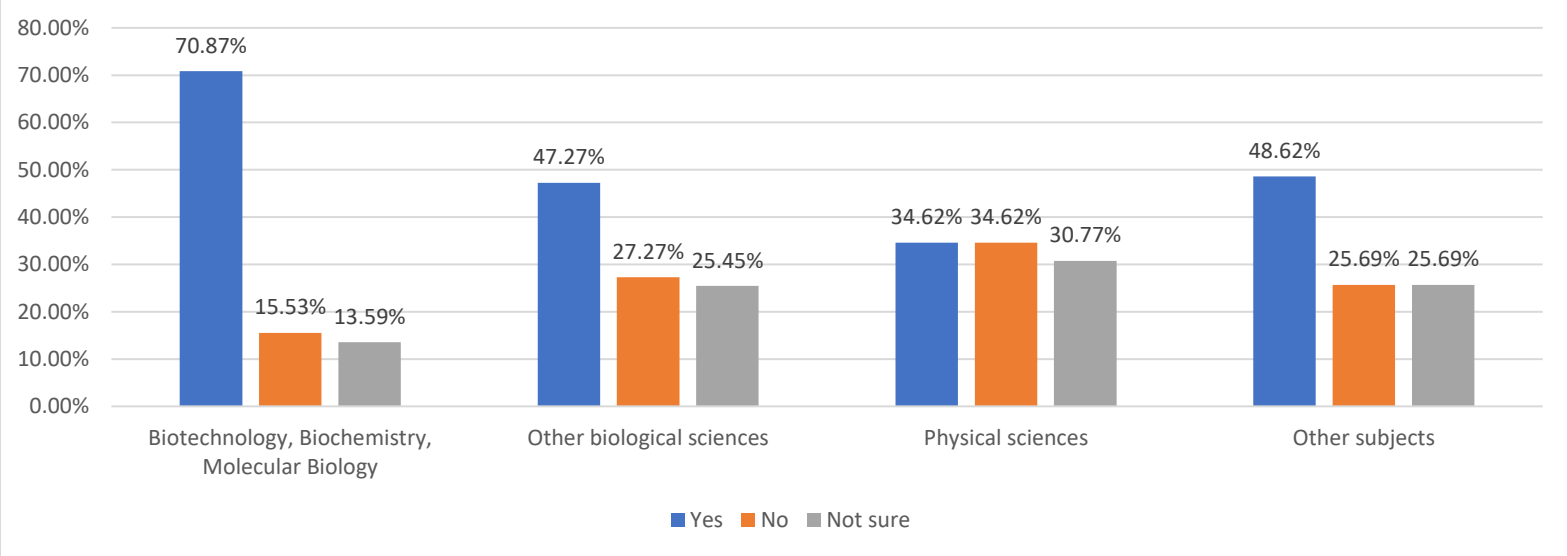

Figure 5: Student Perception of Hybrid vs. Genetically Modified Crops Across Majors

3.4.1 Findings : The majority of students majoring in Biotechnology, Biochemistry, and Molecular Biology do not believe that hybrid crops are the same as genetically modified crops, with 70.87% responding 'No'. Similarly, a significant portion of students in Other biological sciences also responded 'No' (47.27%). However, there is a notable proportion of uncertainty across all majors, with a range of 13.59% to 30.77% responding 'Not sure'. The analysis indicates that students majoring in Biotechnology, Biochemistry, and Molecular Biology had a lower level

of agreement with the statement about hybrid crops compared to GM crops, in contrast to students from other majors. This suggests that even students with specialized knowledge in biotechnology-related fields do not fully have the obvious correct perspective on hybrid and GM crops which is concerning. It shows the clear knowledge gap in their study and awareness which they should work on. In summary, the survey findings reveal a prevailing misconception among students from all the majors. The majority erroneously perceive hybrid crops to be synonymous with genetically modified organisms (GMOs). They don't fully understand the difference between hybrid crops and GMOs.

3.5 Evaluating Student Familiarity with Biotechnological Products: A Likert Scale Analysis

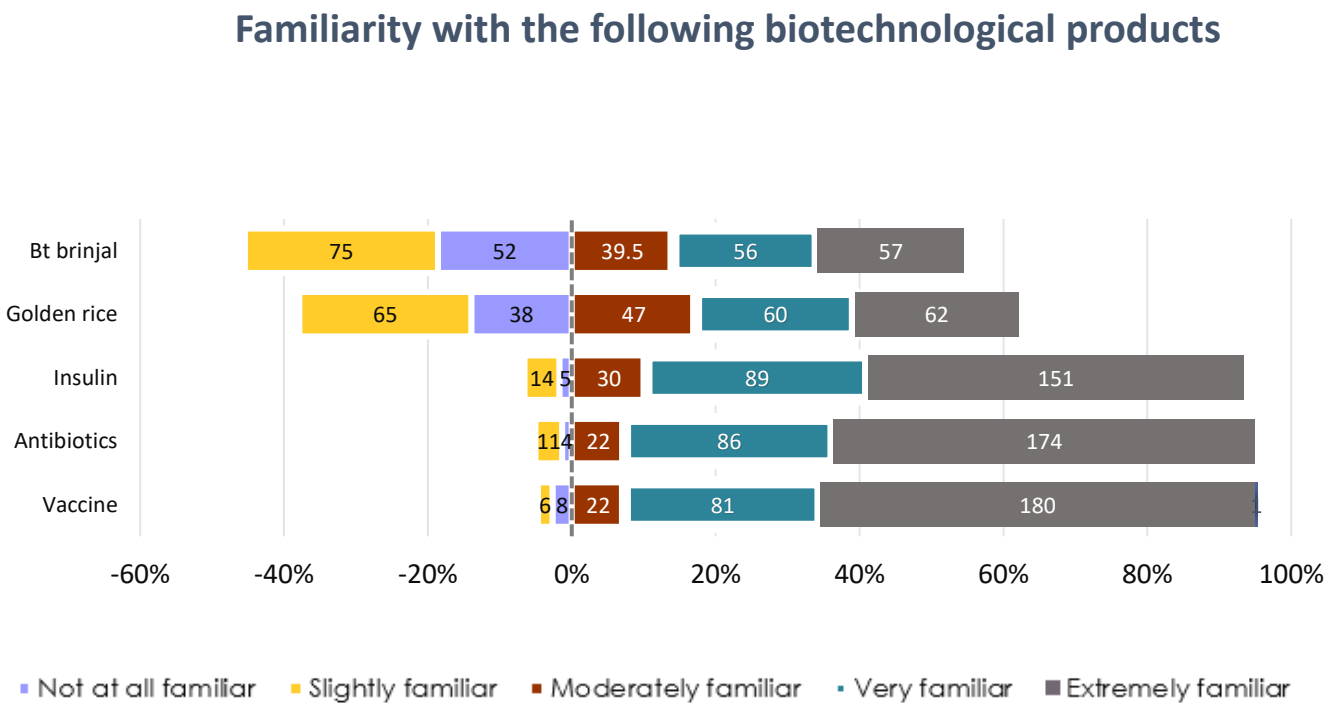

Figure 6: Participant's responses to familiarity with various biotechnological products

The Likert scale analysis was conducted to assess the level of familiarity among students with various biotechnological products. The x-axis of the scale ranged from -60% to 100%, representing the spectrum from low familiarity (on the negative side) to high familiarity (on the positive side) trends. The y-axis denoted the different biotech products.

Vaccines are the most familiar among the students. An impressive 180 of respondents said they knew vaccines. This isn't surprising, considering how common vaccination programs are. Nearly everyone has had a vaccine at some point, showing how important they are for keeping us healthy. Similarly, antibiotics and insulin, important medicines, are well-known among students. An impressive 170 of respondents knew a lot about antibiotics. This shows how widely antibiotics are used to treat infections. Likewise, 151 of students were extremely familiar with insulin, which is crucial for managing diabetes, a common health condition (Fig:6).

The analysis revealed that Bt brinjal and golden rice demonstrated a discernible pattern of lower familiarity, mostly clustered on the negative side of the familiarity spectrum. This pattern suggests that these biotechnological products are not widely recognized or understood by the surveyed student population. In the case of Bt brinjal, the majority of respondents (57) expressed only slight familiarity, signifying a limited knowledge or awareness of this genetically modified crop. Moreover, 56 of respondents reported a very familiar level of knowledge about Bt brinjal, suggesting that while some students possess substantial knowledge, it remains a subject of limited awareness among the broader student cohort. Notably, a significant portion of respondents (52) indicated a complete lack of familiarity with Bt brinjal, which underscores the relatively obscure nature of this biotech product within the surveyed student community. Turning our attention to golden rice, the data portrays a similar trend of limited familiarity. A substantial proportion of students (65) reported only slight familiarity with golden rice, indicating a fundamental lack of in-depth knowledge. Furthermore, 38% of respondents declared no familiarity with this biotechnological product, highlighting a significant knowledge gap. While 47 of students expressed moderate familiarity with golden rice, it is important to note that only a minority of respondents (60 and 62) claimed to be very and extremely familiar, respectively. This suggests that a deep understanding of golden rice is not widespread among the surveyed students (Fig:6).

To sum up, students know a lot about insulin, antibiotics, and vaccines because these products are essential for our health. This shows how important it is for people to understand and appreciate their uses. These insights help us understand more about how familiar students are with different biotechnological products, which is important for discussions about health and education.

3.6 Insights on "GMO" Perspectives through Likert Scale Responses

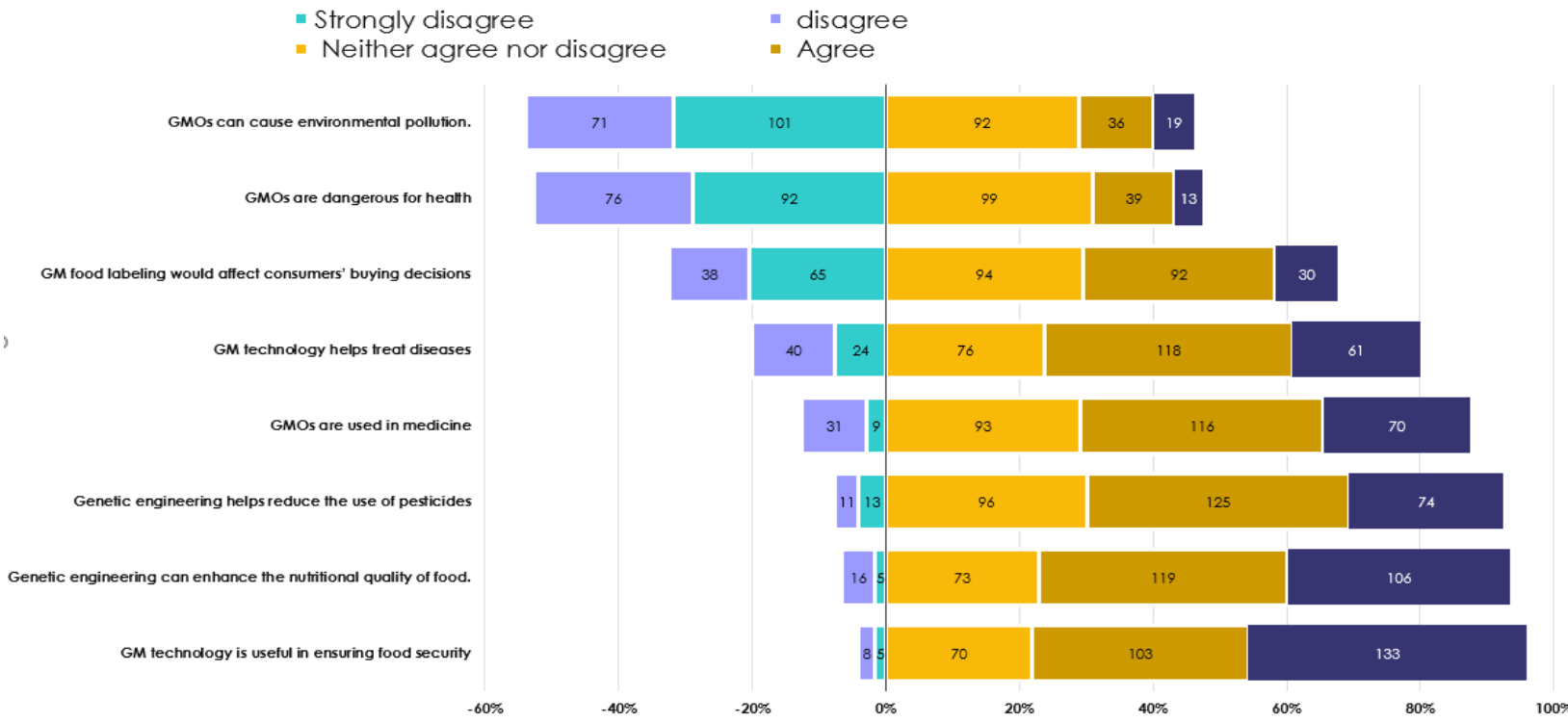

Figure 7: Participant's opinions on GMO related statements

The Likert scale analysis was conducted to elucidate the perspectives of students from various academic backgrounds and age groups concerning GMO-related statements. The x-axis in the graph represented a range of percentages from -60% to 100%, signifying the continuum of familiarity and trends, spanning from negativity to positivity. The y-axis encompassed the GMO-related statements under examination.

For the statement "GMOs can cause environmental pollution," not many people strongly agreed—only 19%. This shows that most students aren't completely convinced that GMOs are to blame for pollution. On the flip side, a big majority, even more than 100, strongly disagreed. This tells us that most students don't think GMOs are the main cause of environmental pollution. However, it's

worth mentioning that 36 agreed with the statement. This means some students do think GMOs could have an impact on the environment, but not everyone feels strongly about it (Fig:7).

As for the statement "GMOs are dangerous to health," only 13 of people strongly agreed. This suggests that most students aren't very worried about GMOs being harmful to health. On the other hand, a huge 92 strongly disagreed, showing that most students don't see GMOs as a big health risk. Still, it's important to note that 39 of respondents did agree with the statement. This means some students do have concerns about GMOs and health, but it's not a unanimous opinion (Fig:7).

On a different note, certain statements, like "GM food labeling would affect consumers' buying decisions" and "GM technology helps treat disease," received considerable support from surveyed students. Notably, 65 of respondents strongly agreed with the former statement, while an impressive 92 agreed with it, showing significant endorsement. Similarly, for the statement "GM technology helps treat disease," 24 of respondents agreed, and an additional 118 strongly endorsed it. This collective support suggests a widespread agreement among respondents regarding the impact of GM food labeling on consumer choices and the therapeutic potential of GM technology in disease treatment(Fig:7).

Furthermore, when we looked at the statement "GMOs are used in medicine," we found that most participants, a whopping 93, neither strongly agreed nor disagreed. Additionally, a significant 70 of respondents explicitly disagreed with this statement. These mixed responses highlight the uncertainty among students about GMOs' involvement in medicine (Fig:7).

