A Knowledge-based Perception Analysis about Biotechnology among University Students in Bangladesh

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

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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 "A Knowledge-based Perception Analysis about Biotechnology among University Students in Bangladesh" submitted by Fariha Fatema Ali (18136050) of Spring has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Science in Biotechnology on October.

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Abstract

Biotechnology is a rapidly evolving field of science. However, the success of this field depends on the acceptance of the research product by the user or consumers. This again depends on the perception of this technology. So, this research explored how tertiary-level students at various educational institutions view biotechnology. Its goal was to assess the perception of this rapidly developing sector. In this regard, the students' perception of its uses in industry, healthcare, agriculture, and food needed to be addressed. For the study, both private and public universities were selected. With due permission and following the standard procedures, the survey was carried out face-to-face in the institutions through a pretested questionnaire. The study highlighted that the educational majors had a great influence on the participants while responding to the questions. The majority of the participants were familiar with the word biotechnology, and had familiarity with genetic engineering (GE)/ genetically modified organisms (GMOs). But almost an equal number of participants responded to the question of believing hybrid and GM crops with Yes, and No, while some of the participants were not sure. 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. Today's students tend to use social media more which has become the major source for gathering information about biotechnology.

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INTRODUCTION

1. Introduction

Biotechnology has taken over the world, as developed countries rely on biotechnology products. Biotechnology is a field where genetic manipulation is possible using biological organisms to develop products for the betterment of humanity (Gupta et al., 2017, 1). It is to be mentioned that genetically modified organisms (GMOs) are one of the products of biotechnology, in which the DNA of animals, plants, or microbes is altered in a desired way using different genetic engineering methods (National Geographic Society, 2022).

As GMO products are modified according to the preferences of the researchers, they usually contain essential elements, nutrition, and resistance (Bawa & Anilakumar, 2012, 1). Many developing countries have also started to introduce GM foods to meet their nutritional needs (Conrow, 2018). Bangladesh, a developing country with a large population, has recently started introducing GM crops and is still working to introduce and commercialize more. Yet, many people have no idea or very little idea about biotechnology or GM technology. On top of that, very few people read newspapers and watch television these days to gather reliable information. Hence, the main sources of knowledge and information are based on digital media in Bangladesh, many people express skepticism about the products associated with biotechnology. According to the "Population and Housing Census 2022" preparatory estimate, 74.66% of Bangladesh's population is now literate. The literacy rate in the urban area is 81.28% whereas the rate is 71.56% in the rural area (Das & Sumit, 2022). Even though the literacy rate has increased over the years, many of them have very little knowledge about biotechnology. They do not know about this sector and its advantages. In today's world of science and technology, people should have basic knowledge about the technology and its products. Previously conducted studies revealed that fewer people know about biotechnology (Abdullah, Afrad, Bhuiyan, Haque, & Islam, 2018). Technology has been upgraded and access to sources of information has become easier these days. So, this current survey is needed to create awareness.

1.1 Industrial application of biotechnology

Biotechnology refers to the utilization of biological objects, particularly cells, and bacteria, to produce various goods that benefit people. It combines a variety of tools with the study of mathematics, physics, chemistry, and engineering, in addition to biology, to study living organisms. Its applications span from agricultural production (animal husbandry, cropping systems, soil science and preservation, plant physiology, seed technology, etc.) to different

industries, cell biology, medicine, and nutrition. As a result, it is one of the fields with the fastest-growing career prospects. The goal of biotechnology is to improve the genetic makeup of plants and animals in the desired manner to produce useful goods (Naz, 2015).

1.1.1 Biotechnology in the healthcare sector: The death rate increases eight times more from antibiotic-resistant diseases every year in low- and middle-income countries due to the lack of availability of antibiotics. This affects around 5.7 million people annually. This battle of drug resistance needs to be addressed. For this, small and medium-sized biotech companies are collaborating with regional businesses in developing countries like China, India, and South Africa. Among these countries, China has the most attention for antibiotics development (Rafiqi, 2021). Biotechnology has eased the way for hereditary disease diagnosis at a lower cost. Again, this field has improved therapeutics and is easily accessible for many fatal diseases like leukemia, other types of cancers, anemia, hemophilia, cystic fibrosis, rheumatoid arthritis, and hepatitis. This technology has made it possible to use natural products, genes, and stimulation and suppression of the immune system as therapeutics for the treatment of diseases. Cell or other organ transplants have been developed because of biotechnology (Biotechnology Innovation Organization, n.d.). Advancement in omics-based technology has resulted in a better understanding of diseases that led to the uncovering the new biomarkers and medications. This also advanced the research in the health sector. Personalized medicine, being an incredible achievement of biotechnology, eased the pace of the healthcare system. (Tanveen, et al., 2022)

1.1.2 Agricultural and Food Biotechnology: Across 29 countries, with the USA leading with 71.5 million hectares, 17 million harvesters planted 190.4 million hectares in 2019. Different kinds of biotech crops such as corn, canola, soybean, and cotton were cultivated. From this cultivation global economic profits reached $224.9 billion. These biotech crops helped improve food security, ecological preservation, climate change mitigation, crop yields, preservation of biodiversity, reduction of pesticide uses, and decreasing carbon dioxide emissions. The economic condition of small farmers was also improved which contributed to reducing poverty (ISAAA Inc., 2019). Transgenic crops were accepted in 72 nations in 2019, including ten Latin American, nine Asian, Pacific, six African, two North American, and two European Union countries. Soybean, maize, cotton, canola, and alfalfa were the five major transgenic crops. Biotech soybeans accounted for 74% of global soybeans and 48% of planting area. In cotton planting, India led the way by 79%. Canada, the US, Australia, and Chile were leading in canola planting by reaching 29%. HarvXtraTM hay was first planted in Argentina. Transgenic sugar

beets, potatoes, papaya, zucchini, and apples were planted in the US (Dionglay, 2022). Golden rice, a GM crop, has the potential to reduce food insufficiency. Yet this crop faces many debated environmental effects. Biotechnology offers synthetic foods and development over traditional plant-breeding technologies. However, some concerns arise about private sector influence and legal enforcement. A threat to small producers remains while outsourcing genetic resources in emerging countries. Nonetheless, this field of technology can increase agricultural security, diminish poverty, and protect the environment. Policymakers should consider innovations in biotechnology sectors as essential tools to address global hunger. Because biotechnology can effectively address the root cause of hunger (Jamil, 2012). In 2019, the USA, Canada, Brazil, Argentina, and India covered 71.5 million hectares and accounted for 38% of the global biotech territory. In these five countries, 26% of the global population benefitted from biotechnology. While Argentina ranked third among the ten countries growing biotech products, Brazil modernized its GM technology approval process and extended decision-making timelines. Changes in soybean planting resulted in a slight drop in biotech crop areas in Canada. In the same year, India's adoption of Bt cotton remained steady at around 95%, making farmers embrace the technology. Latin American countries accounted for 44% of the global biotech area, whereas the Asia-Pacific region accounted for 10.2% of the area. In this case, the Asia-Pacific region was led by China, India, Pakistan, The Philippines, Australia, Myanmar, Vietnam, and Bangladesh (Brookes and Barfoot, 2020). It will be challenging to reach the Zero Hunger goal by 2030 given the 820 million people who were still famished in the globe in 2018, according to the Global Food Insecurity Report of 2019. The greatest incidence of undernourishment is found in African subregions, followed by Asian, Latin American, and Caribbean subregions. Economic contractions and downturns have significantly increased the probability of extreme food insecurity and undernutrition, which affect more than 2 billion people regularly. Globally, climate change has an impact on food output; 20–49% of yield variations are accounted for by yearly variations in climate variables. 190.4 million hectares might be able to solve these issues in the 24th year of the marketing of transgenic crops. For the agrarian, socioeconomic, and environmental advantages of biotech products to reach the famished and impoverished, public approval and facilitating regulations in the government are essential. To guarantee the continuation of these advantages, regional regulatory coordination and progressive regulatory actions are required (*55-2019: Executive Summary | ISAAA.org*, n.d.).

1.1.3 Advantages of Industrial Biotechnology: Modern Biotechnology offers economic benefits but also poses risks to socioeconomic conditions. The environment, and human health. It poses biosafety threats, impacting on biodiversity, farmland, and traditional societies. Implementation lags in developing countries, leaving them vulnerable. Biotechnology is used in various sectors including medicine, sanitation, agriculture, and environmental protection. The technology can help overcome global limitations in substance, health, energy, resources, and climate. These different sectors are expected to become the main industries in the 21st century. Genetically engineering animals and plants can reduce sickness by producing medications like hormones and vaccines (Tisdell & Xue, n.d.).

1.1.4 Disadvantages of Industrial Biotechnology: Biological transformation reactors developed by biotechnology promise to incorporate toxins or residues and degrade them into materials with minimal or no toxicity, although environmental contamination is currently getting worse. Misuse of biotechnology can lead to a variety of risks and dangers, including deadly illnesses and allergic reactions. In addition, the genes of foreign viruses are inserted, and the proteins coded inside transgenic virus-resistance plants may recombine with the genetic material of other viruses and proteins to produce new types of viruses with higher toxicity. Large-scale discharges of transgenic pest-resistance plants will result in selection pressures that will quicken the resistance of target pests. Furthermore, the pest- and pathogen-killing components in transgenic crops may negatively impact other species, including helpful insects, birds, animals, and microbes, through food chains. Once discharged into the ecosystem, the damage they cause could grow over time and become more severe. Biosafety worries have stymied biotechnology research and development, which has led to the public's expressed disdain and dread of biotechnological goods (Tisdell & Xue, n.d.).

1.2. Biotechnological research and developments in Bangladesh

1.2.1 Biotechnological Advancements in Bangladesh: Bangladesh has made significant strides in biotechnology, including the establishment of a National Forensic DNA Profiling Laboratory and insulin production using bacteria, led by Dr. Maqsudul Alam. Genomic research, such as sequencing the jute plant and a lethal fungus, aims to improve jute fiber quality. Biotechnology offers promise in addressing food needs for the growing population, focusing on stress-tolerant crops like rice and jute, along with exploring vitamin A-rich golden rice. Bangladesh has various labs and biotech firms researching GMOs, overseen by the National Bureau of Biotechnology (NIB). The National Taskforce on Biotechnology (NTBB)

has an approved strategy for safe and environmentally friendly biotech advancements, while policy implementation falls under the National Economic Council of Bangladesh (NECB), with sector-specific committees. To maximize the benefits of biotech research, aligning with global advancements is crucial. (Hashem et al., 2020, 35-36). Bangladesh has made substantial strides in biotechnology, with notable achievements such as sequencing the jute plant's DNA in 2010. They also decoded the genome of Macrophomina phaseolina in 2012 and buffalo in 2014. Over 25,000 household biogas plants have been installed, and novel bacterial species have been discovered. Spirulina, biofertilizers, baker's yeast, and citric acid are produced on a large scale. In the field of agriculture, researchers have developed four rice varieties suited for highly salinized soil. The nation is actively researching transgenic plants, including genetically modified Bt-brinjal. Animal biotechnology and aquaculture are advancing, while the National Institute of Biotechnology is focusing on bioinformatics and functional genomics research. Despite these achievements, commercial biotechnology is still emerging. The country is addressing safety concerns through a GMO certification division and implementing a national biotechnology policy to promote safe and sustainable growth across various sectors, emphasizing indigenous practices and innovation (Islam & Ibrahim, 2016).

1.2.2 Biotechnological Achievements in Bangladesh: Bangladesh has made significant progress in biotechnology, with seven DNA testing centers established. Notably, they sequenced the jute plant's genome in collaboration with the DataSoft IT company and BJRI in 2008, becoming the second nation globally to achieve this. In 2012, the Jute Genome Group decoded the genome of Macrophomina phaseolina, a destructive fungus. Additionally, they collaborated with the Beijing Genomics Institute to decode the water buffalo's entire genome in 2014, which has potential implications for increased milk and meat production. Bangladesh gained approval for a restricted field release of Bt-brinjal, a genetically modified food product. Institutions like the National Forensic DNA Profiling Laboratory and organizations like the Bangladesh Fisheries Research Institute are contributing to biotechnological advancements in the country. The National Institute of Biotechnology (NIB) plays a pivotal role in coordinating and overseeing biotechnological research efforts. The government aims to utilize biotechnology for poverty reduction, livelihood security, and environmental protection while promoting awareness of its benefits through initiatives like the National Biotechnology Fair in 2018 (Choudhury & Hossain, 2013).