The high number of neutral responses, with 93 neither agreeing nor disagreeing, suggests that many students are unsure or undecided about GMOs' role in medical applications. This points to a significant gap in knowledge or exposure to the topic, indicating a need for further investigation and educational efforts. At the same time, the sizable portion, comprising 70, who disagreed, suggests that some students may have doubts or reservations about GMOs being used in medicine(Fig:7).

Regarding the statement "GMOs are used in medicine," the survey findings revealed a noticeable split of opinions among the respondents. A significant 31 disagreed with this idea, indicating a sizable portion that doesn't support the notion of GMOs being utilized in medicine. Conversely, a

substantial 93 took a neutral position, neither supporting nor refuting the statement. This widespread neutrality suggests a knowledge gap or a lack of strong convictions among the surveyed students regarding GMOs' role in medicine(Fig:7).

The statements "Genetic engineering helps reduce the use of pesticides" and "Genetic engineering can enhance the nutritional quality of food" generated varied responses, showcasing a range of perspectives within the respondent pool. These responses underscore the complexity of discussions surrounding the impact of genetic engineering on pesticide reduction and food quality enhancement.

Lastly, the statement "GM technology is useful in ensuring food security" received significant and robust support from the respondents. A notable 133 strongly agreed with this statement, while an additional 103 agreed. The relatively low percentage of respondents expressing disagreement or strong disagreement underscores the prevailing belief in the efficacy of GM technology in bolstering food security. These findings highlight a widespread consensus within the student cohort regarding the positive role of GM technology in securing food supplies (Fig:7).

3.7 Gender-Based Distinctions in Perception of GM Food Labeling Impact on Purchasing Behavior

Investigating whether gender influences attitudes toward the impact of GM food labeling on purchasing behavior, a chi-square test, a statistical method suitable for analyzing categorical data, was applied. This method helped assess if there's a meaningful link between gender and the belief that GM food labeling affects consumers' buying decisions.

Table 9
Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	25.559[a]	4	.000
Likelihood Ratio	27.963	4	.000
Linear-by-Linear Association	19.262	1	.000
N of Valid Cases	319		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 9.40.

The chi-square tests, including Pearson Chi-Square, Likelihood Ratio, and Linear-by-Linear Association, revealed significant results. The Pearson Chi-Square statistic of 25.559 with 4 degrees of freedom, and a p-value of .000, suggests a strong association between gender and perceptions of GM food labeling's impact on purchases. Similarly, both the Likelihood Ratio and Linear-by Linear Association tests had low p-values of .000 (Tab:9), supporting the idea of a substantial connection

between gender and attitudes toward GM food labeling's influence on purchasing behavior. These findings indicate that gender plays a significant role in shaping individuals' perspectives on the effect of GM food labeling on their buying decisions.

Upon examination of the chart, notable gender-based distinctions emerged. Females displayed a significantly higher leaning towards disagreement (58) with the statement regarding GM food labeling's impact on purchasing behavior, while males exhibited a more varied set of responses, including neutrality or agreement(42) . These distinctions are statistically significant, indicating that they're not random but meaningful. These findings suggest that gender plays a pivotal role in shaping individuals' perspectives on GM food labeling and its potential impact on purchasing behavior. Females, in particular, appear to be more inclined to disagree with the statement, while males exhibit a more diverse range of opinions (Fig:8).

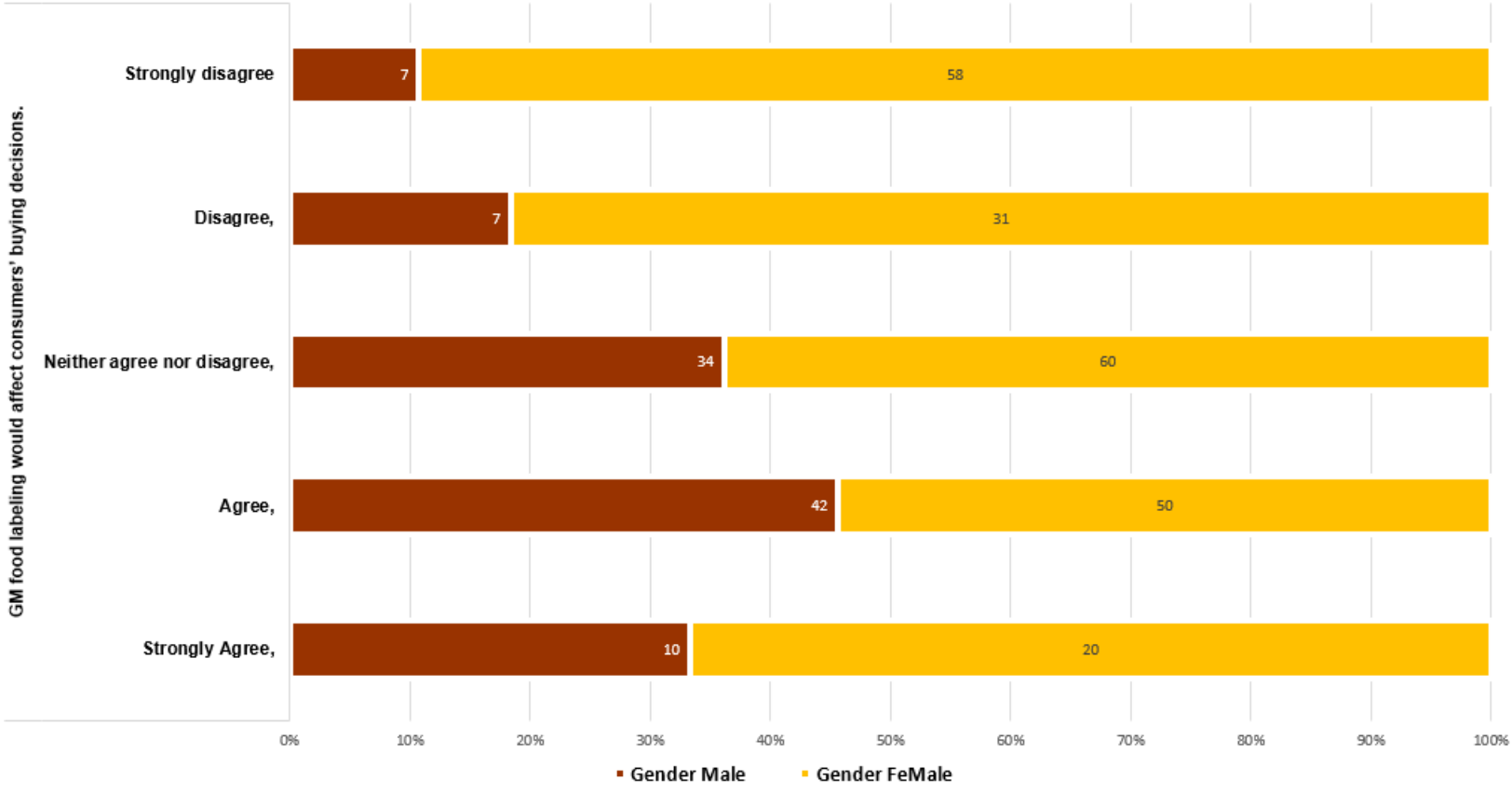

Figure 8 : Gender vs the effect of GM food labeling on their buying decisions.

3.8 A Likert Scale Study on -Understanding Biotech and GM Information Exposure

The Likert scale analysis was conducted to assess the level of exposure among students about how frequently they come across biotechnology or GM related products obtained from different sources. The x-axis of the scale ranged from -60% to 100%, representing the spectrum from low familiarity (on the negative side) to high familiarity (on the positive side) trends. The y-axis denoted the different biotech products.

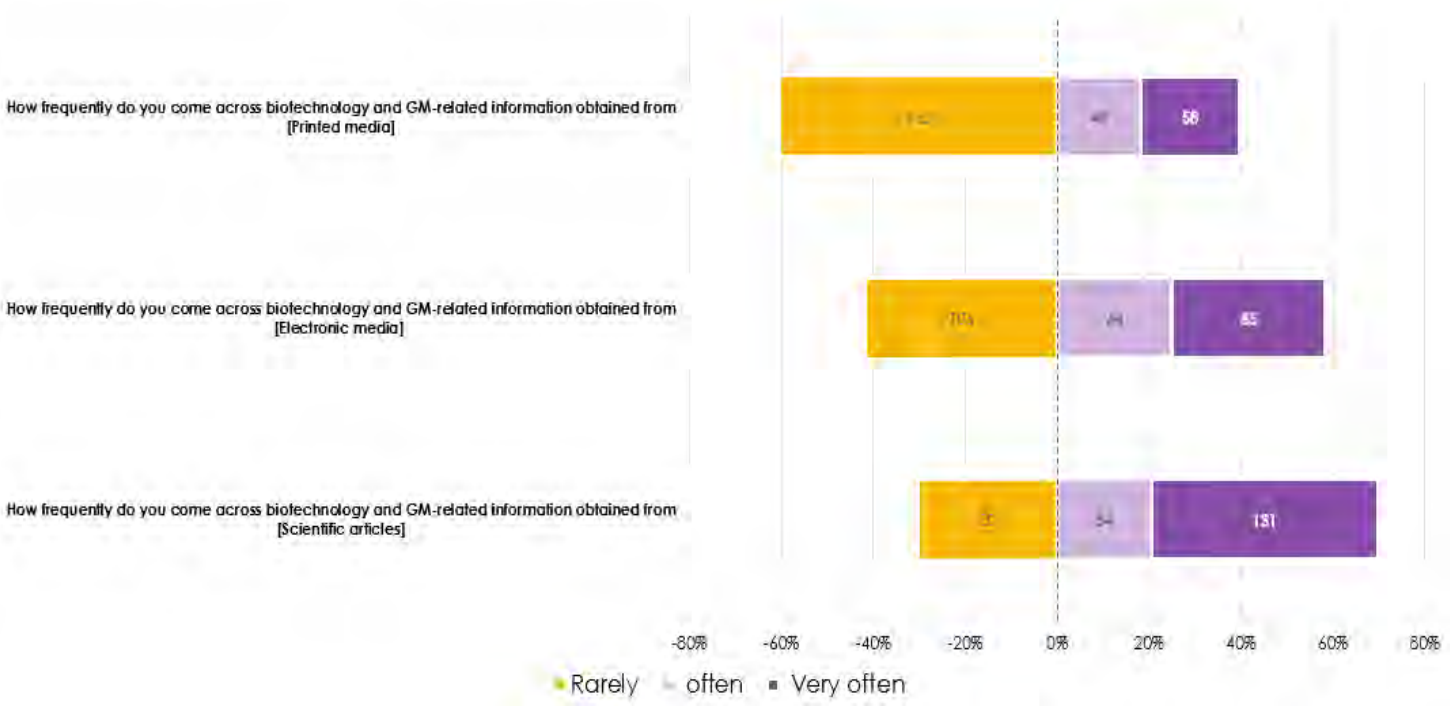

Figure 9: Participants' obtaining information related to biotechnology from different source

3.8.1. In Print Media: Among the participants, 163 mentioned rare exposure to technology-related information in print media. This suggests that a significant portion of individuals infrequently encounter such content through traditional printed sources. Conversely, 58 reported very frequent encounters, indicating a substantial number of participants who frequently come

across technology-related information in print media. Additionally, 49 noted frequent exposure, further highlighting the prevalence of technology-related content in this medium(Fig:9).

3.8.2. In Electronic Media: The data revealed that 106 students reported rare occurrences of exposure to technology-related content through electronic media. Some participants provided a strong sentiment regarding the infrequency of encountering technology-related information through electronic media. Furthermore, 64 participants indicated frequent encounters, suggesting a notable portion of individuals regularly come across such content. Moreover, 85 mentioned very frequent interactions, indicating a significant majority of participants who frequently engage with technology-related content through electronic media(Fig:9).

3.8.3. Scientific Articles: Surprisingly, 131 students stated very frequent exposure to technology-related information through scientific articles. This high percentage indicates a substantial majority of participants who regularly access such content through scientific literature. Additionally, 54 reported frequent encounters, further highlighting the prevalence of technology-related information in scientific articles. Moreover, 80 experienced rare exposure, suggesting that while some participants infrequently encounter GM technology-related content in scientific articles, a considerable portion still does(Fig:9).

3.9. Exploring GMO Perspectives Across Diverse Academic Majors: An Analysis of Opinions and Knowledge

In this segment, the analysis delves into students' perspectives and understanding of various biotechnological products, with a particular focus on genetically modified organisms (GMOs). The goal is to examine how students across different academic disciplines, such as life sciences, commerce, arts, and other sciences, perceive GMOs. By comparing these viewpoints, patterns or disparities between fields and students' comprehension of GMOs can be identified. This examination provides valuable insights into the influence of education on shaping opinions regarding biotechnological advancements.

3.9.1 Academic Majors and their knowledge on Vaccines:

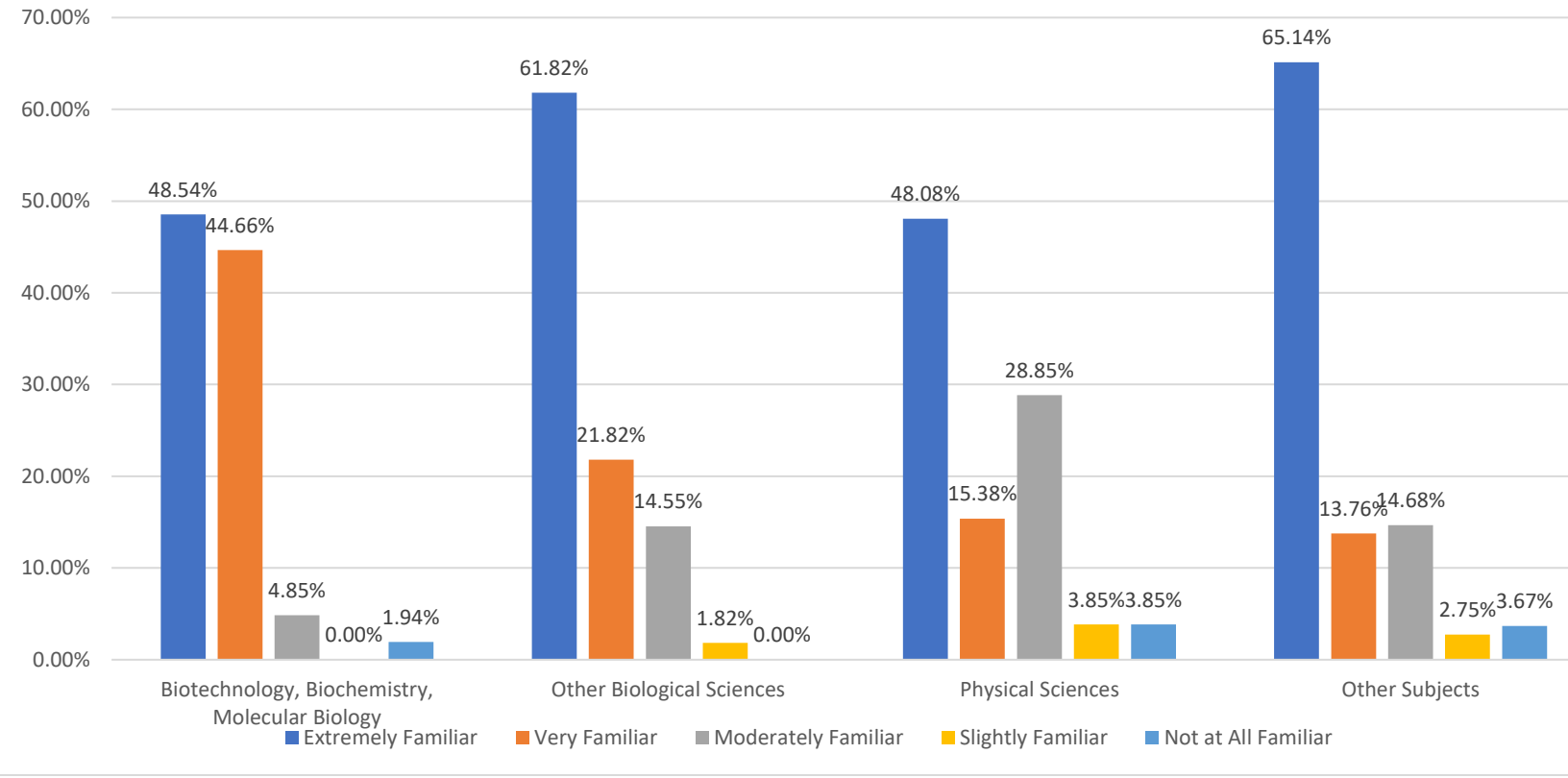

Figure 10: Variations in Vaccine Familiarity Across Diverse Academic Majors

The comparison of familiarity levels with vaccines among students from different majors revealed notable trends:

In the domain of Biotechnology, Biochemistry, and Molecular Biology, a substantial 48.54% displayed an extremely high level of familiarity with vaccines, with an additional 44.66% indicating a very familiar stance. Only a marginal 4.85% reported moderate familiarity, while none expressed slight or no familiarity. Similarly, students from other biological sciences showcased a robust understanding, with 61.82% reporting extreme familiarity and 21.82% indicating a very familiar stance. A smaller percentage, 14.55%, reported moderate familiarity, with none reporting slight or no familiarity.

Within the domain of Physical Sciences, familiarity levels varied, with 48.08% reporting extreme familiarity and 15.38% indicating very familiarity. A notable 28.85% reported moderate familiarity, while 3.85% expressed slight familiarity. A matching 3.85% reported no familiarity. Students from other subjects also exhibited a notable level of familiarity, with 65.14% reporting extreme familiarity and 13.76% indicating a very familiar stance. A smaller percentage, 14.68%, reported moderate familiarity, with 2.75% expressing slight familiarity and 3.67% reporting no familiarity (fig:10).

Overall, students from other subjects reported the highest levels of familiarity with vaccines, followed closely by those from other biological sciences. In contrast, students from Physical Sciences displayed a more varied range of familiarity levels.

3.9.2. Academic Majors and their knowledge on Antibiotics:

The analysis of students' familiarity with antibiotics across different majors revealed insightful findings:

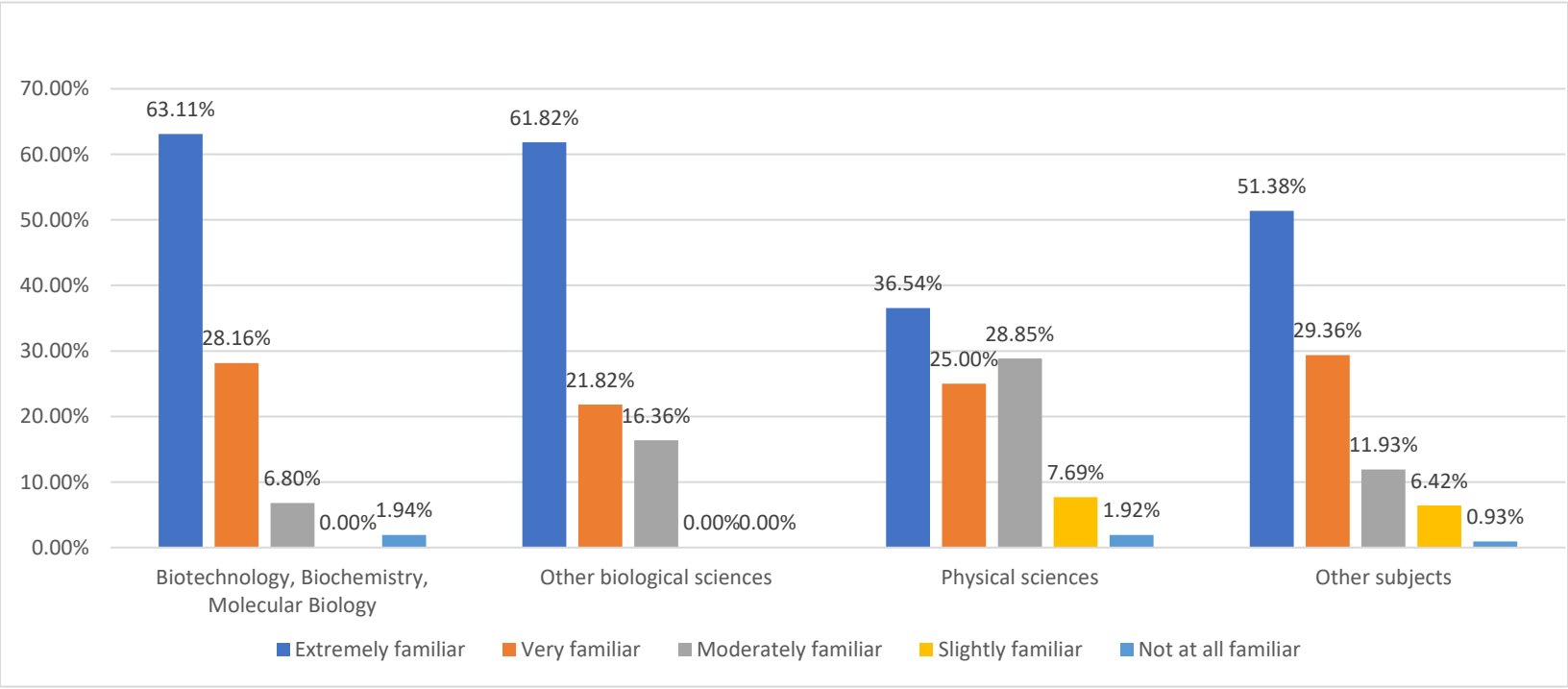

Figure 11: Variations in Antibiotics Familiarity Across Diverse Academic Majors

Among students majoring in Biotechnology, Biochemistry, and Molecular Biology, a significant 63.11% reported extreme familiarity with antibiotics, with an additional 28.16% indicating very familiarity. A smaller proportion, approximately 6.80%, reported moderate familiarity, while only 1.94% expressed slight familiarity. None reported being not at all familiar. Conversely, students from other biological sciences demonstrated a slightly different pattern of familiarity. Approximately 61.82% reported extreme familiarity with antibiotics, while 21.82% indicated very familiarity. A smaller percentage, approximately 16.36%, reported moderate familiarity, with none expressing slight or no familiarity. In the domain of Physical Sciences, familiarity levels varied. Roughly 36.54% reported extreme familiarity with antibiotics, while 25.00% indicated very familiarity. A larger proportion, approximately 28.85%, reported moderate familiarity, while 7.69% reported slight familiarity. Approximately 1.92% reported no familiarity. Similarly, students from other subjects showcased diverse familiarity levels. Around 51.38% reported extreme familiarity with antibiotics, while 29.36% indicated very familiarity. A smaller percentage, approximately 11.93%, reported moderate familiarity, with 6.42% expressing slight familiarity. Approximately 0.92% reported no familiarity (fig:11).

Overall, students majoring in Biotechnology, Biochemistry, and Molecular Biology, as well as those from other biological science, reported relatively higher familiarity with antibiotics and the students from Physical Sciences has lower familiarity with antibiotics . This indicates varying levels of exposure to and understanding of antibiotics across different majors, possibly influenced by differences in curriculum emphasis or personal interests.

3.9.3. Academic Majors and their knowledge on Insulin:

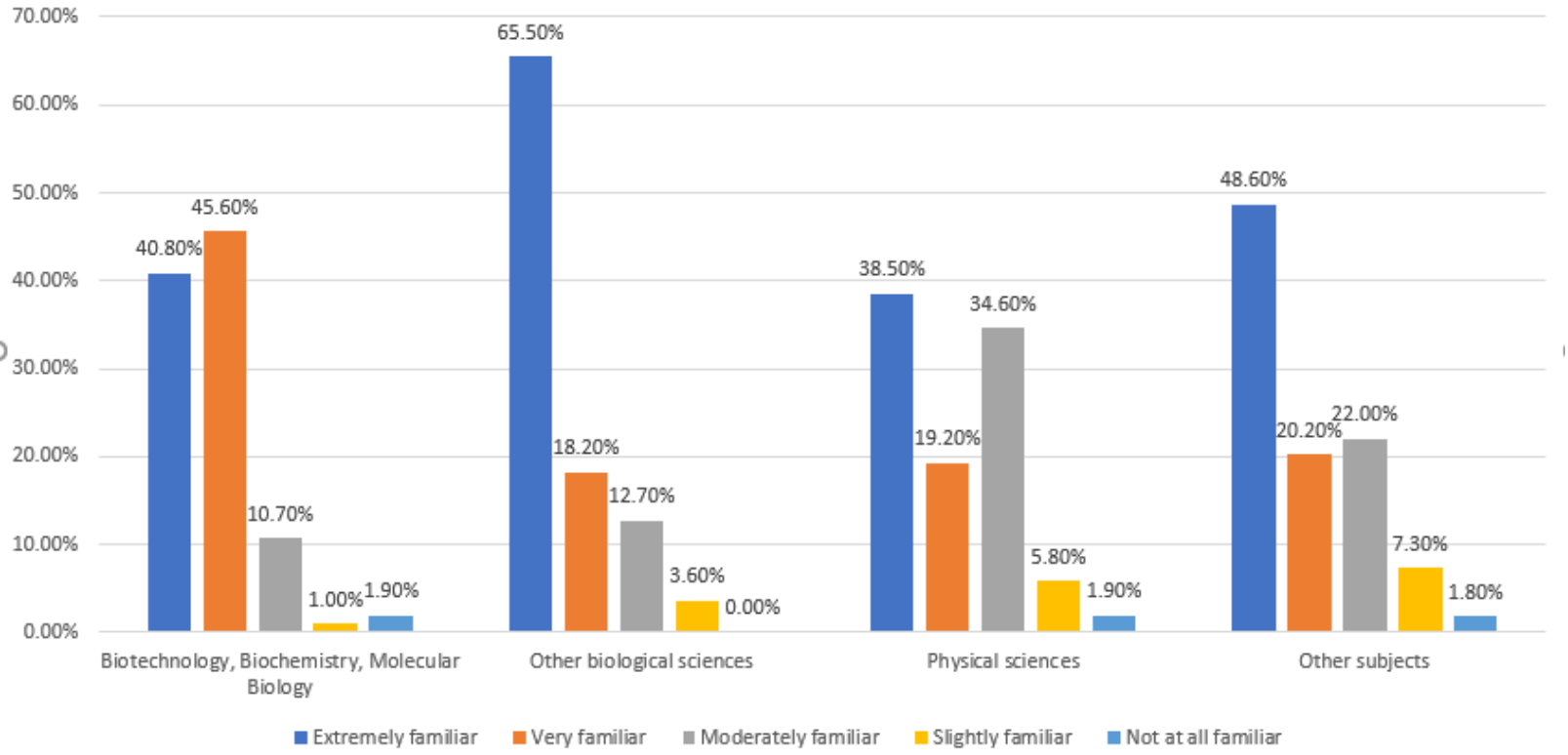

Figure 12: Variations in Insulin Familiarity Across Diverse Academic Majors

The analysis compared the familiarity levels of students from Biotechnology, Biochemistry, and Molecular Biology; other biological sciences; Physical Sciences; and other subjects with insulin biotechnological products. Among those in Biotechnology, Biochemistry, and Molecular Biology, 40.80% displayed a high level of familiarity, with 45.60% indicating a substantial degree of knowledge. Conversely, only 1.90% expressed no familiarity at all. In contrast, students from other biological sciences demonstrated a significant familiarity rate, with 65.50% reporting a strong understanding and 18.20% indicating a considerable level of knowledge. Strikingly, none of the respondents reported no familiarity. Within the domain of Physical Sciences, familiarity levels varied, with 38.50% indicating a high level of familiarity, 19.20% reporting a notable degree of understanding, and 34.60% displaying a moderate level of familiarity. Similarly, students from other subjects showcased a varied spectrum of familiarity, with 48.60% demonstrating a robust understanding and 20.20% indicating a considerable level of knowledge. Notably, only 1.80% reported no familiarity. Overall, students majoring in biological sciences exhibited the highest

familiarity with insulin biotechnological products. In contrast, students from Physical Sciences and other majors displayed a mixed range of familiarity levels, with varying degrees of understanding across the disciplines.

3.9.4. Academic Majors and their knowledge on Bt Brinjal:

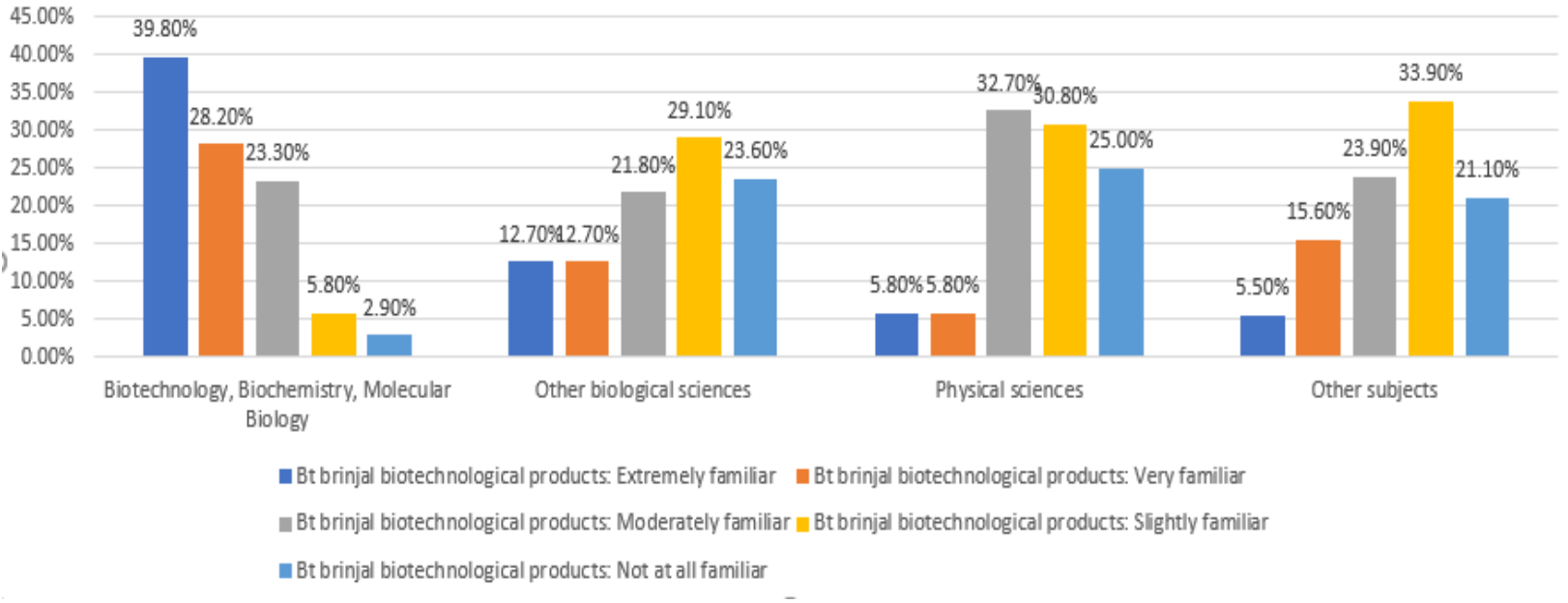

Figure 13: Variations in Bt brinjal Familiarity Across Diverse Academic Majors

The examination compared the familiarity levels of students from Biotechnology, Biochemistry, and Molecular Biology; other biological sciences; Physical Sciences; and other subjects with Bt brinjal biotechnological products. Among those in Biotechnology, Biochemistry, and Molecular Biology, 39.80% showed an extreme familiarity, with an additional 28.20% indicating a very familiar understanding. A substantial 23.30% reported a moderate level of familiarity, while only 2.90% expressed no familiarity at all.