Table 1: Research institutions in Bangladesh and their ongoing projects. 1.3 The major issues concerning biotechnology

The ethical and societal impact of biotechnology advancements, such as genetic engineering, is a cause for concern due to the potential for creating societal and economic inequalities, particularly regarding access to personalized medicine and other benefits (Marris, 2001). Information mismanagement, driven by both anti-GMO and pro-GMO groups, further compounds the issue by spreading misinformation and contributing to public confusion, affecting decision-making and policy development (Lynas et al., 2022). Regulatory uncertainty surrounding genome-edited organisms, including new genomic methods (NGTs), adds complexity to the development and marketing of genetically modified crops, with differing definitions and legal landscapes in various regions. Public perception of plant gene technology varies globally, influenced by factors like media coverage, cultural beliefs, and economic considerations, highlighting the need to address these perceptions for broader acceptance. Ongoing debates persist regarding environmental and health concerns related to GMOs, including gene flow and food safety. Ensuring equitable access to the benefits of genetic engineering, especially in developing nations, remains a challenge. The adoption of GMOs can alter farming practices and potentially displace traditional methods, raising socioeconomic questions. While genetically modified crops are considered a potential solution for global food security, concerns about their long-term effects on ecosystems, biodiversity, and local species require careful consideration. Effective regulatory oversight is essential, particularly in regions where GMO cultivation is prevalent, to evaluate the risks and benefits associated with genetic engineering (Herrera-Estrella & Alvarez-Morales, 2001).

1.3.1 Environmental impact: Critics are concerned about GM crops impacting the environment. There is also a concern for biodiversity and ecosystems facing potential harm. For example, the susceptibility of monarch butterfly larvae to insect-resistant GM maize has raised alarm. The first world is struggling against the global adoption of GM crops in agriculture, while the third world is suffering from food insufficiency. Food manufacturing must be improved in developing countries to ensure food availability and boost their economies. Developing countries can reduce their dependency on developed countries by improving this sector. Over 90% of the world's biodiversity is found in tropical forests, underlining their crucial role in global and regional ecosystems; however, deforestation for agriculture is considered to have a more significant environmental impact than the introduction of GM crops or other technologies. GM technology holds the potential to enhance food supply

by 5–10%, cut herbicide usage by up to 40%, and result in savings of US$60–120 per acre on insecticides (Herrera-Estrella & Alvarez-Morales, 2001).

1.3.2 Resistance development: There are concerns about the development of resistance in insects and weeds due to the widespread use of GM crops. In areas where transgenic crops are extensively cultivated, the emergence of insect pests with pesticide resistance is almost inevitable. (Daniel et al., 2019). While genetically modified crops initially reduce the need for synthetic pesticides, there is a concern about the evolution of insect pests with resistance to the insecticides produced by these crops. This could force farmers to revert to using synthetic pesticides, potentially impacting organic growers (Jordan, 2002).

1.3.3 Antibiotic resistance: GM crops often use antibiotic resistance genes as selectable markers, which can have negative consequences. These genes may reduce the effectiveness of antibiotics when consumed with food and contribute to antibiotic resistance in humans and animals. Herbicide resistance in weeds might quickly develop as a result of the use of herbicide-tolerant crops, wasting important pest susceptibility genes and putting animals in danger. Bt crops and other genetically modified crops may have detrimental effects on animals (Hagedorn, 2000).

1.3.4 Accidental outcome: There is a concern about GM crops having unintentional effects on human health and the environment. For instance, dormant genes could get activated by the genes inserted into crops, resulting in the multiplication of harmful substances in edible tissues. GM plants may interact with the surroundings leading to genetic pollution and the decline or extinction of wild plant species. There may be allergic effects or other negative impacts on human health, so additional research is required to analyze the hazards and advantages of crops more correctly and appropriately. Both scientific advancements and societal perceptions have had an impact on the evolution of genetically modified organisms. Concerning potential hazards to the environment or human health, there are still disagreements. The effects of genetically engineered crops on harvests, commodity pricing, land usage, and the environment should be further studied (Karalis et al., 2020).

1.3.5 Weediness: GM crops can create feeble hybrids when they are crossbred with related plants. This could lead to increased use of herbicides and a probable threat to ecosystems (Hagedorn, 2000).

1.3.6 Surplus and price declines: Genetically modified crops adoption has been praised for improving crop production and reducing losses from pests, diseases, and weeds. However,

there remains a concern that all farmers switching to GM crops might lead to excess and subsequent price downhill in the agricultural market (Jordan, 2002).

1.3.7 Refuge strategy: The effectiveness of the "refuge" strategy in limiting the development of resistance to transgenic Bt corn depends on assumptions about random insect mating and the recessive nature of the resistance gene, which may not always hold (Daniel et al., 2019, 138-141). Moreover, the efficacy of the "refuge" strategy in limiting the development of resistance to transgenic Bt maize depends on assumptions about random insect mating and the recessive nature of the resistance gene, which may not always hold. Additionally, the concern lies in the potential harm to monarch butterflies from transgenic Bt maize and the notion that organic agriculture is often considered unworkable due to its initially low productivity, although it can improve over time (Jordan, 2002).

1.3.8 Impact on non-model agriculture: Engineered non-model microorganisms are effective workhorse strains. This involves the need for creating reliable shuttle vectors with effective selection markers, ensuring minimal similarity to the host's chromosome, stable replication in both E. coli and the non-model strain, and functional expression elements. Additionally, identifying a suitable replication origin in non-model bacteria poses a challenge for stable plasmid replication. The challenges faced by non-model agriculture, particularly organic farming, which is sometimes considered unworkable due to its low yield and labor-intensive nature (Yan & Fong, 2017).

1.3.9 Sustainability in agriculture: Sustainable agriculture is addressed as a potential solution. But initially low in the low productivity of sustainable agriculture might be a concern. For this, a transitional period is needed (Jordan, 2002).

1.4. Biotechnology-based government initiatives and regulations to ensure economic development

1.4.1 Global investment in science and technology: Countries have been investing more in research, technology, and innovation in recent years to meet global issues and adjust to shifting conditions. While Horizon Europe is hastening Europe's economic recovery, President Biden has advocated raising spending in research and technology to 2% of GDP. A sustainable and resilient society is the goal of Japan's Sixth STI Basic Plan, whereas China has witnessed a 14.2% increase in R&D investment under its 14th Five-Year Plan. Identity politics may be influenced by biotechnology as countries struggle with environmental and human development concerns. (Director of National Intelligence, 2021).

1.4.2 Biosafety regulations in industrial biotechnology: Many nations have created biosafety regulations or laws, and international agreements and accords have been published to guarantee the security of biotechnology and its by-products. Crops created through genetic engineering that are herbicide and pest-immune are being widely grown in many different nations. The transgenic crops' herbicide-resistant genes can spread to other crops and their untamed weedy cousins, creating novel weeds and "superweeds" and also increasing the need for pesticide use. A soil bacteria called Bt is used to make an insecticidal toxin that could spread to many products, including cotton, and soybeans. Environmentalists and the Green Peace Corps are worried that these products might make bugs more resistant to the Bt toxins, creating a vicious circle of resilience and significant financial losses. A group of consumers, activists, and organic farms filed a lawsuit against the US Environmental Protection Agency in 1997, demanding that the EPA rescind 11 registrations and finish a report on the environmental effects of the Bt crops that have been authorized so far. The Norwegian Gene Technology Act and the UNEP's "International Technical Guidelines for Safety in Biotechnology" are just two examples of how many nations are treating social concerns resulting from new biotechnology seriously. Socioeconomic effects received particular focus from several involved nations during the "International Biosafety Protocol" negotiations. While developing nations struggle to address biosafety problems, developed nations have a high degree of biotechnological knowledge. Socioeconomic problems brought up by contemporary biotechnology, according to emerging nations like India and China, are significant for all nations, particularly for those with rich genetic variety. International biosafety legislation should be considered as one of the concerns related to biotechnology along with the socioeconomic implications separately. The parties to the Convention on Biological Diversity must inform others about biotechnology-based imports and provide financial and technological support. While biotechnology can have both positive and negative impacts, achieving a global consensus on these issues may be challenging, but it is essential to address the potential negative social effects of bioengineering on a global scale (Tisdell & Xue, n.d.).

1.4.3 Role of BBSRC in the UK: The Biotechnology and Biological Sciences Research Council (BBSRC) plays a vital role in the UK's bioscience landscape, investing in research, innovation, and collaborations to advance the field. It focuses on interdisciplinary research spanning agriculture, food, nutrition, health, organic materials, food security, environmental sustainability, and biodiversity. BBSRC supports research exploring the functioning of

microbes, plants, animals, and humans, contributing to a deeper understanding of biological systems. (*BBSRC Strategic Delivery Plan 2022 to 2025 – UKRI*, 2022).

1.4.4 Europe's proactive biotechnology policy: Europe must make crucial decisions on the acceptance of proactive policies for the proper use of biotechnology and life sciences to comply with European norms and values. The strategy might result in more wealth, especially considering how quickly scientific information was translated into useful applications. GMO and ethical arguments among the public have occasionally covered innovative criteria. Europe's competitiveness was reduced hampering its ability to conduct research. Europe had to create dependable and well-defined policies to meet global responsibilities, advance governance, and maximize the advantages of biotechnology. The European biotechnology market might be valued at more than EUR 100 billion by 2005. By the end of the decade, the worldwide biotechnology markets would be valued at more than EUR 2000 billion (*Life Sciences and Biotechnology — A Strategy for Europe*, 2002).

1.4.5 Flourishing biotechnology sector and government initiatives in Singapore: The Biotechnology industry in Singapore has flourished over the last ten years, investing $1.5 billion in scientific research. The development has been facilitated by government backing and stable conditions. This growth led the country to the establishment of seven research centers, five research collaborations, and several funding and award possibilities. Leading specialists and large pharmaceutical companies like Roche, Takeda, Barry Halliwell, and Jackie Ying have made their way to Singapore. But Singapore's GDP growth fell sharply from 15% in 2010 to 2% in 2016. This fall in GDP provoked worries about less money, scholarships, and reasons for scientists and research organizations. Similarly, as the US government raised R&D finance for colleges during economic crises, Singapore may enhance its R&D investment to counteract this trend (Yung, n.d.). Through several organizations, including the Economic and Development Board (EDB), the Agency for Science, Technology, and Research (ASTAR), the Ministry of Trade and Industry, the Ministry of Education, the Ministry of Health, and the National Research Foundation, the Singaporean government actively supported the expansion of the country's biomedical manufacturing sector. While ASTAR concentrated on resources, policy, and research infrastructure, EDB recruited investments. Biopolis, MedTech Hub, and Tuas Biomedical Park were founded by JTC Corporation. Utilizing its robust industrial foundation, Singapore's biomedical cluster grew significantly in its early years. Global companies including Novartis, Eli Lilly, GlaxoSmithKline, Baxter, and Merck Sharp & Dohme participated in 19 new projects that spent $845 million in fixed assets in 2001. In 2015, this

industry produced S$28 billion in industrial production and 19,000 employees. (University of Cambridge, 2021).

1.4.6 Regulatory configuration: GM crops and other forms of agricultural biotechnology enhance food security and production, being beneficial to the farmers and the environment. GM crops adoption has been delayed due to public concerns. Even though GM products are introduced more widely for their affordability and food stability. It is to mention, Bt cotton improves the availability of food sustainably. In 2016, South Africa and Sudan led African biotech crop cultivation, making the country rank top worldwide. However, Bt maize was banned in Egypt because of safety issues. Also, Burkina Faso suspended Bt cotton for fiber concerns. Many African countries lay back immense biosafety regulations, resulting in an uneven regulatory system; while Bt cotton was allowed in Sudan in 2012. A strong regulatory plan for GM crops is essential. It is suggested that risk assessments and regulations must be conducted for the assurance of the safety of the crops before commercialization. (Daniel et al., 2019)

1.4.7 Public perception: Public pressure is mounting in various countries to restrict or delay GM crop adoption. To enhance food availability, especially in poorer nations, food production must improve, boosting their economies and reducing dependence on developed nations. GM crops are not limited to the USA; they also thrive in Argentina, China, and Mexico, showcasing the benefits for developing nations. Instead of opposing GM agricultural technologies, government-funded and non-governmental organizations should focus on sharing information with underdeveloped nations. It acknowledges the need for clear regulations to address public concerns and provide consumers with information about GM content in food (Herrera-Estrella & Alvarez-Morales, 2001).