Contrastingly, students from other biological sciences demonstrated a notably different pattern. Only 12.70% claimed extreme familiarity, with an equal percentage (12.70%) indicating a very familiar understanding. A larger proportion, 21.80%, reported a moderate level of familiarity, while 29.10% indicated slight familiarity, and 23.60% expressed no familiarity at all. Within the realm of Physical Sciences, familiarity levels varied significantly. Only 5.80% expressed extreme familiarity, with an equal percentage (5.80%) indicating a very familiar understanding. Notably,

32.70% reported a moderate level of familiarity, while 30.80% indicated slight familiarity, and 25.00% expressed no familiarity at all. Similarly, students from other subjects showcased diverse familiarity levels. 5.50% claimed extreme familiarity, while 15.60% indicated a very familiar understanding. A notable 23.90% reported a moderate level of familiarity, while 33.90% indicated slight familiarity, and 21.10% expressed no familiarity at all (fig:13).

Overall, students majoring in Biotechnology, Biochemistry, and Molecular Biology exhibited the highest familiarity with Bt brinjal biotechnological products, followed by those in other biological sciences. In contrast, students from other majors displayed a highest range of unfamiliarity levels, indicating potential differences in curriculum emphasis. This underscores the importance of tailored educational strategies to ensure comprehensive knowledge dissemination in the field of biotechnology.

3.9.5. Academic Majors and their knowledge on Golden rice:

The examination scrutinized the familiarity levels of students from various majors with Golden rice biotechnological products:

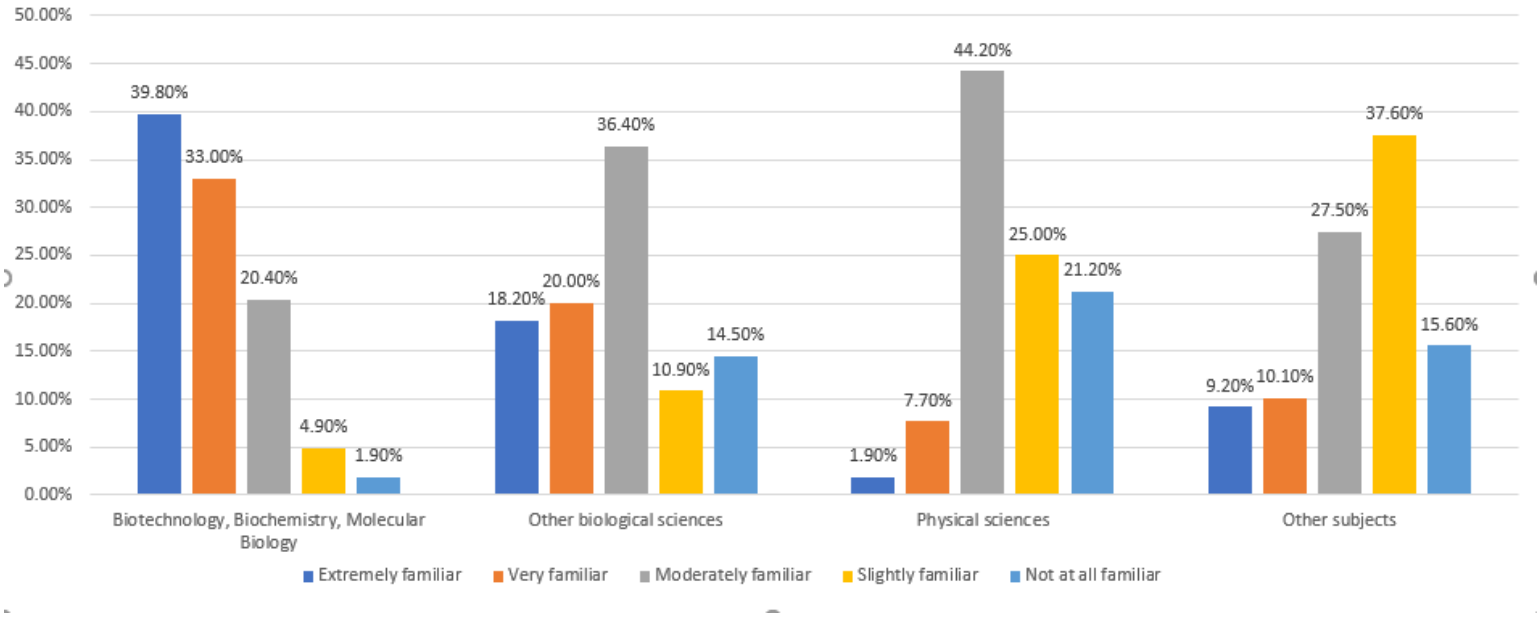

Figure 14: Variations in Golden rice Familiarity Across Diverse Academic Majors

Among those in Biotechnology, Biochemistry, and Molecular Biology, a significant 39.80% exhibited an extreme familiarity, with an additional 33.00% indicating a very familiar understanding. A notable 20.40% reported a moderate level of familiarity, while only 1.90% expressed no familiarity at all. In contrast, students from other biological sciences displayed a different distribution of familiarity levels. Only 18.20% claimed extreme familiarity, with 20.00% indicating a very familiar understanding. A larger proportion, 36.40%, reported a moderate level of familiarity, while 10.90% indicated slight familiarity, and 14.50% expressed no familiarity at all. Within the domain of Physical Sciences, familiarity levels exhibited significant variance. Merely 1.90% expressed extreme familiarity, while 7.70% indicated a very familiar understanding. Notably, 44.20% reported a moderate level of familiarity, while 25.00% indicated slight familiarity, and 21.20% expressed no familiarity at all. Similarly, students from other subjects showcased diverse familiarity levels. 9.20% claimed extreme familiarity, while 10.10% indicated a very familiar understanding. A notable 27.50% reported a moderate level of familiarity, while 37.60% indicated slight familiarity, and 15.60% expressed no familiarity at all (fig14).

Overall, students majoring in Biotechnology, Biochemistry, and Molecular Biology demonstrated the highest familiarity with Golden rice biotechnological products. In contrast, students from Physical Sciences and other majors displayed a varied range of familiarity levels, emphasizing the need for tailored educational strategies to ensure comprehensive knowledge dissemination in the realm of biotechnology.

3.9.6. Academic Majors and their views on "GM technology in ensuring food security":

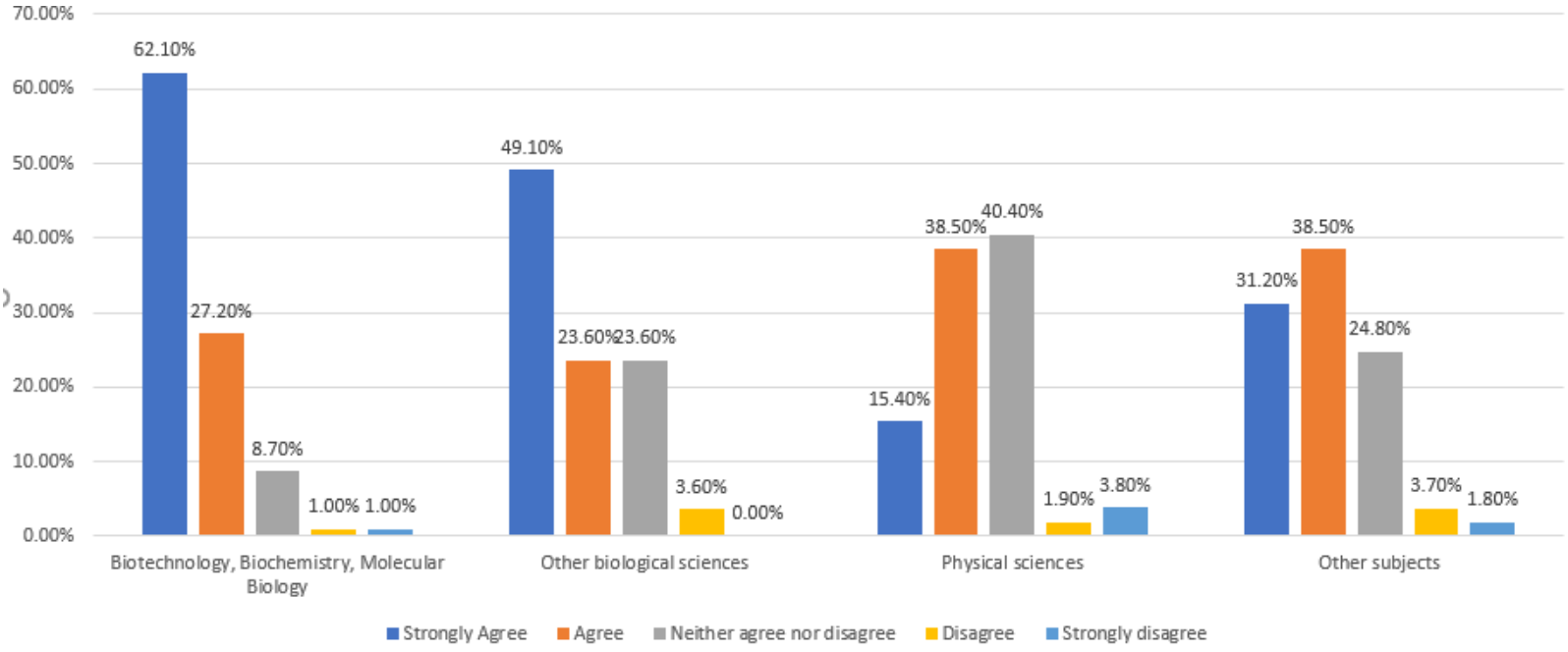

Figure 15: Variations views on "GM technology in ensuring food security " Across Diverse Academic Majors

The analysis explored the opinions of students from different majors regarding the usefulness of GM technology in ensuring food security:

Among those in Biotechnology, Biochemistry, and Molecular Biology, a significant 62.10% strongly agreed that GM technology is useful for ensuring food security, with an additional 27.20% expressing agreement. Only a small percentage (1.00%) disagreed or strongly disagreed. In contrast, students from other biological sciences exhibited a slightly different distribution of opinions. 49.10% strongly agreed with the usefulness of GM technology, while 23.60% agreed. Another 23.60% remained neutral on the matter. Notably, none strongly disagreed. Within the realm of Physical Sciences, opinions varied significantly. Only 15.40% strongly agreed with the usefulness of GM technology, while a larger proportion (38.50%) agreed. However, a substantial 40.40% remained neutral, with smaller percentages disagreeing (1.90%) or strongly disagreeing

(3.80%). Similarly, students from other subjects showcased diverse opinions. 31.20% strongly agreed with the usefulness of GM technology, while 38.50% agreed. 24.80% remained neutral, with smaller percentages disagreeing (3.70%) or strongly disagreeing (1.80%) (fig:15).

Overall, students majoring in Biotechnology, Biochemistry, and Molecular Biology exhibited the highest agreement with the notion that GM technology is useful in ensuring food security, followed by those in other biological sciences. In contrast, students from Physical Sciences displayed a neutral opinion and other majors displayed more varied opinions on the matter, emphasizing the need for nuanced discussions and education regarding GM technology in addressing food security concerns.

3.9.7. Academic Majors and their views on "genetic engineering can enhance the nutritional quality of food":

The analysis investigated the opinions of students from different majors regarding whether genetic engineering can enhance the nutritional quality of food:

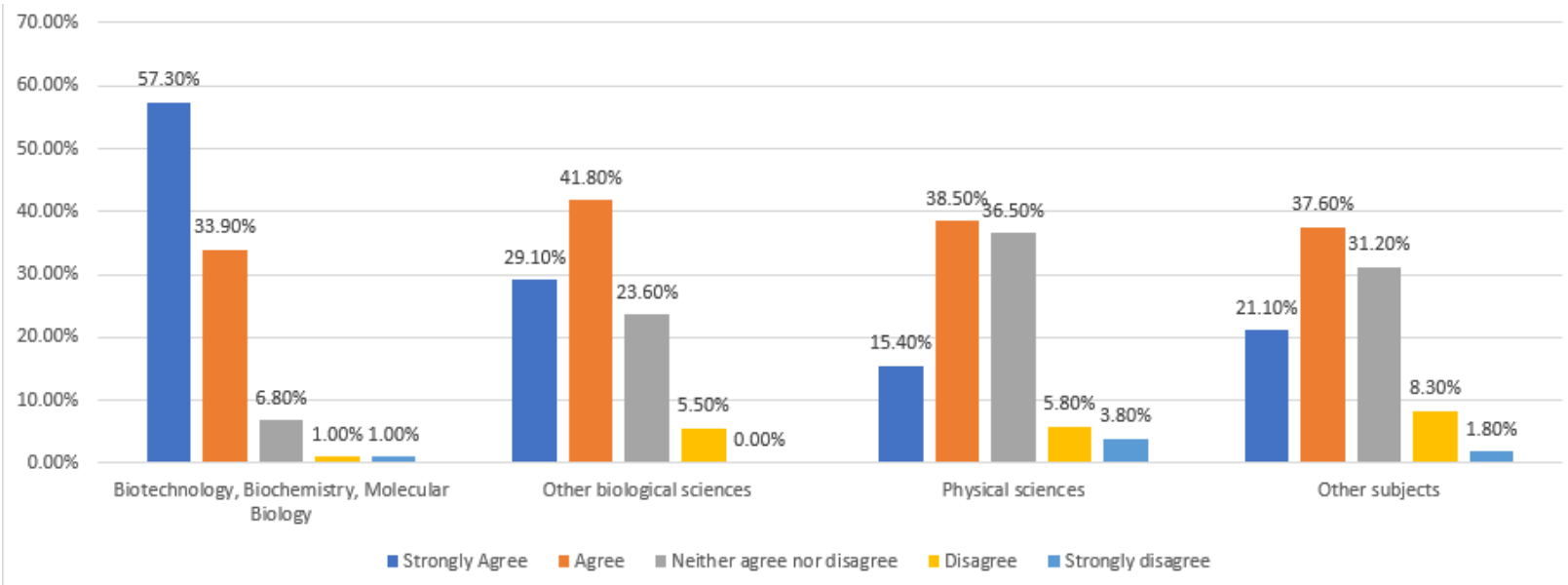

Figure 16: Variations views on "genetic engineering can enhance the nutritional quality of food" Across Diverse Academic Majors

Among those in Biotechnology, Biochemistry, and Molecular Biology, a significant 57.30% strongly agreed that genetic engineering can enhance the nutritional quality of food, with an

additional 33.90% expressing agreement. Only a small percentage (1.00%) disagreed or strongly disagreed. In contrast, students from other biological sciences exhibited a different distribution of opinions. 29.10% strongly agreed that genetic engineering can enhance nutritional quality, while 41.80% agreed. Another 23.60% remained neutral on the matter. Notably, none strongly disagreed. Within the realm of Physical Sciences, opinions varied significantly. Only 15.40% strongly agreed with the notion that genetic engineering can enhance nutritional quality, while a larger proportion (38.50%) agreed. However, a substantial 36.50% remained neutral, with smaller percentages disagreeing (5.80%) or strongly disagreeing (3.80%). Similarly, students from other subjects showcased diverse opinions. 21.10% strongly agreed with the notion that genetic engineering can enhance nutritional quality, while 37.60% agreed. 31.20% remained neutral, with smaller percentages disagreeing (8.30%) or strongly disagreeing (1.80%) (fig:16).

Overall, students majoring in Biotechnology, Biochemistry, and Molecular Biology exhibited the highest agreement with the idea that genetic engineering can enhance the nutritional quality of food. In contrast, students from Physical Sciences and other majors displayed more varied opinions on the matter, indicating the need for further discussion and education regarding the potential benefits of genetic engineering in food production.

3.9.8. Academic Majors and their views on "genetic engineering helps reduce the use of pesticides"

The examination explored the opinions of students from different majors regarding whether genetic engineering helps reduce the use of pesticides:

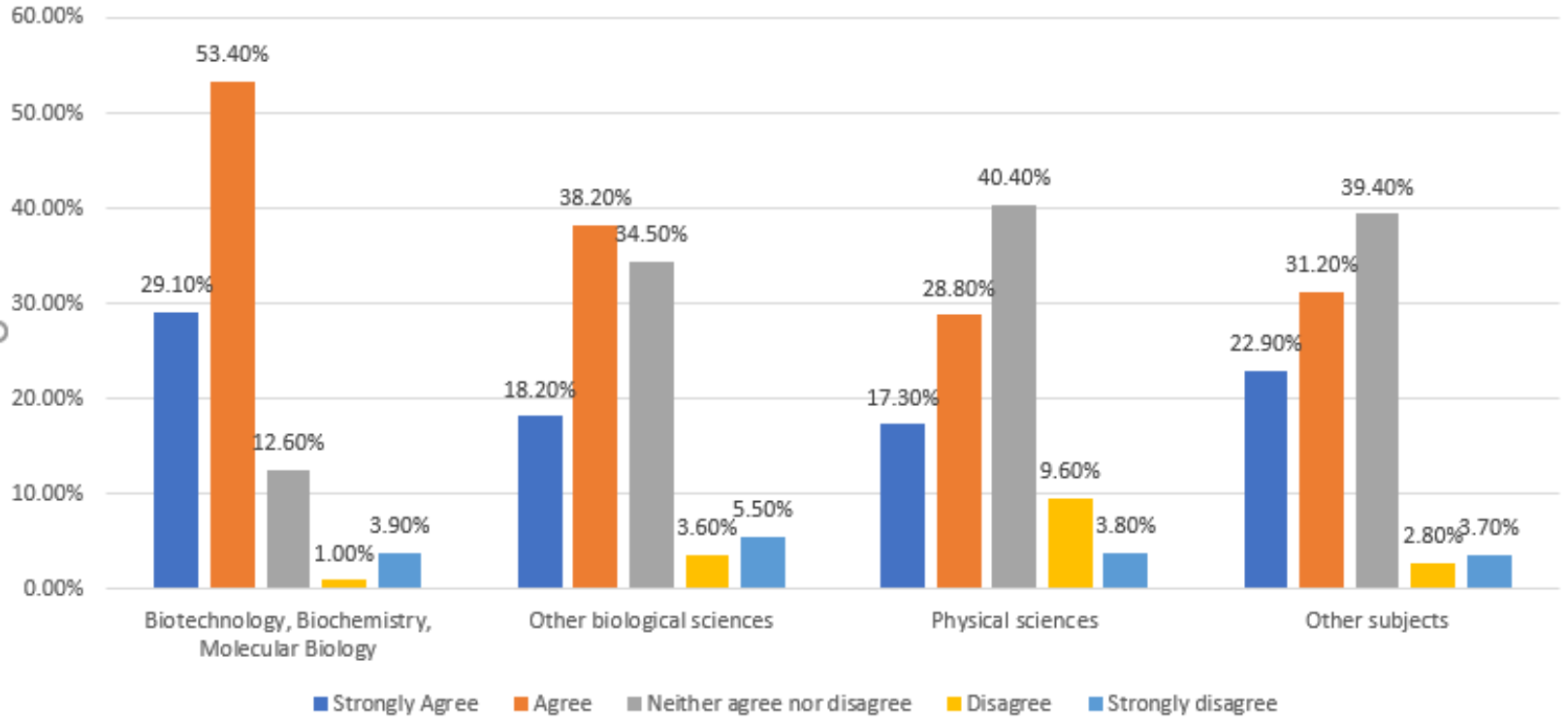

Figure 17: Variations views on " genetic engineering helps reduce the use of pesticides" Across Diverse Academic Majors

Among those in Biotechnology, Biochemistry, and Molecular Biology, 29.10% strongly agreed that genetic engineering helps reduce the use of pesticides, with an additional 53.40% expressing agreement. A moderate 12.60% remained neutral on the matter, while only a small percentage (1.00%) disagreed, and 3.90% strongly disagreed. In contrast, students from other biological sciences exhibited a slightly different distribution of opinions. 18.20% strongly agreed that genetic engineering helps reduce pesticide use, while 38.20% agreed. Another 34.50% remained neutral on the matter. A small percentage (3.60%) disagreed, and 5.50% strongly disagreed. Within the realm of Physical Sciences, opinions varied significantly. Only 17.30% strongly agreed that genetic engineering reduces pesticide use, with 28.80% agreeing. However, a notable 40.40%

remained neutral on the matter, with 9.60% disagreeing, and 3.80% strongly disagreeing. Similarly, students from other subjects showcased diverse opinions. 22.90% strongly agreed that genetic engineering reduces pesticide use, while 31.20% agreed. 39.40% remained neutral on the matter, with smaller percentages disagreeing (2.80%) or strongly disagreeing (3.70%) (fig:17).

Overall, students majoring in Biotechnology, Biochemistry, and Molecular Biology demonstrated the highest agreement with the notion that genetic engineering helps reduce the use of pesticides, followed by those in other subjects. In contrast, students from other biological sciences and Physical Sciences displayed more neutral opinions on the matter or it can also be said that they are confused in this matter, emphasizing the need for further discussion and education regarding the potential role of genetic engineering in pesticide reduction.

3.9.9. Academic Majors and their views on "GMOs are used in medicine"

The investigation examined the opinions of students from different majors regarding the use of GMOs in medicine:

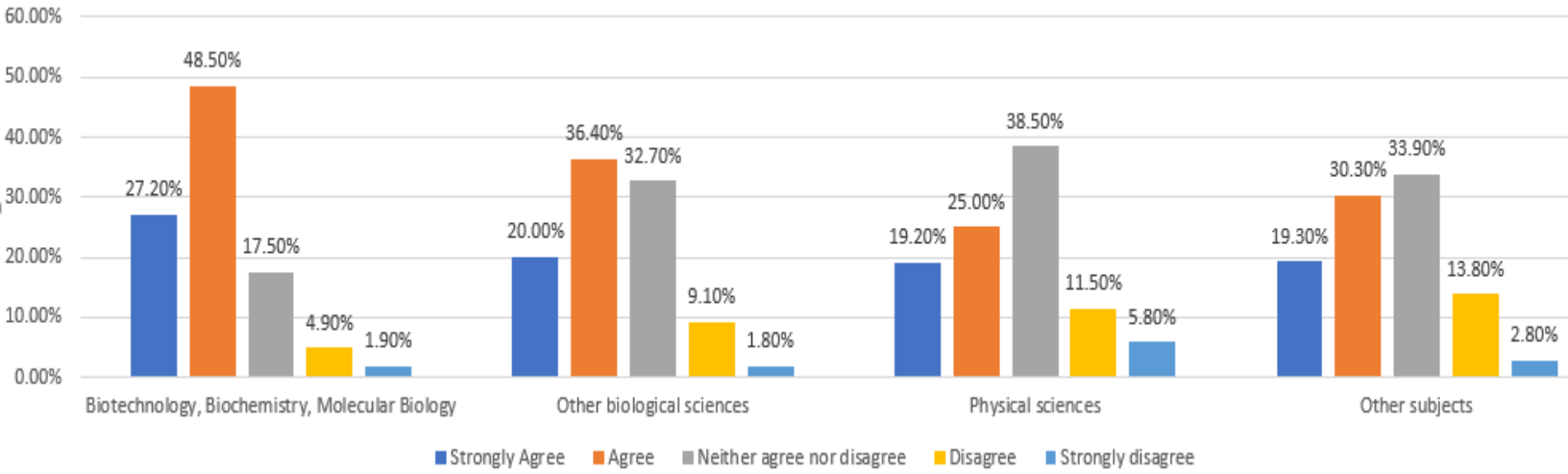

Figure 18: Variations views on "GMOs are used in medicine" Across Diverse Academic Majors

Among those in Biotechnology, Biochemistry, and Molecular Biology, 27.20% strongly agreed that GMOs are used in medicine, with an additional 48.50% expressing agreement. A significant 17.50% remained neutral on the matter, while only a small percentage (4.90%) disagreed, and 1.90% strongly disagreed. In contrast, students from other biological sciences displayed a slightly

different distribution of opinions. 20.00% strongly agreed that GMOs are used in medicine, while 36.40% agreed. Another 32.70% remained neutral on the matter. A moderate percentage (9.10%) disagreed, and 1.80% strongly disagreed. Within the realm of Physical Sciences, opinions varied significantly. Only 19.20% strongly agreed that GMOs are used in medicine, with 25.00% agreeing. However, a notable 38.50% remained neutral on the matter, with 11.50% disagreeing, and 5.80% strongly disagreeing. Similarly, students from other subjects showcased diverse opinions. 19.30% strongly agreed that GMOs are used in medicine, while 30.30% agreed. A significant 33.90% remained neutral on the matter, with smaller percentages disagreeing (13.80%) or strongly disagreeing (2.80%) (fig:18).

Overall, students majoring in Biotechnology, Biochemistry, and Molecular Biology exhibited the highest agreement with the notion that GMOs are used in medicine, followed closely by those in other subjects. In contrast, students from other biological sciences and Physical Sciences displayed more varied opinions on the matter, suggesting the need for further education and discussion regarding the applications of GMOs in medicine.

3.9.10. Academic Majors and views on "GM technology help to treat diseases"

The analysis investigated the perspectives of students from different majors regarding whether GM technology helps treat diseases:

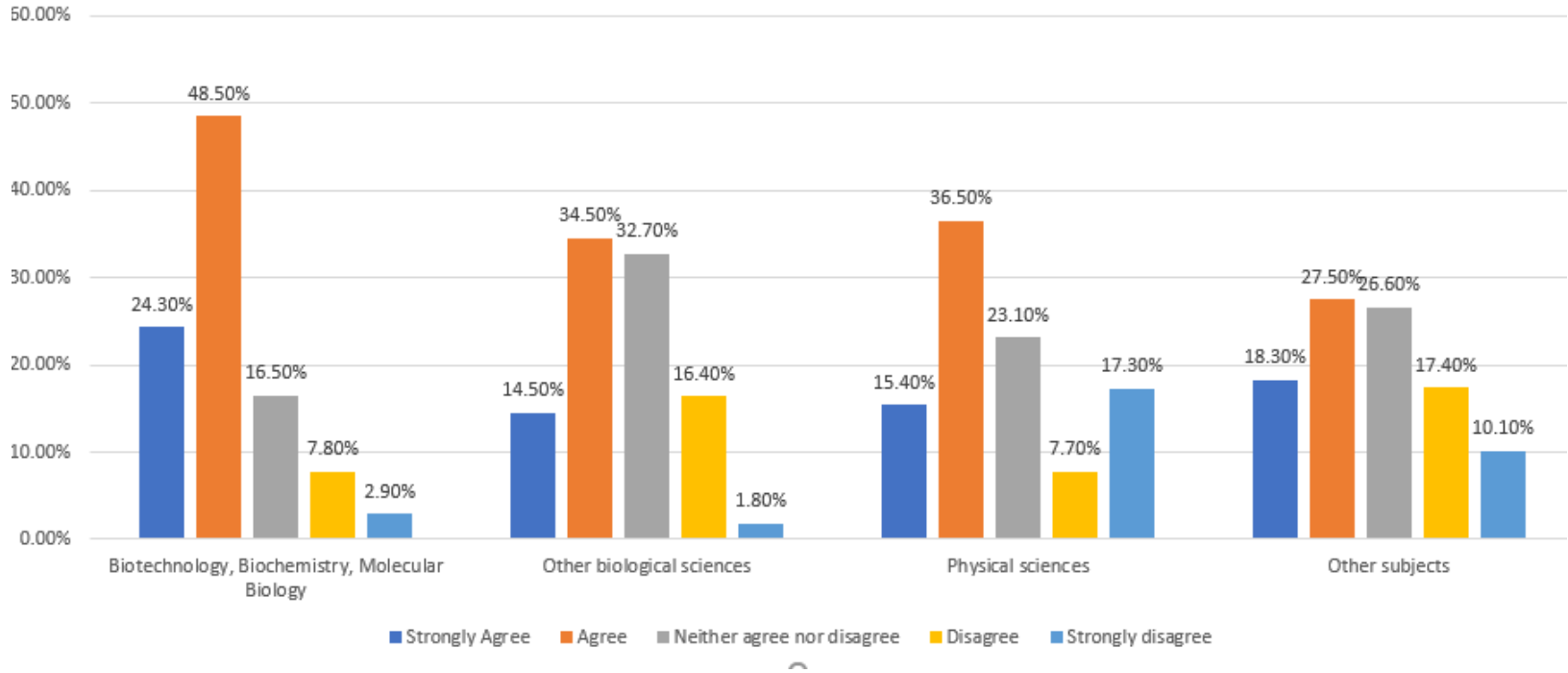

Figure 19: Variations views on "GM technology help to treat diseases" Across Diverse Academic Majors

Among those in Biotechnology, Biochemistry, and Molecular Biology, 24.30% strongly agreed that GM technology helps treat diseases, with an additional 48.50% expressing agreement. A considerable 16.50% remained neutral on the matter, while 7.80% disagreed, and 2.90% strongly disagreed. In contrast, students from other biological sciences displayed a slightly different distribution of opinions. 14.50% strongly agreed that GM technology helps treat diseases, while 34.50% agreed. Another 32.70% remained neutral on the matter. A notable percentage (16.40%) disagreed, and 1.80% strongly disagreed. Within the realm of Physical Sciences, opinions varied significantly. Only 15.40% strongly agreed that GM technology helps treat diseases, with 36.50% agreeing. However, a notable 23.10% remained neutral on the matter. A smaller percentage (7.70%) disagreed, while 17.30% strongly disagreed. Similarly, students from other subjects

showcased diverse opinions. 18.30% strongly agreed that GM technology helps treat diseases, while 27.50% agreed. A significant 26.60% remained neutral on the matter. A notable percentage (17.40%) disagreed, while 10.10% strongly disagreed (fig:19).