1.4.8 Global acceptance: Many developed countries like the USA, Mexico, China, and Argentina have adopted genetically modified crops. This focuses on the contribution of national and international regulatory agencies in supervising the introduction and cultivation of GM crops. Moreover, UNESCO should enact technology transfer and address political, economic, and social issues related to GM crops. This indicates the necessity of international cooperation and regulation in cases of GM agriculture. (Herrera-Estrella & Alvarez-Morales, 2001)

1.4.9 Risk assessments: Genetically modified crops must only be approved when there is insignificant and minimal risk. From the study, it was found that the idea of regulatory

authorities monitoring GM crops carefully and publishing them after confirming the absence of unfavorable effects or environmental harms was supported. (Herrera-Estrella & Alvarez-Morales, 2001).

1.4.10 Small and large farms: Different types of farms were compared in terms of their agricultural practices, resource management, and sustainability. The study indicated that policies and regulations must be considered the differences. (Jordan, 2002)

1.4.11 Genetic engineering in developing countries: Genetic engineering has an effective role in developing countries and their agriculture. A study suggested that policies must be adapted to inspire sustainable and regionally adapted crop verities. (Hagedorn, 2000)

1.4.12 Subsidies and uses of land: The overproduction by reconsidering agricultural subsidies needed to be addressed. Besides, promoting the transfer of land to conservation efforts should be discussed. Also, promoting the discovery of regional crops adapted to the local environment was emphasized as a potential strategy for food-insecure countries. (Jordan, 2002)

1.5 Worldwide surveys to analyze the public perception of biotechnology products and innovations

A study conducted in Poland in 2019, showed that over half of the Polish participants had observed that products made using methods of genetic engineering are sold on the market, according to the survey's findings. Despite their misgivings about them, 39 to 69% of Poles supported biotechnology and genetic engineering studies. Furthermore, 62% of Poles disapproved of GM foods because they thought they could be hazardous to human lives and health (WOŹNIAK-GIENTKA et al., 2022, 1). In another survey in 2011, it was found that in Malaysia, businesses have a poor opinion of colleges' technological innovation, particularly in the biotechnology and automotive industries. However, it lost its significance once knowledge transfer channels and barriers mediate the connection (Zainol et al., 2011).

In an internationally conducted study, the findings implied that regardless of whether livestock or other GM implementations are the "target" of the application, perceptions of risk and benefit related to all facets of genetically engineered agri-food use have been rising over time. Compared to customers in North America and Asia, European consumers generally had a worse opinion of GM. The top-ranked demand among US consumers, national food security, is satisfied by GM crops. Both Americans and Canadians place a high value on profitability, and NBTs primarily favor the private sector. Americans have the least faith in merchants and food

producers and the highest faith in university scientists and farmers. Citizens believe that government organizations have dual tasks in assisting the farming industry and guaranteeing nutritious foods for American consumers, giving government organizations and environmental groups an average degree of confidence in this hierarchy. With a necessary adoption date of January 1st, 2022, the US mandates labeling GMO and genetically altered food as "bioengineered food" (BE) to ensure its disclosure. Who will be responsible for paying for segregation measures, potential identity preservation, and product tracking associated with exports and/or domestic usage is not yet known. US customers seem to like GM and NBT products and are ready to spend 19–26% more, provided certain demands are met and transparent information is supplied. Canadian customers were less inclined to purchase a GM product at a greater cost than a non-GM one, indicating that the product's price—rather than its manufacturing process—is what influences consumers' purchasing decisions. Only a few countries in Central and South America have studied public perceptions of GMO, GM, and GE foods. A large proportion of respondents in Jamaica believed that genetic engineering was dangerous, whereas the general population in Costa Rica was open to using technology to enhance crops, cure diseases, and conserve the environment. The majority of the stakeholders in Mexico were worried about the possible effects on the biological diversity of the nation. In Paraguay, 68% of the participants said they had heard of or were familiar with genetically altered crops, but more than half of them thought they were harmful. In Latin America, consumer attitudes about using items created through genetic engineering were the most frequently questioned subject. The availability or lack of GM in food and the newly developed characteristics are more important to Chilean supermarket buyers than the product's price or brand. Only 3% of Brazilians believed the current control was effective, and 63% deemed the government's food surveillance efforts to be weak. Between 86% in 1999 and 60% in 2019, opinions about GM food have declined throughout Europe. Due to their early use of plant gene technology, Nordic nations differ in terms of their views toward and perception of GE, GMO, and GM food. Most Norwegian consumers supported the use of GMOs for societal good and sustainability. Nearly 50% of Swedish respondents favored increased plant production. Higher agricultural yields, disease resistance, and greater drought tolerance received the best ratings in Poland while decreasing hunger and using GM technology received the lowest rankings. According to 61% of respondents, utilizing new biotechnology techniques may pose harm to the environment or human health. 46% of respondents believed there are too many hazards associated with utilizing microbes to treat sewerage and other pollutants, while 69% said it should be promoted. In Italy, 81% of exports and 54% of the majority agreed that eating GM

food is safe, whereas 49% of French customers said they would buy fresh fruit made using biotechnology. Self-reported healthiness, eating habits away from home, and environmental awareness have all been proven to increase the propensity to buy fruit grown using biotechnology (Ewa et al., 2022).

According to a study of South African respondents, 41% felt that eating GM food violated their religious convictions, while 30% disagreed. 86% of farmers in Uganda said they would cultivate GM maize since they saw it as a chance to reduce yield loss. If offered the option of non-GM or GM seeds, Ghanaian farmers would select the former. The trust of Ugandan consumers in local authorities and a few ministries, followed by scientists, was highest in restricting the release of GM crops. 75% of respondents in South Africa agreed with the assertion that GM food items should be labeled. People with higher levels of education tend to be more skeptical and use deliberate reasoning when forming their opinions. In China, 40% of respondents thought GM foods were safe, 26% thought they were hazardous, and 35% were unsure. Consumers who intend to buy GM food said so in 79% of cases. Residents of South Korea were more inclined to pay greater costs for GMO labeling regulations. While the focus on food security and innovative food news was linked with widespread backing for labeling in Singapore as well as India, 80% of students in Turkey demonstrated an overwhelming desire to label GMOs. 70% of students in Pakistan agreed that food ought to have correct labels. Due to the immediate advantages of GM crops, farmers in Asia were more accepting of them. While Bt-brinjal producers in Bangladesh expressed satisfaction with the yields and fruit quality, Bt-cotton farmers in China displayed a positive attitude. In Malaysia, Iran, Australia, and New Zealand, moral and ethical convictions and religion were the most effective predictors of social danger perception. Consumers in New Zealand would not purchase genetically modified food until there were obvious environmental advantages. High school pupils in Australia were overwhelmingly in favor of using biotechnology to modify both humans and germs. Australian farmers were interested in growing GM pulses and were aware of GMOs. High school pupils thought GM crops had advantages, but consumers would only buy GM food if it was inexpensive. Less than 20% of high school students believed the media and the internet, but more than 80% trusted researchers. The public's perspective on plant gene technology has revealed that the strictest rules for GMO/GE food and feed are in place in Europe, where people have the most unfavorable opinions against GM foods. Greater support is given to GM and GE in North and South America, which are world leaders in the development and commercialization of GM crops. With two approaches, the US, which is a major proponent of

GMOs through authorization and production, and the EU, where the principle of precaution is being used, global GMO policy demonstrates divergence, not convergence. The public has to be made aware of the advantages of NGTs to reduce the resistance of GM crops. According to Lougheed (2009), scientific knowledge and analysis are now more important than ever in determining societal ideals. The study's findings demonstrated that education level has a significant influence on how the public views plant gene technology, with persons with backgrounds in molecular biology or biology bringing a more favorable attitude than laypeople. The general population in every part of the world concurred that labeling GM goods is vital and required. However, direct comparison of results is restricted due to the absence of standardized survey methodologies. The study concluded that there are several potential future avenues for plant gene technology. To undertake comparison studies, the scientific community should strive for a uniform evaluation of public views regarding plant gene technologies for various target groups. In public discussions concerning the future of GM goods, researchers and specialists should participate, and dissemination of SSH research findings is crucial for assuring their influence on policy and educating the general public. For scientists and scientific communicators to continue expanding the communication of science past the deficit-based approach, Simis and his team (2016) recommended several options. For trustworthy science communication on biotechnology in general and GM and GE food in particular, social media and well-known blogs should be employed. To increase public knowledge and comprehension of plant gene technologies, scientists, decision-makers, and businesspeople must provide chances for the public to engage in pertinent conversations and activities. Which genetically sequence-edited plants are governed by present GM legislation needs to be determined by policy decisions. Consumer opinion of GM food may improve with product labeling, but caution is suggested as it may also have unintended consequences. A well-planned and executed GM food labeling effort is necessary to adequately inform consumers (Ewa, et al., 2022)

Several industrialized and developing nations have adopted GM crops, including maize, cotton, sugar beet, canola, papaya, and petunia. These crops have been adopted by several industrialized and developing nations. The majority of these genetically modified plants feature a unique trait for herbicide or insect resistance. The National Biosafety Authority has been given the authority to manage Ghana's regulation of contemporary biotechnology under the Biosafety Act of 2011. However, some advocacy organizations voted against the bill, citing misinformation and fear. Geographical location, economic prosperity, educational attainment,

cultural and religious beliefs, and tradition will all have an impact on public opinion. Biosafety regulations and policies will be crucial in directing the marketing and usage of biotech goods as Africa embraces cutting-edge methods. According to this study held in Africa, a large majority of respondents agreed on the fact that non-GM foods are generally preferred over GM foods, that biotechnologists have an enormous duty to guarantee that GM crops are not hazardous, that the cultivation of GMOs should wait till biosecurity is achieved, and that the 90 participants who accepted that GM foods are extremely beneficial to health likewise agreed to the suggestion of using pharmaceutical products made from GMOs. The respondents were given a choice of whether they agreed, disagreed, or were unclear with seven assertions that a large proportion of Ghanaians believed to be of the highest importance. A proportion of respondents (44.2%) believed that GMOs and their methods are unethical and immoral, and 55.5% believed that extended use of GM foods could have negative health effects. This survey looked at respondents' opinions on genetically modified organisms. Results revealed that non-GM foods tend to be favored over GM foods, with 37.5% of respondents admitting that GM foods are very beneficial to health and 5% more respondents stating that GM crops had greater nutritional content than non-GM crops than those who disagreed. The vast majority of survey participants who believed that GM foods were extremely beneficial to health also supported the suggestion that people utilize pharmaceuticals made from GMOs. The poll also revealed that farmers in Ghana's northern area were concerned about potential hazards related to the growing of GM crops, including potential environmental, health, market, and policy failure concerns. According to the study, respondents were worried about how GMOs would affect the environment. They concurred that the development of GMOs in Ghana needed to be delayed until biosecurity was established and that biotechnologists had a significant duty to assure the safety of GM foods. However, most of them concurred that Ghana faces a commercial risk if foreign firms monopolize planting supplies and technology. A sizable portion of respondents (30%) doubted that foreign corporations like Monsanto, Syngenta, and DuPont could control the technology and planting materials. According to one survey, most UCC students appeared to be aware of GMOs but to have a low degree of genetic literacy. Gender and attitudes about GMOs were significantly correlated, with men holding more favorable views. African nations should adopt GM agriculture practices similar to those of South Africa (Frimpong, 2016). A framework known as "biosafety" outlines the use of certain procedures, instruction, safety gear, and specifically constructed structures to safeguard the environment, the community, and workers against unintended exposure to infectious pathogens and toxic substances (Science Safety Security, n.d.).

1.6 Previously conducted surveys in Bangladesh

In an article published in 2003, the target population was the professionals of different sectors. According to the survey, 83% of the respondents agreed that biotechnology research in Bangladesh should focus on enhancing iron and vitamin A-containing rice. The country should assess the product. Only 9% of the respondents objected because of the probable health risks, morality concerns, and lack of resources. The study found that agriculturists (90%) and university professors (88%) showed positive attitudes and maximum support, while strong opposition came from 63% of environmentalists on the concept of combining iron and vitamin A in rice. However, 75% of NGO personnel and policymakers were in favor of incorporation. The study revealed that 53% of the respondents considered vitamin A deficiency as a severe issue, while iron deficiency was seen as a significant health concern in Bangladesh by 87%. (Husain et al., n.d.). Another survey conducted targeting non-biotechnology students of 1st to 5th year in Bangladesh in 2022 showed the consumption of widely used biotechnology-derived product insulin and the respondents' awareness of the products. Among the respondents, 7% said diarrhea, 68% selected diabetics, 13.5% selected AIDS, and 11.5% answered hepatitis B for the question about the use of insulin. On the contrary, 42% of respondents reported not knowing insulin-generated technology, while only 32% were aware of the production. Moreover, 25.5% answered incorrectly regarding the technologies used in insulin manufacture. (Uddin et al., 2022). The literature review indicated that many people are unaware of their consumption of biotechnology products. Yet, public perception was that the proper use of bioengineering would lead the country to economic independence. (Uddin et al., 2022). For the present study, no question was taken from this survey as this was an unbiased knowledge-based analytical study that targeted tertiary-level students from both biotechnology and non-biotechnology subjects.

1.7 Rationale of the current study

Biotechnology is an evolving field with versatile uses in healthcare, agriculture, and industry. Although people have been using the technology for centuries, many of them do not know about it. These new areas of technology need recognition. The final goal is to spread awareness about biotechnology. However, spreading awareness demands people’s perceptions. Perceptions between people learning about biotechnology academically and others with non-biotechnology backgrounds vary. This study is focused on the tertiary-level students of

different educational institutions. Investigating the students helps them perceive the educational alignment of different institutions.

The questionnaire is divided into three different sections. The first section contains questions about their familiarity with biotechnology, genetic engineering (GE)/ genetically modified organisms (GMOs), and their knowledge of the difference between hybrid crops and GM crops. These first three questions are basics. These are asked to know if the participants are familiar with biotechnology which makes the further questions easily understandable for them. The second section is about the level of familiarity with the products of biotechnology. In this part, five products of biotechnology are included (Dawson & Schibeci, 2003). Vaccines, antibiotics, and insulin are the three products that are widely used biotechnology products in Bangladesh. On the other hand, Bt brinjal is the first biotechnology-derived product in Bangladesh that has been commercialized and is being used daily (Shelton, et al., 2019). Moreover, golden rice is enlisted as it is a matter of discussion nowadays and in the process of commercialization (Rashid, 2020). These questions are added to observe the students' familiarity and knowledge of the most common biotechnology products. The third section of the questionnaire had some statements related to biotechnology. This part was to know the perceptions about biotechnology (Prokop, Leskova, Kubiatko, & Diran, 2007). Different statements were put in the section with levels of agreement and disagreement to analyze the participants' opinions about the field of biotechnology. Lastly, in this section, a question was added to know about how the students gain knowledge or come across information about biotechnology and its products.

1.8 Objectives of the study

The objectives of the study are-

- To analyze how the tertiary-level students' age, level of education, and educational institutions affect their perception of biotechnology.
- To understand how much they know about biotechnology.
- To know what they think about biotechnology and its products.

METHODOLOGY

2. Methodology

2.1 Study design

This was a cross-sectional study. For the survey, university students in BSc programs were targeted, and both public and private universities were selected for the study. Both the private and public universities were targeted to get an unbiased analysis out of the study. The target population was divided into students from biotechnology, molecular biology, biomedical engineering, and other biological sciences as well as students of physical sciences and other subjects. The universities mentioned above are chosen for having all these subjects. Moreover, these universities are known universities in Bangladesh where students from different districts come to study. This will also help to capture the regional diversity (Table 2).

Table 2: Distribution of the selected universities.

2.2 Sample size determination

As the survey was a cross-sectional study and the population number was infinite, a minimum sample size was calculated using the following formula-

$$\mathbf{n = Z^2pq/d^2}$$

Where **n** = Desired sample size

Z = Standard normal deviate; because the confidence level is 95%, it is 1.96

p = Estimated prevalence 37%, it is 0.37

q = 1 - p = 1 - 0.37 = 0.63

d = Acceptable error, which is 10% = 0.1

So, $\mathbf{n = (1.96)^2\ (0.37)\ (0.563)\ /\ (0.1)^2}$

n = 88.32 ∼88

So, this is to mention that the calculated sample size of **88** is from each center.

2.3 Questionnaire preparation

For a quantitative study, a pre-tested questionnaire was developed on a Likert scale, taking into account ethical and biosafety rules. The questionnaire was developed through a vivid literature review among the researchers and the supervisors. As the study was designed for an unbiased analysis, the questionnaire was made in a way that is easily understandable for the participants regardless of their subject background.

2.4 Tools of the study

There were both virtual and in-person meetings for discussions among the researchers and the supervisors. The collected data was input and analyzed using SPSS. Microsoft Excel was used to create the graphical presentation of the data. To calculate the margin of error, an online Sample Size Calculator named “CheckMarket by Medallia” was used.

2.5 Study population

The focus was on the BSc students studying any year from the enlisted universities. The targets were divided into four categories according to the departments, which are:

1. Biotechnology, Biochemistry and Molecular Biology
2. Other biological sciences.
3. Physical sciences.
4. Other subjects.

2.6 Data collection

A convince and simple random sampling was chosen for the study. 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 each 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.

2.7 Statistical analysis

A descriptive analysis using SPSS 29 for the analysis of the collected data. In descriptive analysis, frequencies of the data were observed for a better understanding of the dataset and to summarize and explore the distribution of individual variables. The output displayed tables showing the counts, percentages, and various measures of central tendency and difference for the selected variable. The chi-square test was used in crosstab analysis to determine whether there was a significant difference between two categorical variables. The null hypothesis is that there is no difference. SPSS calculates the chi-square statistic and provides a p-value to determine significance. In the chi-square test, the chi-square statistic (X^2), degrees of freedom (df), and the associated p-value were included. Usually, the significance level is chosen to be 0.005. So, when the p-value is less than 0.005, there is a significant difference between the variables and the difference is not significant if the p-value is not less than the significance level.

RESULTS

3. Results

3.1 Participants information

The interview was sought from undergraduate students from different universities. The total response in the study was 784 in the survey. The study was conducted in 6 universities of which 2 were private and 4 were public universities. In the percentile, the participation was from private universities and from public universities. In the current study, of the total participants were students of BRAC University, and were from Independent University, Bangladesh (IUB). The other four public universities were Dhaka University (DU), Khulna University (KU), Rajshahi University (RU), and Shahjalal University of Science and Technology (SUST) from which correspondingly took part in the study (Table 3). In addition, among the 784 participants, the numbers of students coming from Bangla, English Version, and English medium schools and colleges.

Table 3: Number of participants of the universities selected for this study. The study questionnaires were completed by the students pursuing their undergraduate programs in different subjects. The overall number of participants was divided into 4 categories, Biotechnology, Biochemistry, and Molecular Biology, other biological sciences, physical sciences, and other subjects (Table 4).

Table 4: Participants from different educational majors.

3.2 Participants' acquaintance with biotechnology

The first question was about the familiarity with biotechnology. A good number of students were familiar with biotechnology which was, whereas only few of participants did not hear about biotechnology. On the other hand, of participants were not sure about being familiar. Lastly, students did not respond to the question. (Fig 1)

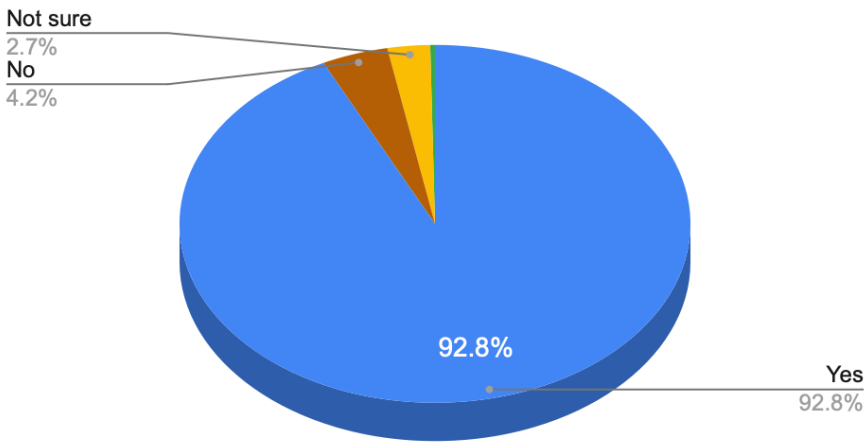

Figure 1: Participant's familiarity with the word biotechnology.

In this overall study, participants from biotechnology, biochemistry, and molecular biology all the respondents had knowledge about biotechnology which was obvious. From other biological sciences were familiar with biotechnology, few were unfamiliar, some were uncertain about the familiarity and other did not respond. Additionally, maximum of the physical sciences and of other subjects had familiarity with biotechnology. While physical sciences and of other subjects did not hear about biotechnology, of participants from other biological subjects did not respond to the question. The differences between the groups of educational majors were highly significant, as the p-score for each question was <0.001 (Table 5).

Table 5: Participant's response regarding "Have you ever heard about biotechnology?"

X^2= 41.589[a], df= 9, p= <0.001

Additionally, participants were familiar with genetic engineering (GE)/ genetically modified organisms (GMOs). On the contrary, respondents were not familiar with the terms; while only were not sure and very few did not respond (Fig 2).

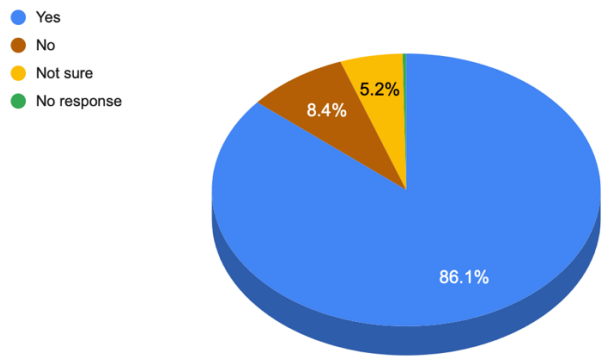

Figure 2: Participants' familiarity with the terms genetic engineering/ GMOs.

In this question, people from fields like biotechnology, biochemistry, and molecular biology, along with from other biological sciences, from physical sciences, and from various subjects were familiar with genetic engineering (GE)/genetically modified organisms (GMOs). However, participant in the first group, in the second group, in the third group, and in the fourth group had no familiarity with the terms. Additionally, from biotechnology, from other biological sciences, from physical sciences, and from other subjects were uncertain about their familiarity with GE/GMOs. Two participants from the other biological sciences group did not respond. The p-score was less than 0.001, indicating the difference was statistically significant. (Table 6)

Table 6: Participant's familiarity with genetic engineering (GE)/ genetically modified organisms (GMOs).

X^2= 71.547[a], df= 9, p= <0.001

After asking about the participants' familiarity with biotechnology and genetic engineering (GE) or GMOs, a question about the participants' knowledge of the difference between hybrid crops and genetically modified crops was asked. The difference between the percentages of students who believed or did not believe that hybrid crops and genetically modified crops are the same is very small. Because the numbers of the respondents were for yes and for no. On the other hand, students said that they were not sure about the statement, and some students did not respond to this question (Fig 3).