Overall, students majoring in Biotechnology, Biochemistry, and Molecular Biology exhibited the highest agreement with the notion that GM technology helps treat diseases, followed by those in Physical Sciences. In contrast, students from other biological sciences displayed more varied opinions on the matter, and students from and other subjects portrayed highest level of disagreement suggesting the need for further education and discussion regarding the potential role of GM technology in disease treatment.

3.9.11. Academic Majors and views on "GMOs are dangerous for health"

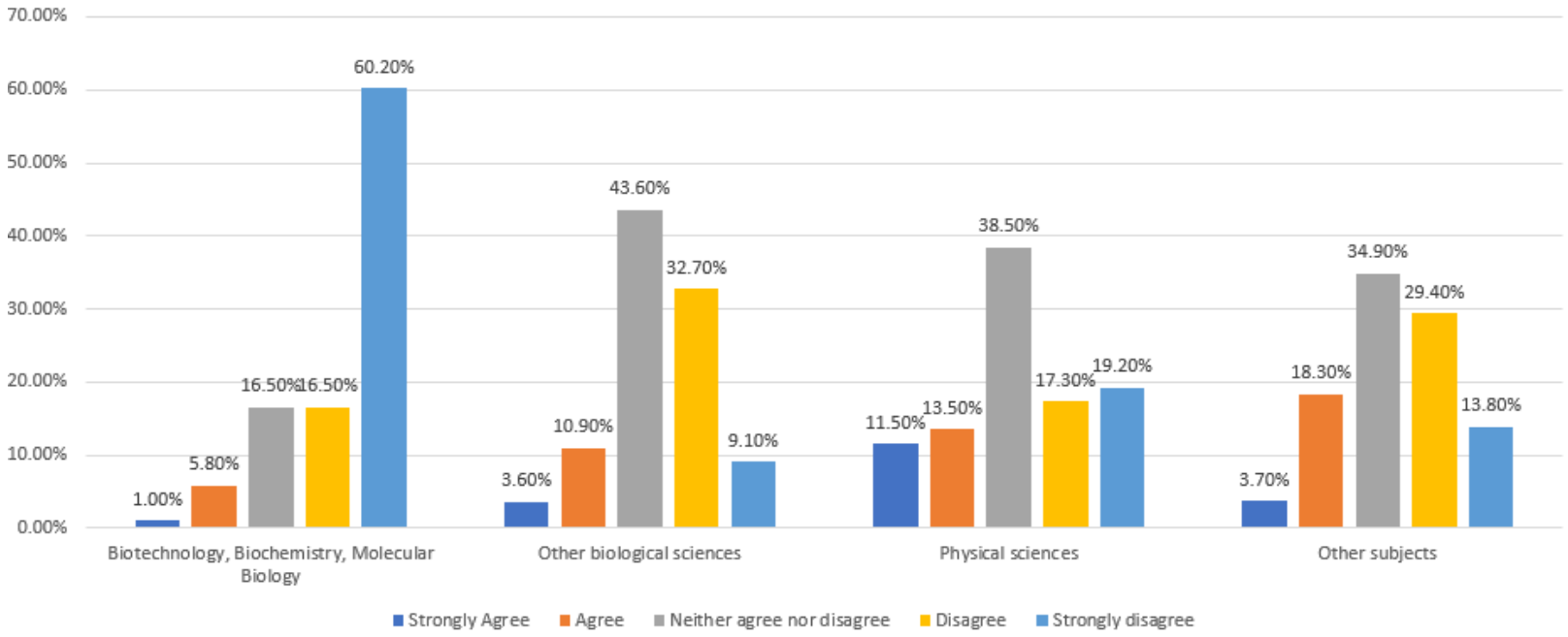

Figure 20: Variations views on "GMOs are dangerous for health" Across Diverse Academic Majors

The study examined the perceptions of students from different majors regarding whether GMOs are dangerous for health:

Among those in Biotechnology, Biochemistry, and Molecular Biology, only 1.00% strongly agreed that GMOs are dangerous for health, with an additional 5.80% expressing agreement. A

substantial 16.50% remained neutral on the matter, while 16.50% disagreed, and the majority, 60.20%, strongly disagreed. In contrast, students from other biological sciences displayed a different distribution of opinions. 3.60% strongly agreed that GMOs are dangerous for health, while 10.90% agreed. Another 43.60% remained neutral on the matter. A notable percentage (32.70%) disagreed, while 9.10% strongly disagreed. Within the realm of Physical Sciences, opinions varied significantly. 11.50% strongly agreed that GMOs are dangerous for health, with 13.50% agreeing. However, a substantial 38.50% remained neutral on the matter. A smaller percentage (17.30%) disagreed, while 19.20% strongly disagreed. Similarly, students from other subjects showcased diverse opinions. 3.70% strongly agreed that GMOs are dangerous for health, while 18.30% agreed. A significant 34.90% remained neutral on the matter. A notable percentage (29.40%) disagreed, while 13.80% strongly disagreed (fig20).

Overall, students majoring in Biotechnology, Biochemistry, and Molecular Biology exhibited the highest disagreement with the notion that GMOs are dangerous for health. In contrast, students from other biological sciences and Physical Sciences displayed more neutral opinions on the matter, suggesting the need for further education and discussion regarding the safety of GMOs for health.

3.9.12. Academic Majors and views on "GMOs can cause environmental pollution"

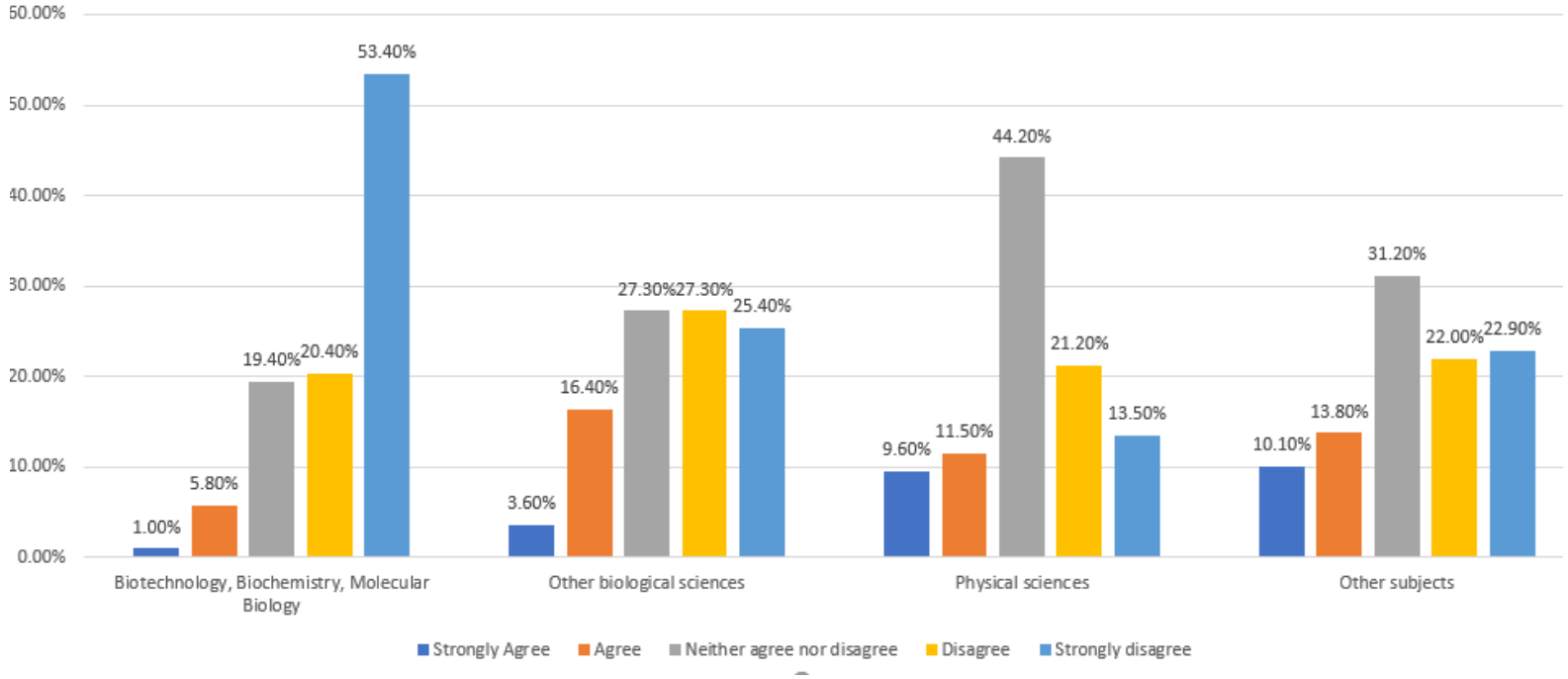

Figure 21: Views on "GMOs can cause environmental pollution" Across Diverse Academic Majors

The investigation analyzed the perspectives of students from different majors regarding whether GMOs can cause environmental pollution:

Among those in Biotechnology, Biochemistry, and Molecular Biology, only 1.00% strongly agreed that GMOs can cause environmental pollution, with an additional 5.80% expressing agreement. A substantial 19.40% remained neutral on the matter, while 20.40% disagreed, and the majority, 53.40%, strongly disagreed. In contrast, students from other biological sciences exhibited a different distribution of opinions. 3.60% strongly agreed that GMOs can cause environmental pollution, while 16.40% agreed. Another 27.30% remained neutral on the matter. A notable percentage (27.30%) disagreed, while 25.40% strongly disagreed. Within the realm of Physical Sciences, opinions varied significantly. 9.60% strongly agreed that GMOs can cause environmental pollution, with 11.50% agreeing. However, a substantial 44.20% remained neutral on the matter. A smaller percentage (21.20%) disagreed, while 13.50% strongly disagreed. Similarly, students from other subjects showcased diverse opinions. 10.10% strongly agreed that GMOs can cause environmental pollution, while 13.80% agreed. A significant 31.20% remained neutral on the matter. A notable percentage (22.00%) disagreed, while 22.90% strongly disagreed.

Overall, students majoring in Biotechnology, Biochemistry, and Molecular Biology exhibited the highest disagreement with the notion that GMOs can cause environmental pollution, followed by those in other subjects. In contrast, students from Physical Sciences displayed more neutral opinions on the matter (fig21).

3.9.13. Academic Majors and views on "GM food labeling would affect consumers buying decisions"

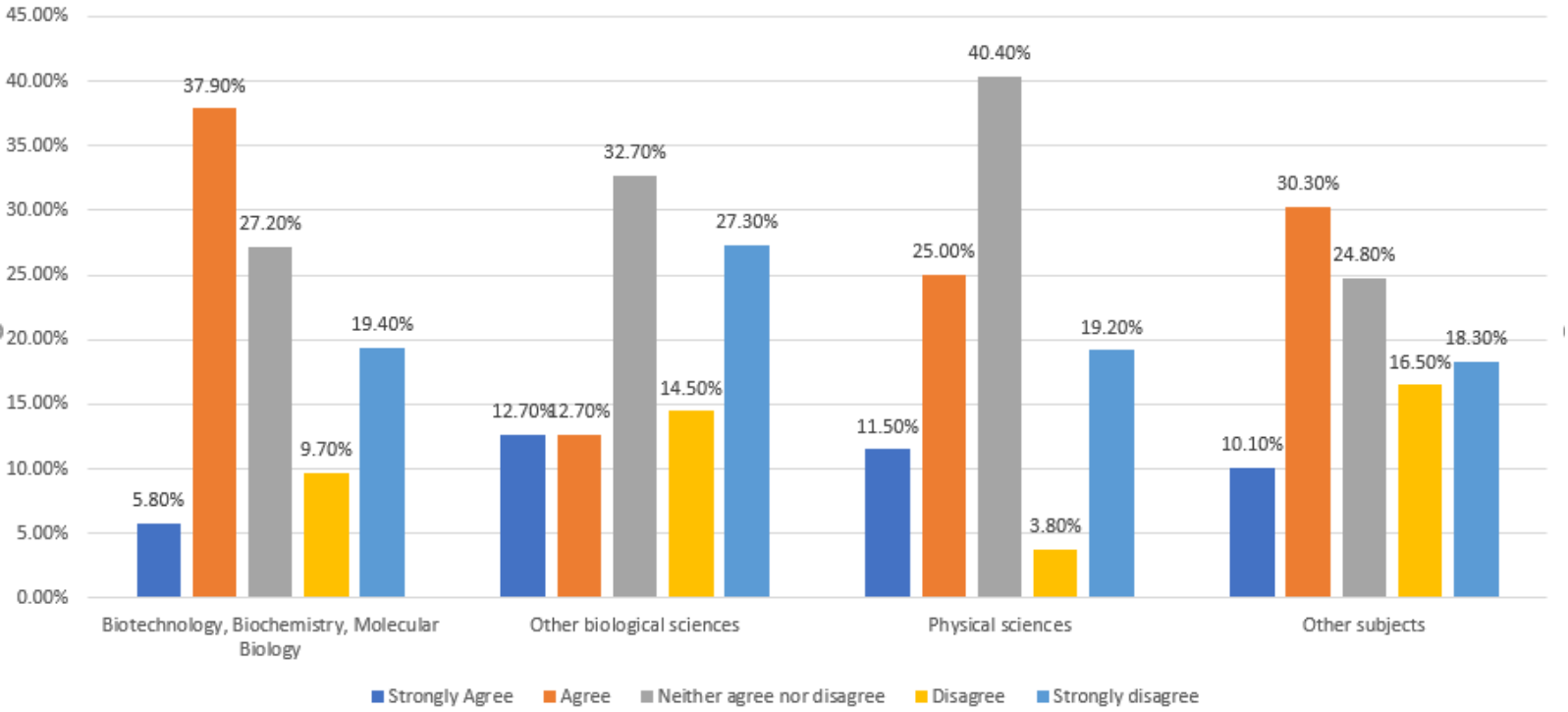

Figure 22: Variations views on "GM food labeling would affect consumers buying decisions" Across Diverse Academic Majors

The investigation examined the perceptions of students from different majors regarding whether GM food labeling would affect consumers' buying decisions:

Among those in Biotechnology, Biochemistry, and Molecular Biology, 5.80% strongly agreed that GM food labeling would affect consumers' buying decisions, with an additional 37.90% expressing agreement. A significant 27.20% remained neutral on the matter, while 9.70% disagreed, and 19.40% strongly disagreed. In contrast, students from other biological sciences displayed a slightly different distribution of opinions. 12.70% strongly agreed that GM food labeling would affect consumers' buying decisions, while another 12.70% agreed. Another 32.70% remained neutral on

the matter. A notable percentage (14.50%) disagreed, while 27.30% strongly disagreed. Within the realm of Physical Sciences, opinions varied significantly. 11.50% strongly agreed that GM food labeling would affect consumers' buying decisions, with 25.00% agreeing. However, a substantial 40.40% remained neutral on the matter. A smaller percentage (3.80%) disagreed, while 19.20% strongly disagreed. Similarly, students from other subjects showcased diverse opinions. 10.10% strongly agreed that GM food labeling would affect consumers' buying decisions, while 30.30% agreed. A significant 24.80% remained neutral on the matter. A notable percentage (16.50%) disagreed, while 18.30% strongly disagreed (fig:22).