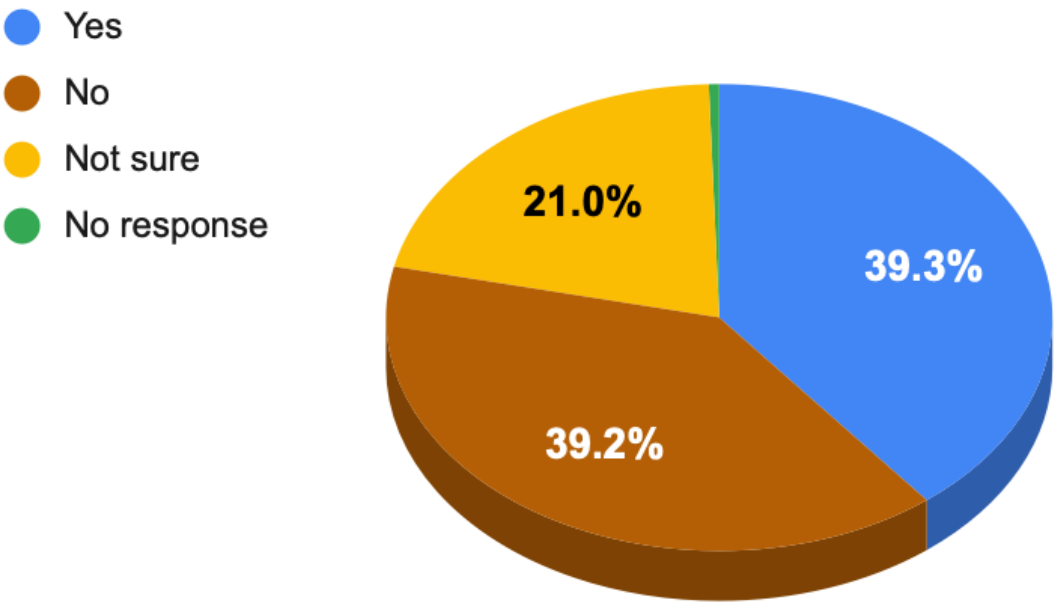

Figure 3: Participants' opinions on hybrids and GM crops.

In the biotech group, participants believed that hybrids and GM crops are the same, while disagreed, were unsure, and did not respond. In the other biological sciences group, individuals thought they were the same. Among the physical sciences group some believed and some did not. In the other subjects' group, about whether hybrids and GM crops are the same. The differences among the educational major groups were notably significant, with a p-value less than 0.001 for each question. (Table 7)

Table 7: Participant's response to "Do you believe that hybrid crops are the same as genetically modified crops?"

X^2= 62.103[a], df= 9, p= <0.001

3.3 Participants' familiarity with biotech products

In the second phase, knowledge and perception of various biotechnology products, both in medicine and food were asked.

(Fig 4). As the vaccine is a product that people come across in their daily lives, the number of participants having a good level of familiarity with it was obvious. Yet, there was a very small number of participants who had little or no knowledge about the product.

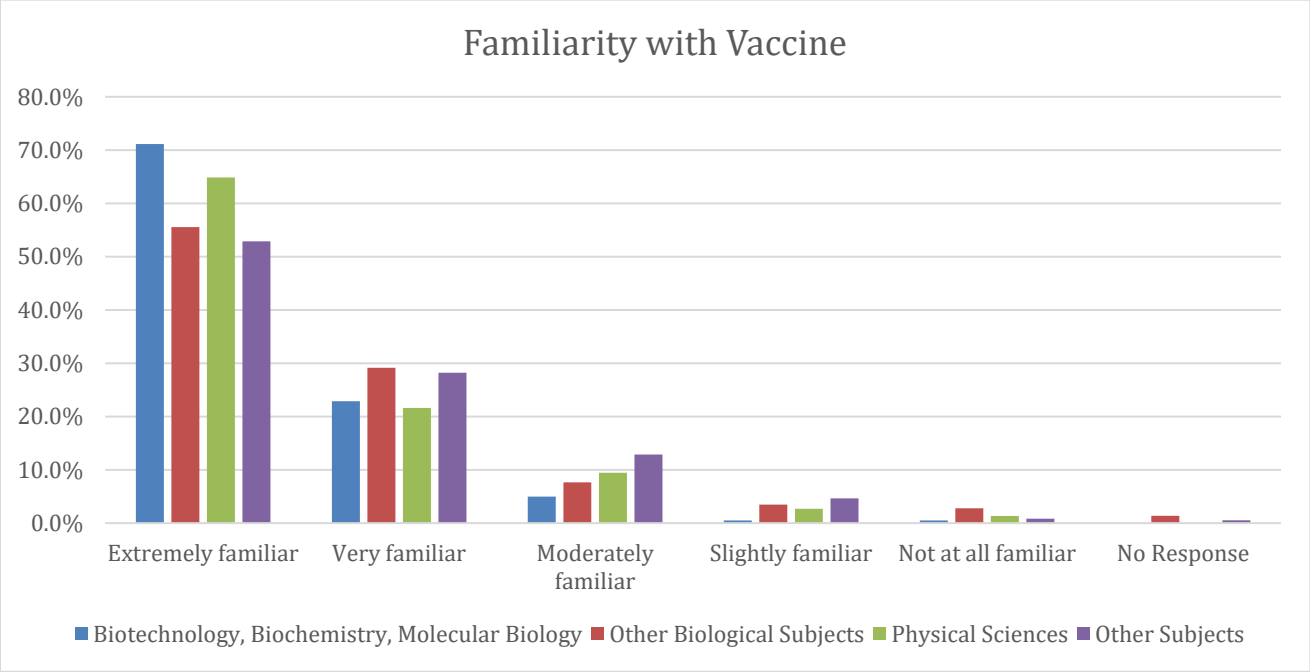

Figure 4: Participant's responses to familiarity with vaccines.

The target students were asked about their level of familiarity with antibiotics. (Fig 5). Like vaccines, the familiarity rate was high because of the regular use of antibiotics, although a negligible number of participants were unfamiliar with the product.

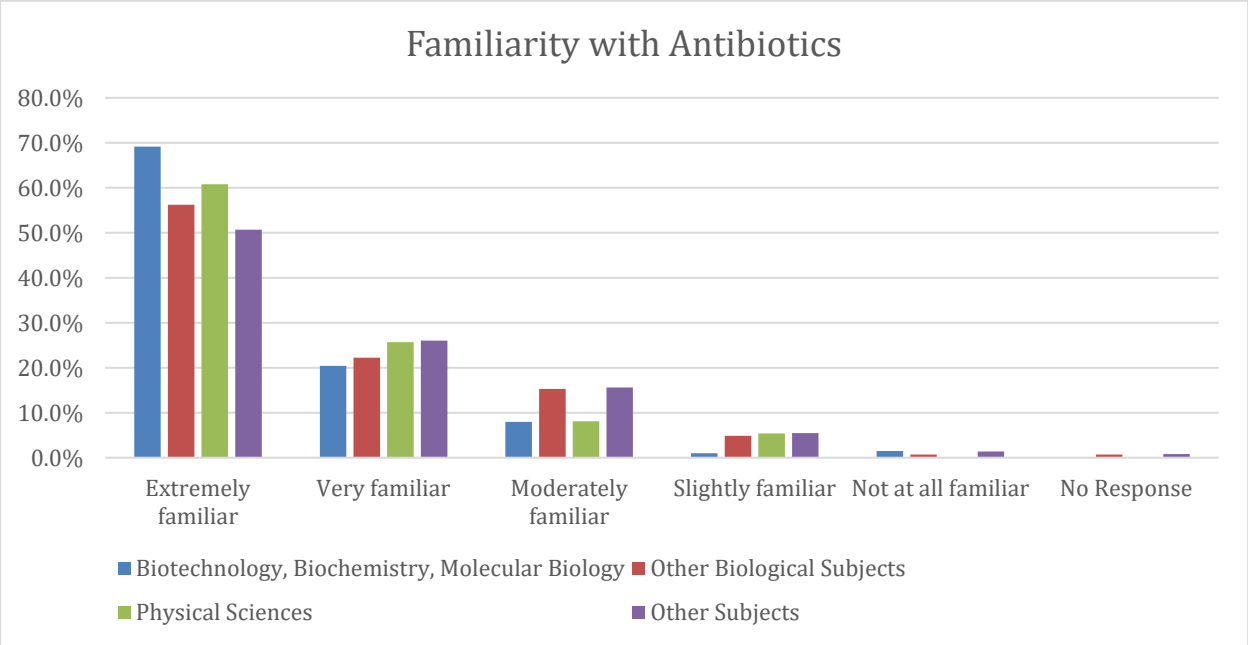

Figure 5: Distribution of the participants' familiarity with antibiotics.

(Fig 6). For insulin is also a common product derived from biotechnology, extreme familiarity was much higher than the other levels of familiarity regardless of their educational major. Although participants who learn about biotechnology academically have higher chances of familiarity.

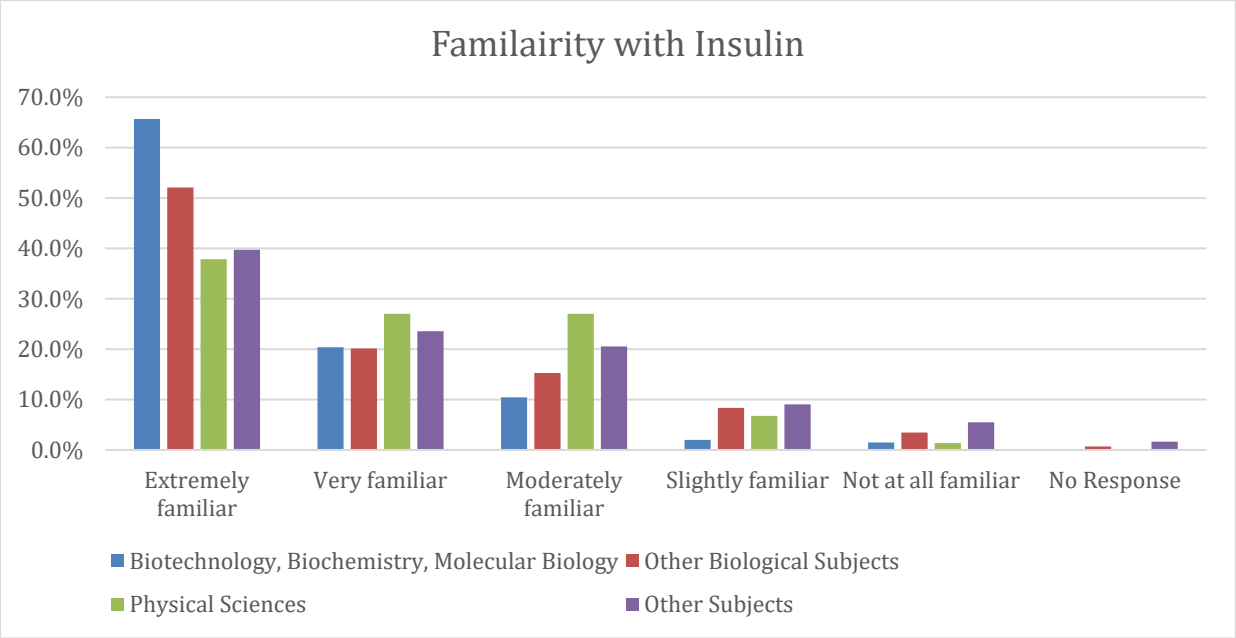

Figure 6: Distribution of the participants' familiarity with insulin.

(Fig 7). Thus, the tendency to be familiar with the product is higher when individuals are regarded as having studied biological science, but the converse is shown with people who did not major in biology.

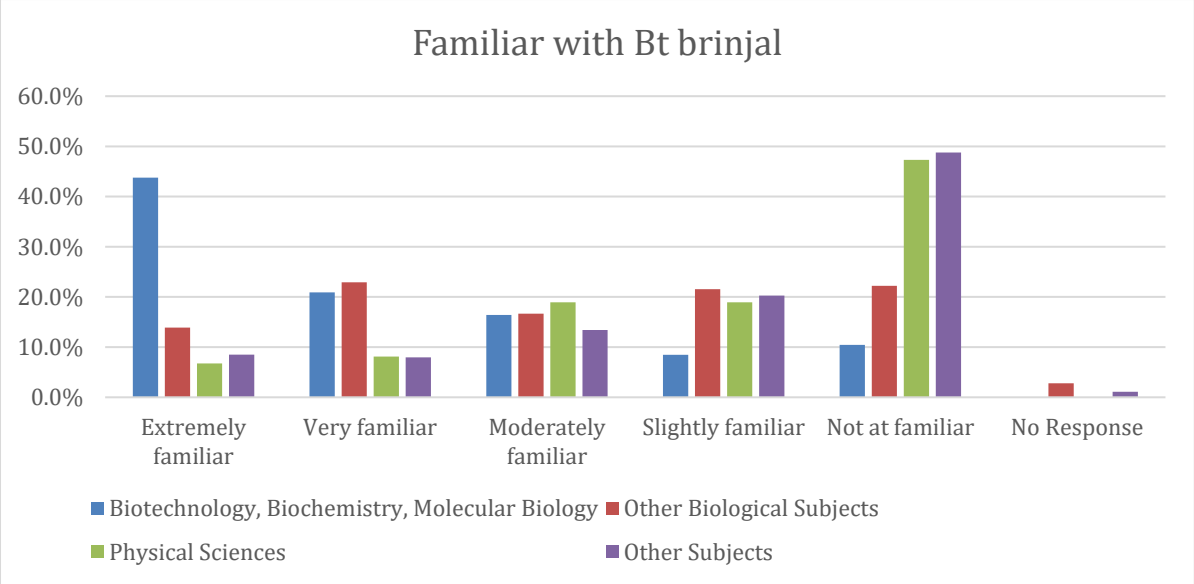

Figure 7: Distribution of the participants' familiarity with Bt brinjal.

(Fig 8). So, there is a trend that familiarity is higher when participants are accounted with the biological science, while the opposite is observed with non-biology majoring participants. Yet, there was a small group of participants in biotechnology who had little knowledge or no familiarity with Bt brinjal and golden rice, this might be because the students were in their 1st or 2nd years of university and were still new to these biotechnology products. Also, because of the variety of sources and coming across the terms, 4th students have a better understanding.

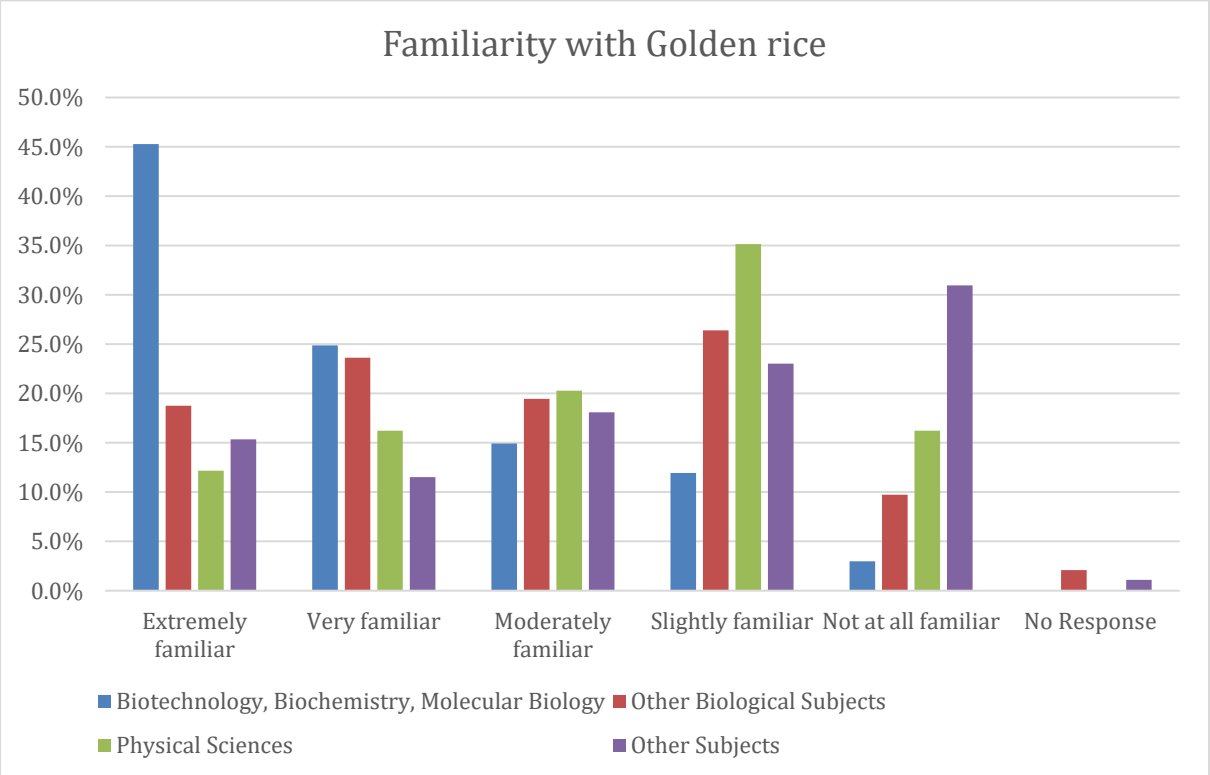

Figure 8: Distribution of the participants' familiarity with golden rice.

3.4 Participants' opinion of the application of biotechnology

After asking the participants' familiarity with biotechnology, GE/ GMOs, or other biotechnology products, they got a little idea of this field. The question was about the participants' opinion on the statement "GM technology is useful in ensuring food security". In the current study, the majority was from biotechnology in the strongly agreed group in the case of the statement. (Fig 9) Knowledge of biology had a similar impact on this question's answer, as the familiarity with biotechnology products.

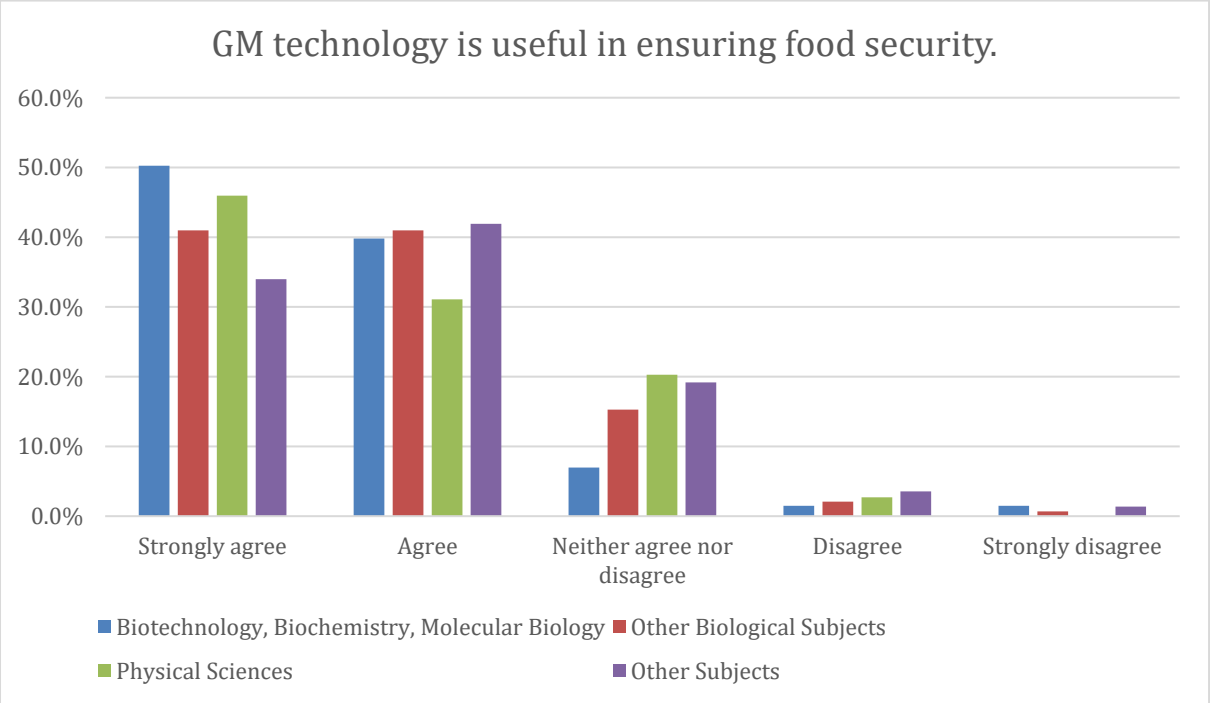

Figure 9: Participants' opinion on "GM technology is useful in ensuring food security".

In the bar chart of the study, it is found that most of participants in biotechnology showed strong agreement and agreement with the statement "Genetic engineering can enhance the nutritional quality of food" while no one disagreed strongly. (Fig 10). The response was similarly affected by the participants' knowledge of biological sciences.

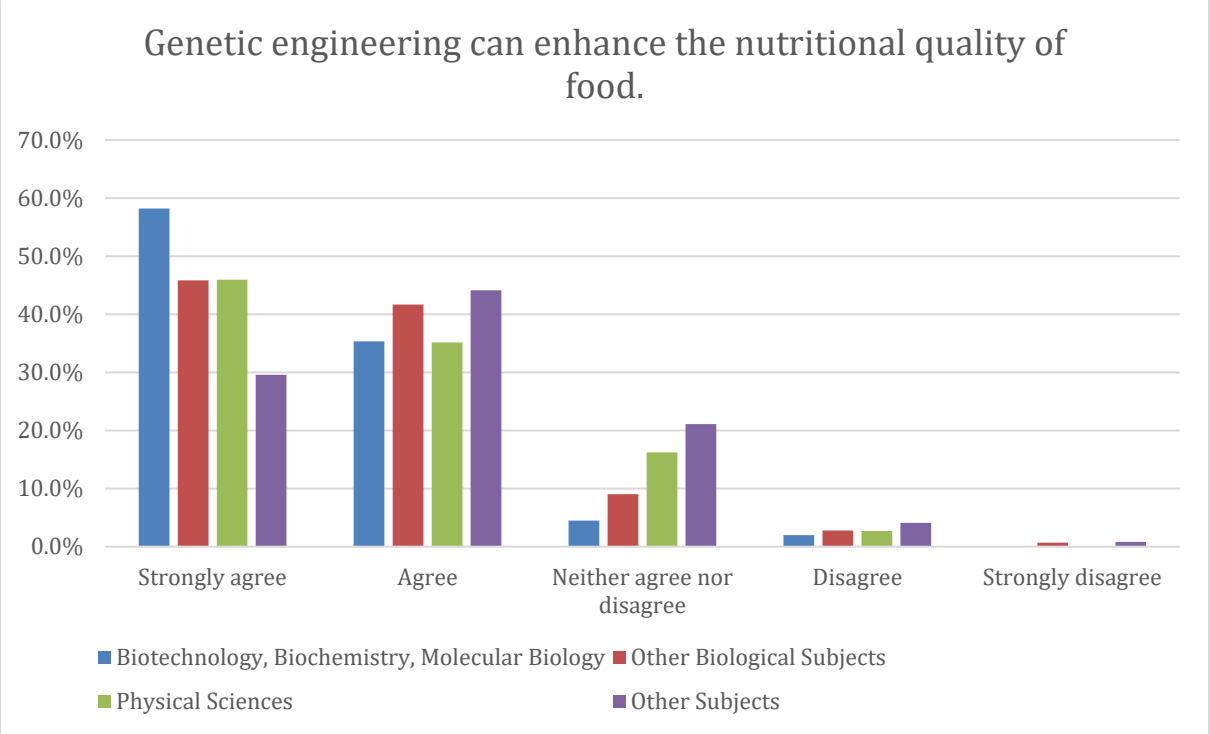

Figure 10: Participants' opinion on "Genetic engineering can enhance the nutritional quality of food."

(Fig 11). The response to this statement was influenced by both familiarity with biotechnology-derived products and knowledge of biology. However, non-biological science background participants also had a positive impression on this matter.

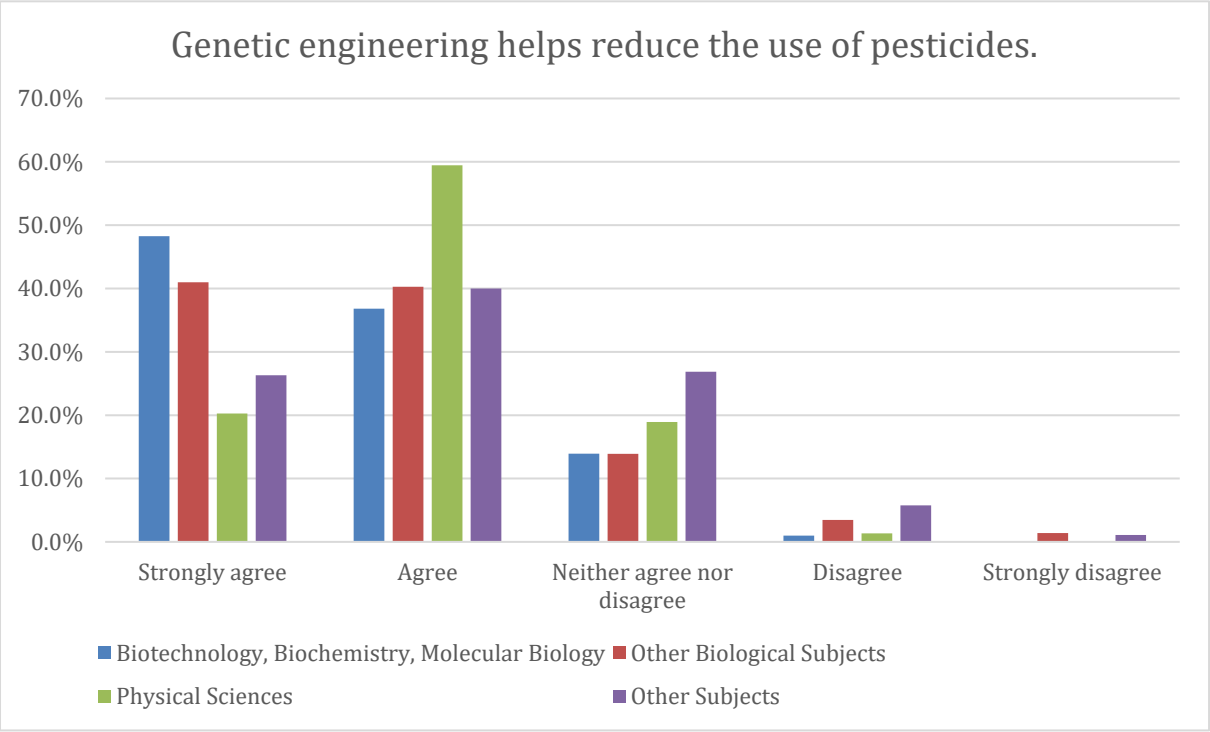

Figure 11: Participants' opinion on "Genetic engineering helps reduce the use of pesticides."