Overall, students majoring in Biotechnology, Biochemistry, and Molecular Biology and those in other subjects exhibited the highest agreement with the notion that GM food labeling would affect consumers' buying decisions. In contrast, students from other biological science displayed highest disagreement Physical Sciences displayed more neutral opinions on the matter.

3.9.14. Diverse Majors' Exposure to Biotech & GM Info: Scientific articles

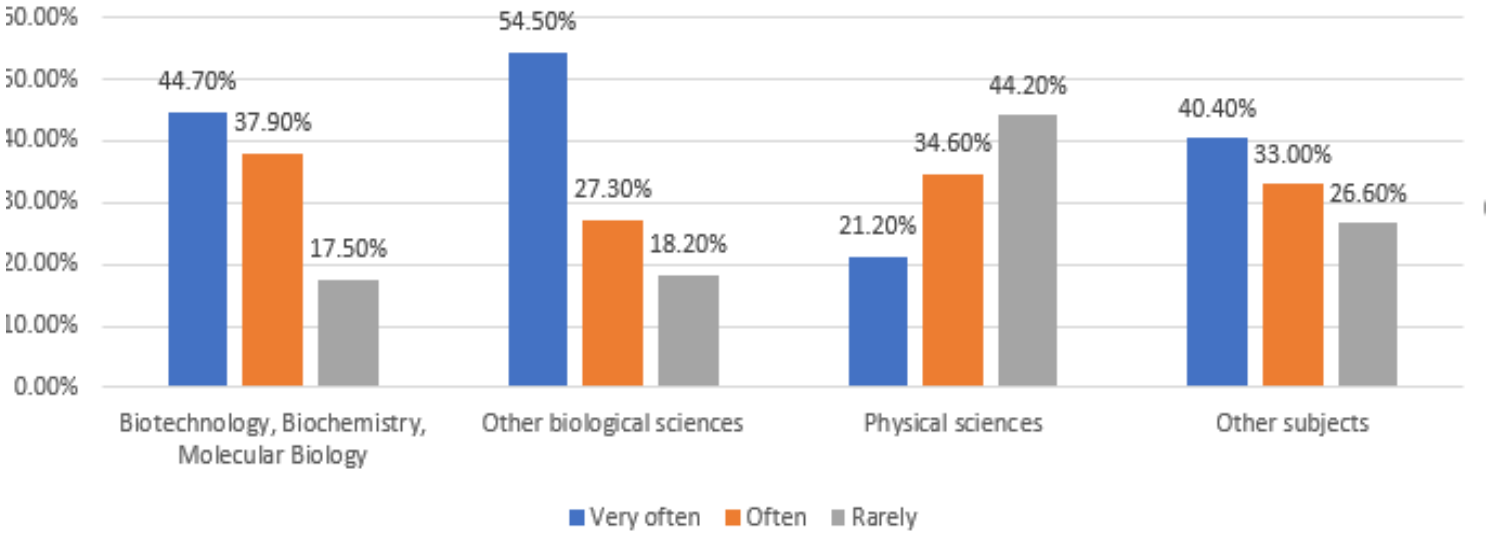

Figure 23: Variations Exposure to Biotech & GM Info: Scientific articles ,Across Diverse Academic Majors

The study investigated the frequency of encountering biotechnology and GM-related information obtained from scientific articles among students from different majors:

Among those in Biotechnology, Biochemistry, and Molecular Biology, 44.70% reported encountering such information very often, with an additional 37.90% indicating encountering it often. A smaller proportion, 17.50%, reported encountering it rarely. In contrast, students from other biological sciences exhibited a different distribution of responses. A majority, 54.50%, reported encountering biotechnology and GM-related information very often, while 27.30% indicated encountering it often. A smaller percentage, 18.20%, reported encountering it rarely. Within the realm of Physical Sciences, responses varied significantly. Only 21.20% reported encountering biotechnology and GM-related information very often, while 34.60% indicated encountering it often. A larger proportion, 44.20%, reported encountering it rarely. Similarly, students from other subjects showcased diverse responses. 40.40% reported encountering biotechnology and GM-related information very often, while 33.00% indicated encountering it often. A smaller percentage, 26.60%, reported encountering it rarely(fig23).

Overall, students majoring in other biological sciences reported the highest frequency of encountering biotechnology and GM-related information from scientific articles, compared to students from Physical Sciences and other subjects. This suggests varying levels of exposure to such information across different majors, highlighting potential differences in curriculum emphasis or personal interests.

3.9.15. Diverse Majors' Exposure to Biotech & GM Info: Electronic media

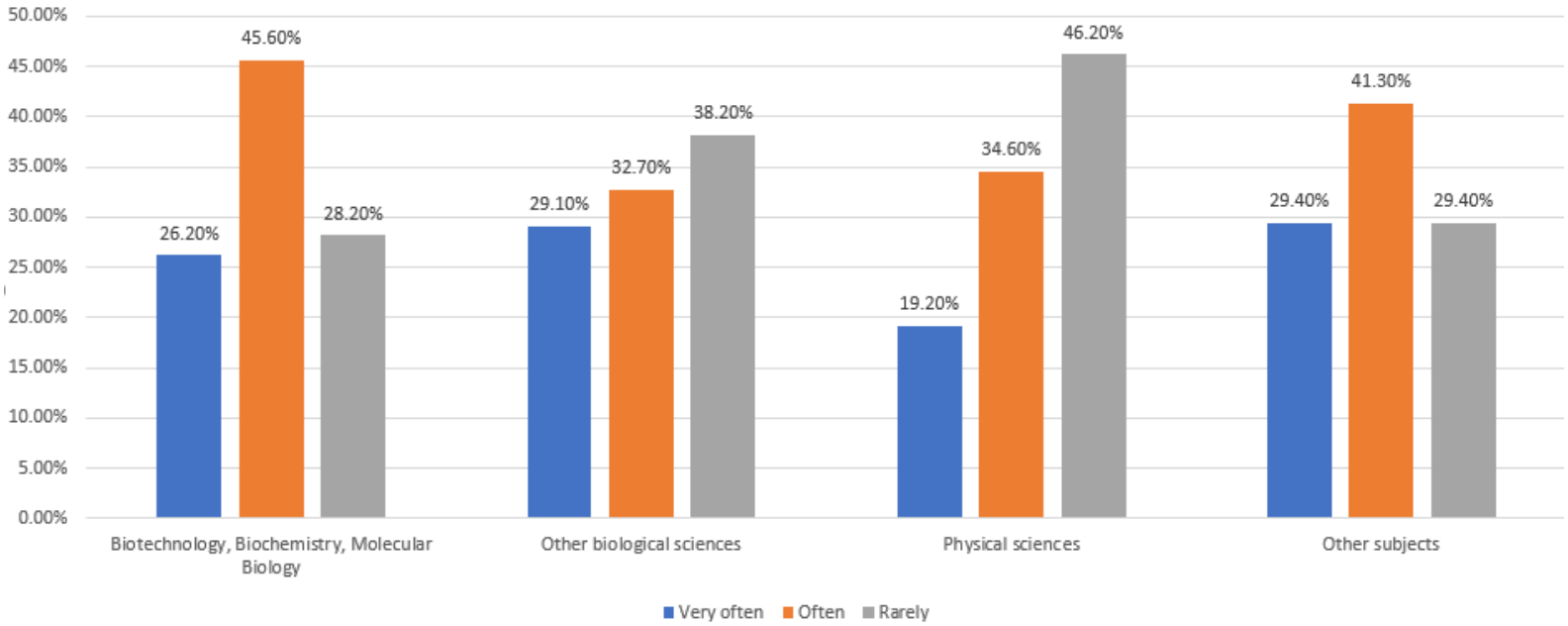

Figure 24: Variations Exposure to Biotech & GM Info: Electronic media, Across Diverse Academic Majors

The investigation examined the frequency of encountering electronic media related to biotechnology among students from different majors:

Among those in Biotechnology, Biochemistry, and Molecular Biology, 26.20% reported encountering electronic media related to biotechnology very often, with an additional 45.60% indicating encountering it often. A smaller proportion, 28.20%, reported encountering it rarely. In contrast, students from other biological sciences exhibited a slightly different distribution of responses. 29.10% reported encountering electronic media related to biotechnology very often, while 32.70% indicated encountering it often. A larger percentage, 38.20%, reported encountering it rarely. Within the realm of Physical Sciences, responses varied significantly. Only 19.20% reported encountering electronic media related to biotechnology very often, while 34.60% indicated encountering it often. A larger proportion, 46.20%, reported encountering it rarely. Similarly, students from other subjects showcased diverse responses. 29.40% reported encountering electronic media related to biotechnology very often, while 41.30% indicated encountering it often. A smaller percentage, 29.40%, reported encountering it rarely(fig:24).

Overall, students majoring in Biotechnology, Biochemistry, and Molecular Biology reported relatively higher frequencies of encountering electronic media related to biotechnology and students from Physical Sciences rarely came across it.

3.9.16. Diverse Majors' Exposure to Biotech & GM Info: Social media

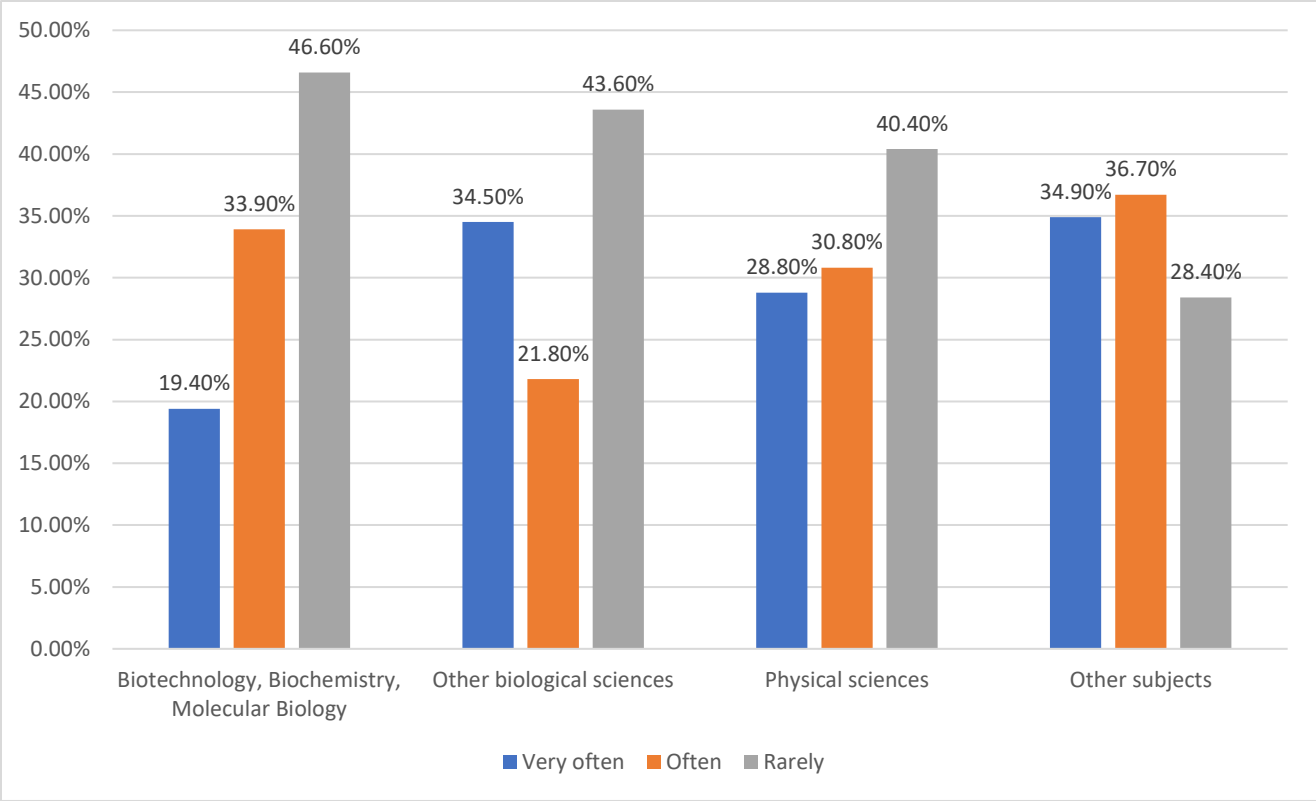

Figure 25: Variations Exposure to Biotech & GM Info: Social media, Across Diverse Academic Majors

The investigation examined the frequency of encountering social media related to biotechnology among students from different majors:

Among those in Biotechnology, Biochemistry, and Molecular Biology, 19.40% reported encountering social media related to biotechnology very often, with an additional 33.90% indicating encountering it often. A larger proportion, 46.60%, reported encountering it rarely. In contrast, students from other biological sciences exhibited a slightly different distribution of responses. 34.50% reported encountering social media related to biotechnology very often, while 21.80% indicated encountering it often. A larger percentage, 43.60%, reported encountering it rarely. Within the realm of Physical Sciences, responses varied significantly. 28.80% reported

encountering social media related to biotechnology very often, while 30.80% indicated encountering it often. A larger proportion, 40.40%, reported encountering it rarely. Similarly, students from other subjects showcased diverse responses. 34.90% reported encountering social media related to biotechnology very often, while 36.70% indicated encountering it often. A smaller percentage, 28.40%, reported encountering it rarely (fig 25).

Overall, students majoring in Biotechnology, Biochemistry, and Molecular Biology reported relatively lower frequencies of encountering social media related to biotechnology compared to students from other subjects.