(Fig 12). Familiarity with the products impacted participants' responses to this statement. Medicine also tends to have more acceptance compared to agriculture and food.

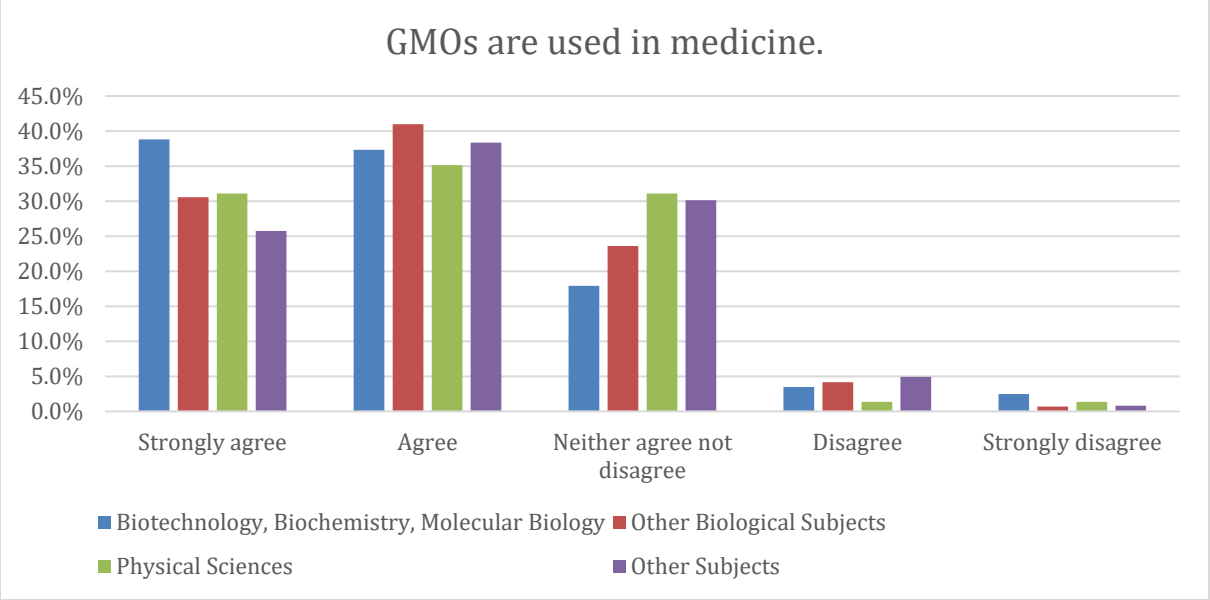

Figure 12: Participants' opinion on "GMOs are used in medicine."

(Fig 13). In this statement, knowledge of biology affected the responses. Thus, the number of participants in agreement was much higher than that of those in disagreement. Also, there was a moderate number of respondents who remained neutral. This was a very interesting observation.

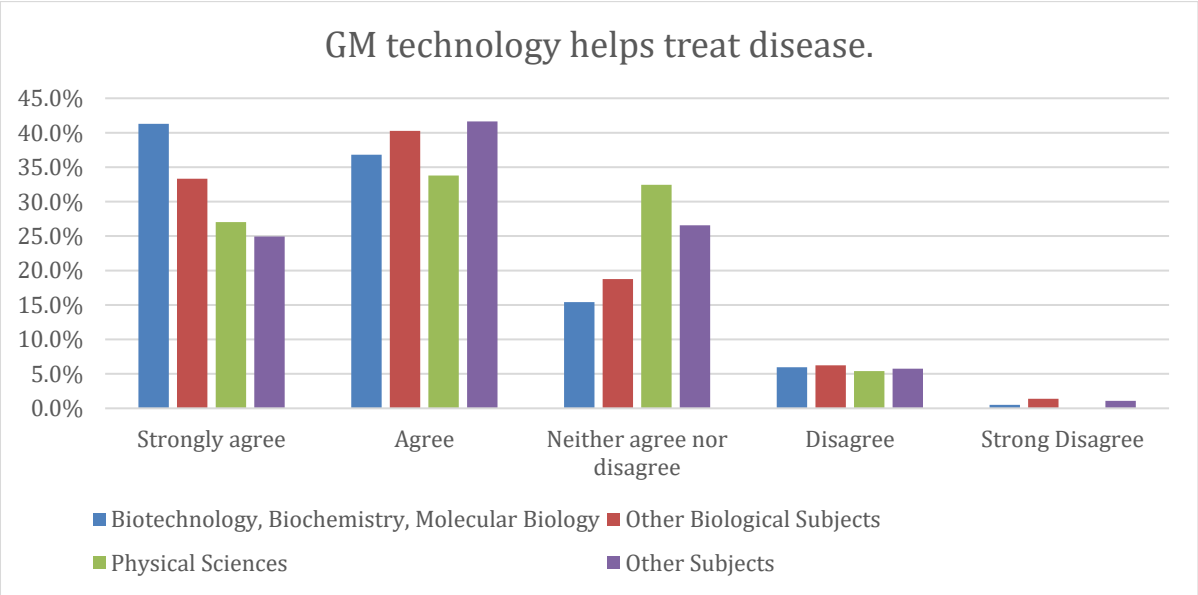

Figure 13: Participants' opinion on "GM technology helps treat disease."

(Fig 14). Here not the benefit, but the disadvantage of the biotech products was asked. Knowledge of biology was found to have an impact here as well. However, the impact is not as linear, but more towards mixed opinion.

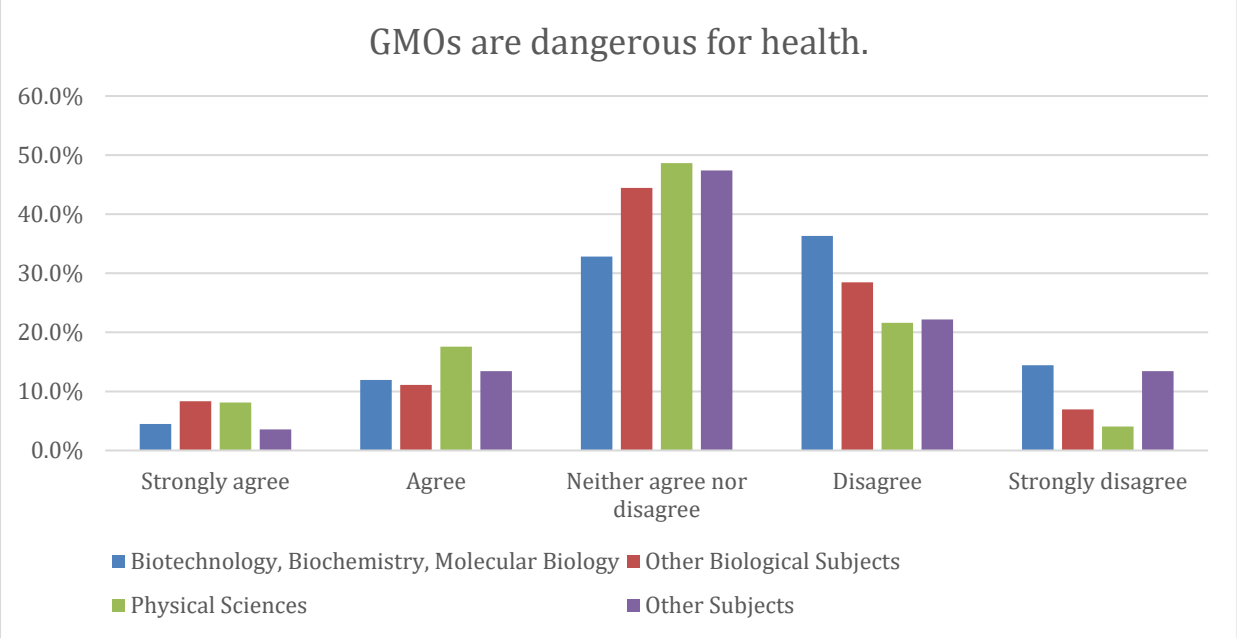

Figure 14: Participants' opinion on "GMOs are dangerous for health."

Almost similar patterns were observed in the bar charts for the statement "GMOs can cause environmental pollution." In this case, a small number of participants from every subject group agreed and disagreed strongly. (Fig 15). This statement also depicted the drawbacks of biotechnological products. Responses were affected by the knowledge of biology. Similar to the previous statement, the impression was not linear. Again, the academic year influenced the perceptions of the participants as students' viewpoint changed with their growth academically.

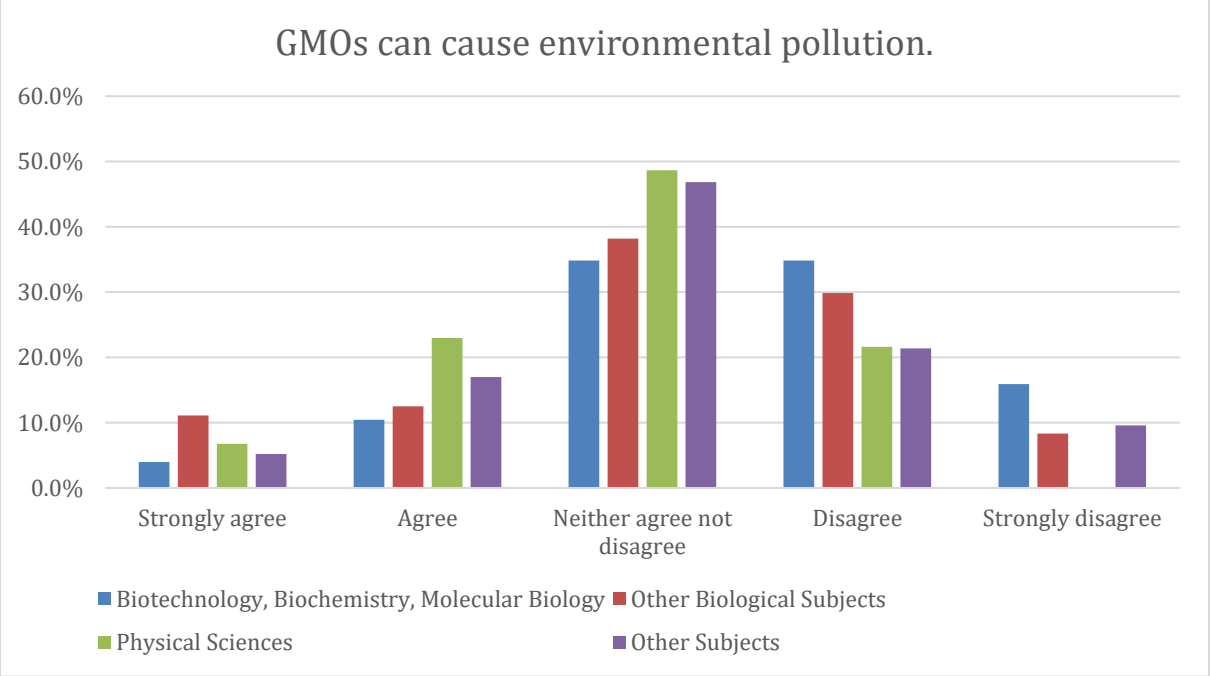

Figure 15: Participants' opinion on "GMOs can cause environmental pollution."