3.9.17. Diverse Majors' Exposure to Biotech & GM Info: Printed media

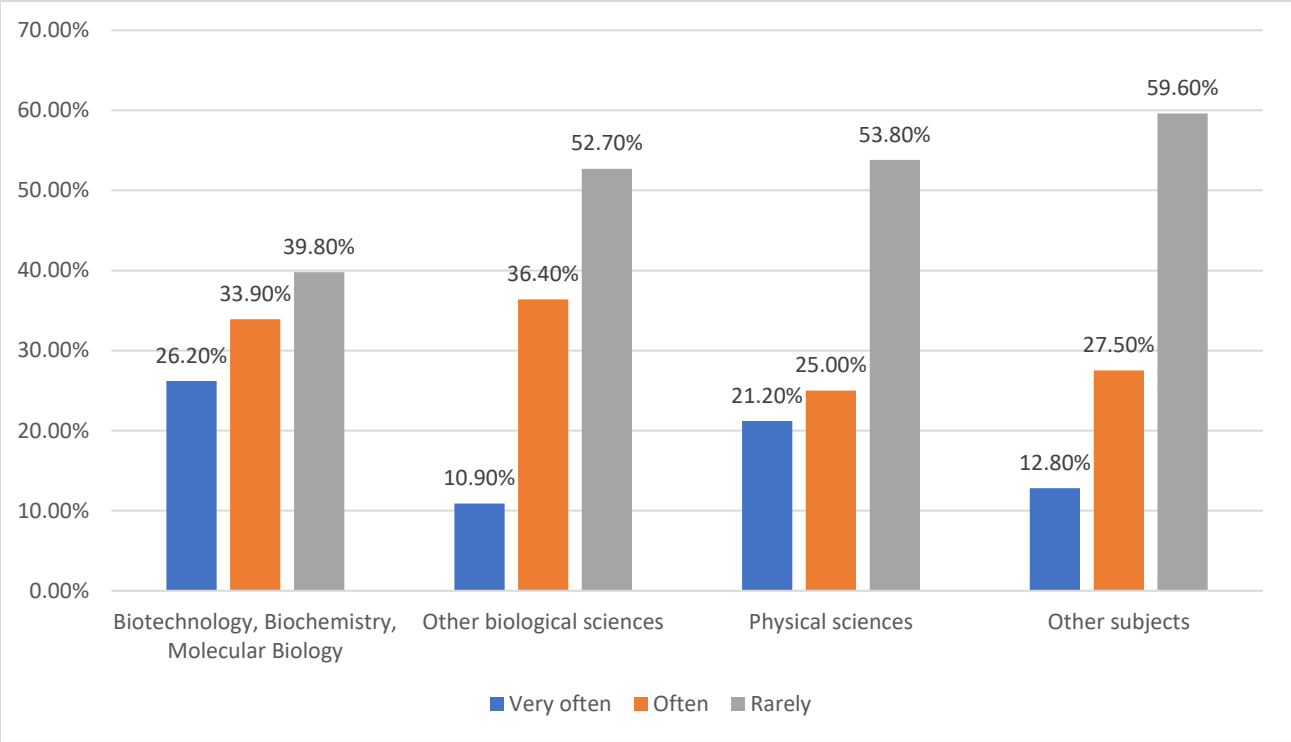

Figure 26: Variations Exposure to Biotech & GM Info: Printed media, Across Diverse Academic Majors

The study investigated the frequency of encountering printed media related to biotechnology among students from different majors:

Among those in Biotechnology, Biochemistry, and Molecular Biology, 26.20% reported encountering printed media related to biotechnology very often, with an additional 33.90%

indicating encountering it often. A larger proportion, 39.80%, reported encountering it rarely. In contrast, students from other biological sciences exhibited a slightly different distribution of responses. Only 10.90% reported encountering printed media related to biotechnology very often, while 36.40% indicated encountering it often. A larger percentage, 52.70%, reported encountering it rarely. Within the realm of Physical Sciences, responses varied significantly. 21.20% reported encountering printed media related to biotechnology very often, while 25.00% indicated encountering it often. A larger proportion, 53.80%, reported encountering it rarely. Similarly, students from other subjects showcased diverse responses. 12.80% reported encountering printed media related to biotechnology very often, while 27.50% indicated encountering it often. A larger percentage, 59.60%, reported encountering it rarely(fig 26).

Overall, maximum students across all the majors reported relatively lower level of frequencies of encountering printed media related to biotechnology.

DISCUSSION

4.Discussion

The study aimed to explore the awareness and familiarity levels with biotechnology and genetically modified organisms (GMOs) among undergraduate students from different universities in Chattogram. A total of 319 participants, comprising 219 females and 100 males, were interviewed, representing a diverse gender distribution. The study encompassed three universities, with 210 participants from private institutions and 109 from a public university, offering a comprehensive view of students from various educational backgrounds.

The analysis of participants' awareness of biotechnology revealed a high level of familiarity within the surveyed population, with 96.2% reporting awareness of the concept. This indicates a widespread understanding of biotechnology among university students. Further examination across different academic majors showed consistent awareness levels, with students from disciplines such as Biotechnology, Biochemistry, Molecular Biology, Other Biological Sciences, and Physical Sciences displaying notable familiarity with biotechnology. Even among students from diverse academic backgrounds categorized as Other Subjects, a majority demonstrated awareness of biotechnology, underscoring its pervasiveness across various fields of study. These findings lay the foundation for understanding students' baseline knowledge and perceptions of biotechnology, setting the stage for a deeper exploration into their attitudes towards GMOs and related biotechnological advancements.

The comparison of familiarity levels with Genetic Engineering (GE) and Genetically Modified Organisms (GMOs) across various academic departments revealed intriguing disparities among students from different disciplines. While departments like "Bioinformatics," "Biotechnology," and "Genetic Engineering" demonstrated a high level of familiarity with biotechnological concepts. Physical science and others subject majors, such as "Dramatics," "Environmental Science," "Science," and "Soil Science," exhibited lower levels of familiarity. These differences likely stem from various factors, including the focus of departmental curricula, exposure to related coursework, and individual interests.

The comparison of attitudes towards hybrid crops and genetically modified organisms (GMOs) among students majoring in Biotechnology, Biochemistry, and Molecular Biology and those from other academic disciplines revealed shocking perceptions. While students studying in biotech

related subjects has specialized knowledge in biotechnology-related fields, many of them demonstrated unclear understanding of the distinction between hybrid and GM crops, just like the students from other majors, as they also exhibited a prevailing misconception regarding this distinction. This highlights the importance of gaining the accurate knowledge to eradicate the misconceptions. Even if the people are knowing about biotechnology , it is very important to make sure that people knows the accurate information. Otherwise false information can lead to various misunderstanding, which can harm the future of biotechnology.

The analysis of Likert scale responses concerning familiarity with various biotechnological products revealed intriguing patterns across different groups of students and age categories. Vaccines, antibiotics, and insulin emerged as the most familiar biotech products among students across all backgrounds and age groups. This high familiarity can be attributed to the widespread use and essential nature of these products in healthcare. However, Bt brinjal and golden rice exhibited lower levels of familiarity, particularly among the students who are studying other subjects or physical science subjects among surveyed student population. The data suggest a lack of widespread understanding or awareness of these genetically modified crops, indicating a need for increased education and outreach efforts in this area. Notably, the analysis of GMO-related statements unveiled diverse perspectives among students regarding the environmental and health impacts of GMOs. While a significant majority disagreed with the notion that GMOs cause environmental pollution or pose health risks, a notable portion expressed concerns or uncertainties. This divergence in opinion underscores the complexity of discussions surrounding GMOs and suggests the influence of various factors such as academic background and age on perceptions. Moreover, statements related to the potential benefits of GM technology received considerable support from surveyed students, particularly regarding food security and disease treatment. This consensus highlights a positive outlook on the role of genetic engineering in addressing global challenges. However, there was notable uncertainty regarding the use of GMOs in medicine, indicating a knowledge gap or a lack of clarity on this topic among students. Additionally, the analysis of information sources revealed varying levels of exposure to technology-related content across different mediums. While scientific articles emerged as a prominent source of information for students, traditional print media and electronic media played les significant roles in shaping their understanding of biotechnology.

The findings unveiled that scientific articles predominantly serve as the conduit for encountering GM or biotech-related information among students, with printed and electronic media following in close succession. This underscores the significant reliance on scientific literature within this field. However, it also illuminates the limited exposure to genetic-related information through traditional mediums like newspapers and electronic platforms such as websites and social media, exemplified by the underutilization of these channels in disseminating genetic-related content.

This observation underscores the existing gap in leveraging popular media channels to educate the public about genetic technology. Enhancing the accessibility of genetic-related content through widely accessed media platforms is imperative, given their pivotal role as primary information sources in today's digital landscape. By ensuring the availability of accurate and accessible genetic information on these platforms, individuals can be empowered to make informed decisions and foster a more positive outlook towards genetic technology.

In conclusion, the analysis of Likert scale responses offers valuable insights into students' perceptions and knowledge regarding biotechnological products and GMOs. The observed patterns highlight the need for targeted educational initiatives and interdisciplinary discussions to enhance understanding and promote informed decision-making in this rapidly evolving field.

Conversely, in response to statements such as "GMOs are dangerous for health" or "Genetic engineering helps to reduce the use of pesticides," students from physical sciences and other disciplines exhibited confusion or neutral opinions. This indicates a lack of comprehensive understanding about the benefits and safety of GM technology. This knowledge gap significantly influences their perceptions.

Several factors may contribute to the observed differences in attitudes towards GMOs between these two distinct groups. Firstly, students majoring in Biotechnology, Biochemistry, and Molecular Biology are likely exposed to coursework and research focusing on biotechnological concepts, including genetic engineering and GMOs. This specialized education may enhance their understanding of biotechnological processes and their implications, leading to more informed perspectives on GMOs.

Contrariwise, students from other majors may have limited exposure to biotechnology-related topics and may rely on general knowledge or misconceptions regarding GMOs. The lack of

specialized education in biotechnology may contribute to misunderstandings or oversimplifications of complex biotechnological concepts.

This situation is concerning, especially considering the ongoing research and activities in our country by various research institutions and pharmaceutical companies in the field of biotechnology. The lack of awareness and accurate information among students from diverse sectors about biotechnology can impact the future development and acceptance of this field. Without a well-informed public, misconceptions and unwarranted fears may hinder the progress and implementation of beneficial biotechnological advancements. This gap in knowledge can also affect the development of policies and regulations, as public opinion often influences legislative decisions.

Moreover, the biotechnology industry is a crucial driver of economic growth and innovation. If students, who are the future workforce and policymakers, remain uninformed or misinformed, it could result in a shortage of skilled professionals and advocates for the field. This could ultimately slow down the pace of scientific progress and technological adoption, placing our country at a disadvantage in the global landscape of biotechnology research and industry.To bridge this gap, it is imperative to foster a more science-literate society where individuals are equipped with the knowledge to understand and appreciate the complexities and benefits of biotechnological innovations. Investing in education and public engagement is not just about enhancing individual knowledge but also about securing a prosperous and technologically advanced future for our nation.

The significant association between gender and attitudes towards GM food labeling's impact on purchasing behavior underscores the role of gender in shaping consumer perceptions. Females displayed a higher inclination towards disagreement with the statement, while males exhibited a more diverse range of responses. These findings suggest that gender-related factors may influence individuals' attitudes towards GMO labeling and consumer behavior, potentially reflecting differences in risk perception, information processing, or socio-cultural influences.

The implications of these associations are multifaceted. Firstly, the highlight the importance of education and awareness in shaping attitudes towards biotechnology and GMOs. Providing

accurate information about biotech products and their applications may help bridge knowledge gaps and foster more informed discussions. Secondly, the findings underscore the need for targeted interventions to address perceptions and concerns related to GMOs, considering factors such as academic background and gender. Tailored educational programs and communication strategies can help address specific misconceptions and promote balanced perspectives on biotechnology and its implications for society and the environment.

Departments with high familiarity levels likely offer specialized courses directly related to genetic engineering and biotechnology, providing students with a comprehensive understanding of these concepts. Contrarywise, departments with limited familiarity may have fewer opportunities for students to engage with biotechnological topics, leading to lower overall familiarity levels. It's important to note that departments with smaller sample sizes, such as "Dramatics" and "Environmental Science," may have contributed to the lower mean scores observed in these areas.

These findings underscore the significance of tailored educational initiatives and interdisciplinary collaboration in addressing knowledge gaps and promoting a holistic understanding of biotechnology across departments. By implementing cross-disciplinary approaches and fostering collaboration among students from diverse academic backgrounds, educators can ensure that all students receive exposure to essential biotechnological concepts. Initiatives such as joint seminars, workshops, and interdisciplinary courses can provide valuable opportunities for knowledge exchange and skill development. Furthermore, efforts should be made to increase awareness and interest in biotechnology-related subjects among students in departments with lower familiarity levels. Targeted outreach programs, guest lectures, and extracurricular activities can help highlight the relevance and applications of genetic engineering and GMOs in various fields, thereby fostering a deeper appreciation and understanding of biotechnological advancements.

These differences in attitudes towards GMOs between science students and non-science students are relevant in understanding public perceptions of GMOs. Public opinion and understanding of GMOs play a crucial role in shaping regulatory policies, consumer choices, and public discourse surrounding agricultural biotechnology. Misconceptions or lack of understanding among the general public can lead to skepticism, fear, or opposition towards GMOs, impacting their acceptance and adoption in agriculture and food production.

Therefore, addressing misconceptions and improving public understanding of GMOs through education, outreach programs, and science communication efforts are essential steps towards fostering informed decision-making and promoting constructive dialogue on biotechnological advancements. By bridging knowledge gaps and promoting scientific literacy, society can engage in more informed discussions and make evidence-based decisions regarding the role of GMOs in agriculture and food security.

The integrated analysis of findings from various aspects of the study reveals overarching themes and nuanced patterns in students' viewpoints and knowledge regarding GMOs. Firstly, familiarity with biotechnological products, including vaccines, antibiotics, and insulin, emerged as a significant factor influencing beliefs in the benefits of genetic engineering, suggesting the influence of knowledge on perceptions. This finding complements the observed disparities in attitudes across academic disciplines, where departments with higher familiarity levels demonstrated a clearer understanding of biotechnological concepts. Moreover, gender-related differences in attitudes towards GM food labeling's impact on purchasing behavior were notable, indicating the role of gender in shaping consumer perceptions. These gender-related distinctions complement the broader patterns of influence observed in the analysis, highlighting the multifaceted nature of factors shaping attitudes towards GMOs.

However, despite the positive correlation between familiarity with biotech products and beliefs about genetic engineering's benefits, uncertainties and concerns regarding the environmental and health impacts of GMOs were still evident. This suggests a nuanced understanding where knowledge influences perceptions but may not fully alleviate all concerns or uncertainties.

In a nut shell the results underscore the need for targeted educational initiatives and interdisciplinary collaboration to bridge knowledge gaps and promote a holistic understanding of biotechnology. By fostering a more science-literate society, we can ensure that individuals are equipped to make informed decisions and engage in constructive dialogue about the benefits and implications of biotechnological advancements. This is crucial for the future development and acceptance of biotechnology, as well as for shaping policies that support scientific progress and innovation.

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