In the present study, the students were asked to put their opinion on the statement "GM food labeling would affect consumers' buying decision". (Fig 16). In this statement, the impact was not linear. It also was not as similar as the previous one. Here, most of the participants, regardless of their educational major, could not agree or disagree if GM food labeling would affect the consumers' decision. But the number of agreements was more than that of disagreement.

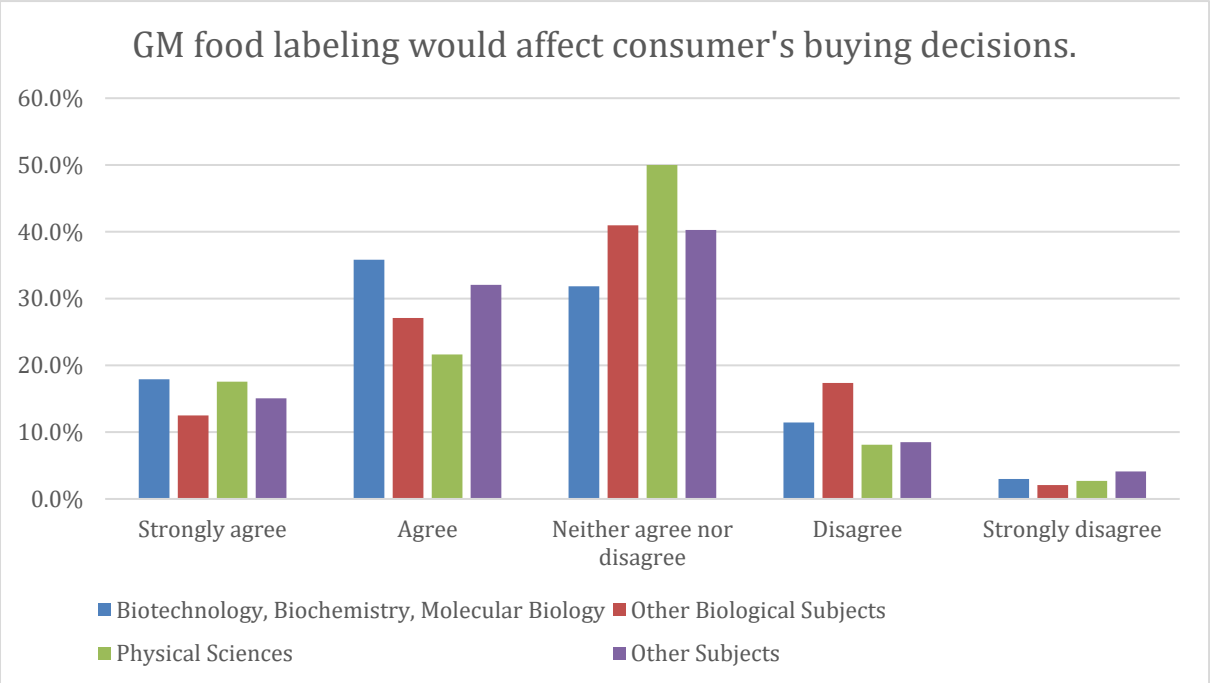

Figure 16: Participants' opinion on "GM food labeling would affect consumers' buying decision."

3.5 Sources of biotechnology-related information

Sources of information can influence the perception. In this part of the study, it was discovered that most of the biotechnology students get information from scientific articles very often; while rarely use the source. (Fig 17). These responses were obvious.

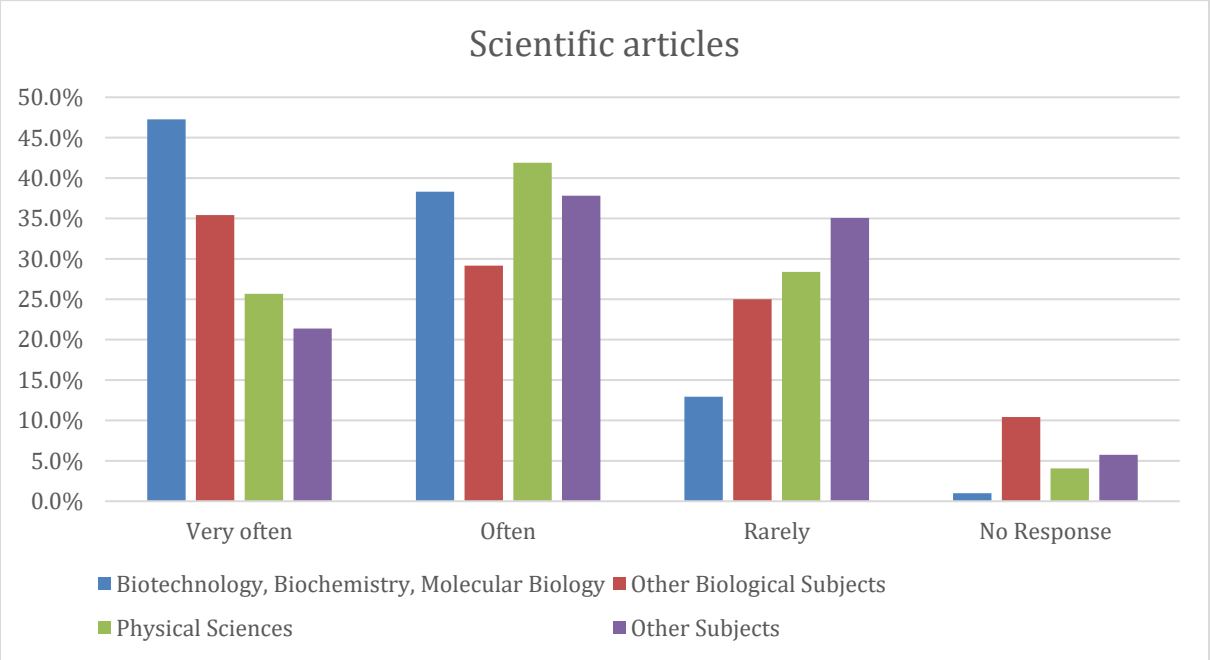

Figure 17: Participants' obtaining information related to biotechnology from scientific articles.

(Fig18). Here, the participants' educational major influenced their use of electronic media.

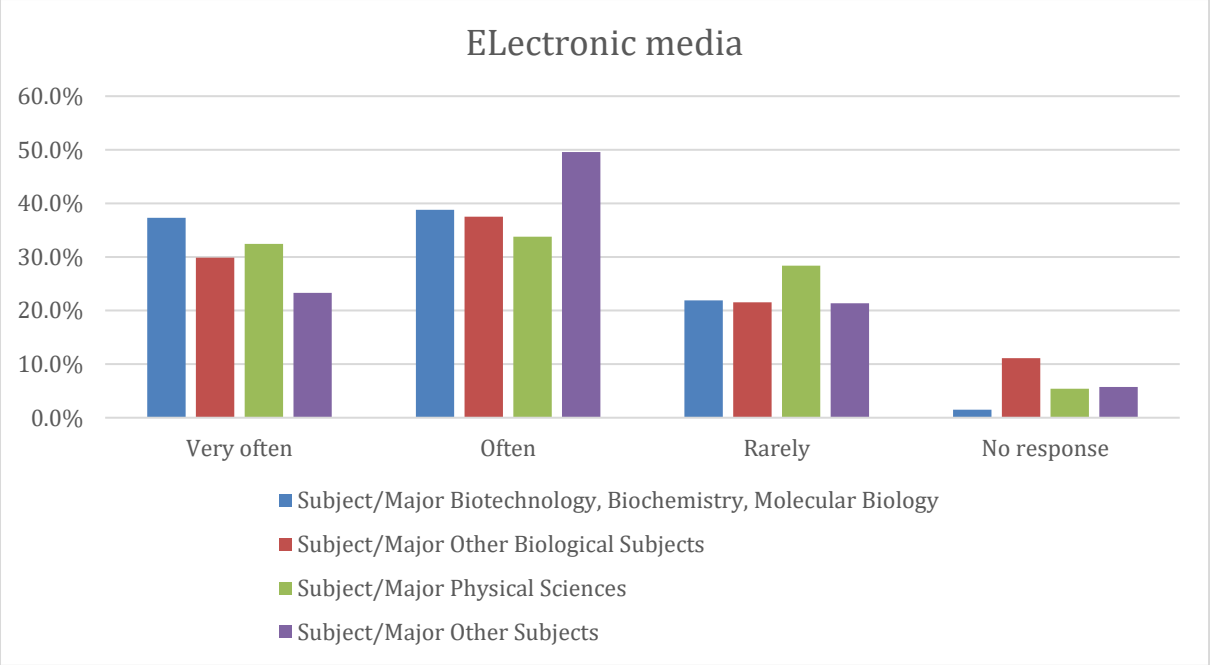

Figure 18: Participants' obtaining information related to biotechnology from electronic media.

(Fig 19). In today's world of digitalization, people tend to use electronic media more than printed media. This is why, the graph highlights that rarely using participants are higher. Then some of the participants use this printed media often.

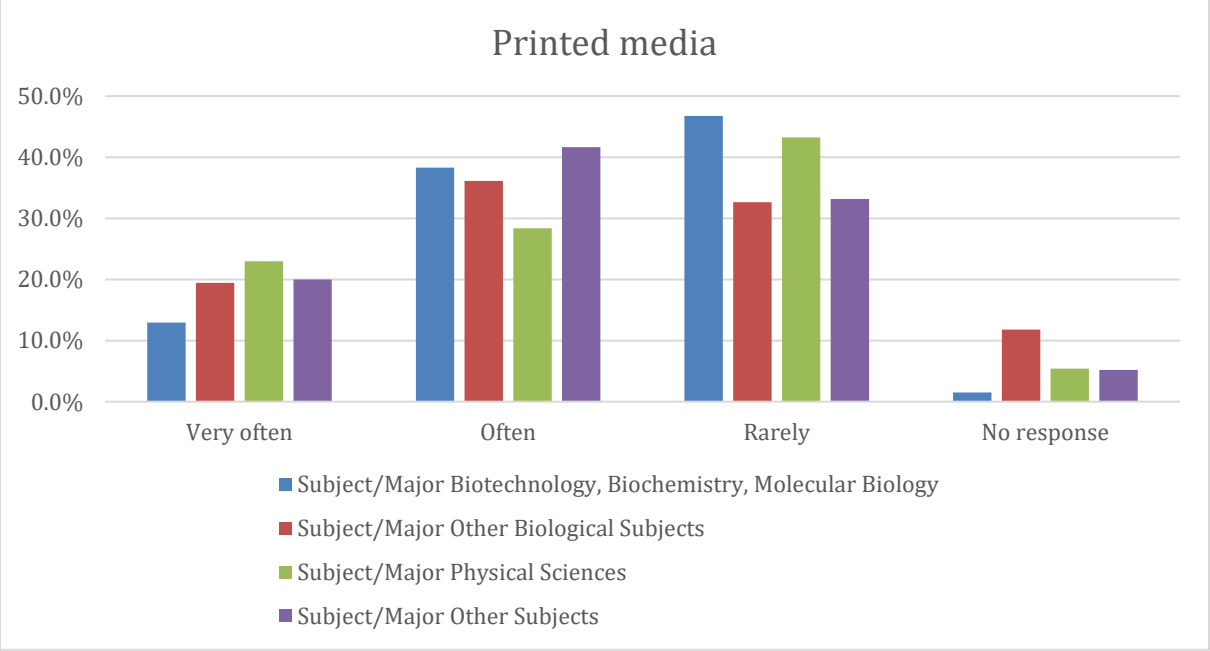

Figure 19: Participants' obtaining information related to biotechnology from printed media.

Lastly, this part of the question indicates that the participants are coming across biotechnology-related information using social media. In this case, almost similar, yet the maximum of each group responded that they get information from social media very often. (Fig 20). Nowadays, students use social media more often for communication, looking for study and job-related information. Thus, no matter what the educational major, the number of participants preferring social media was higher than the other media sources. The influence of social media is one of the major factors in perception development. In addition, the use different media sources for knowledge varied form 1st year participants to 4th year participants.

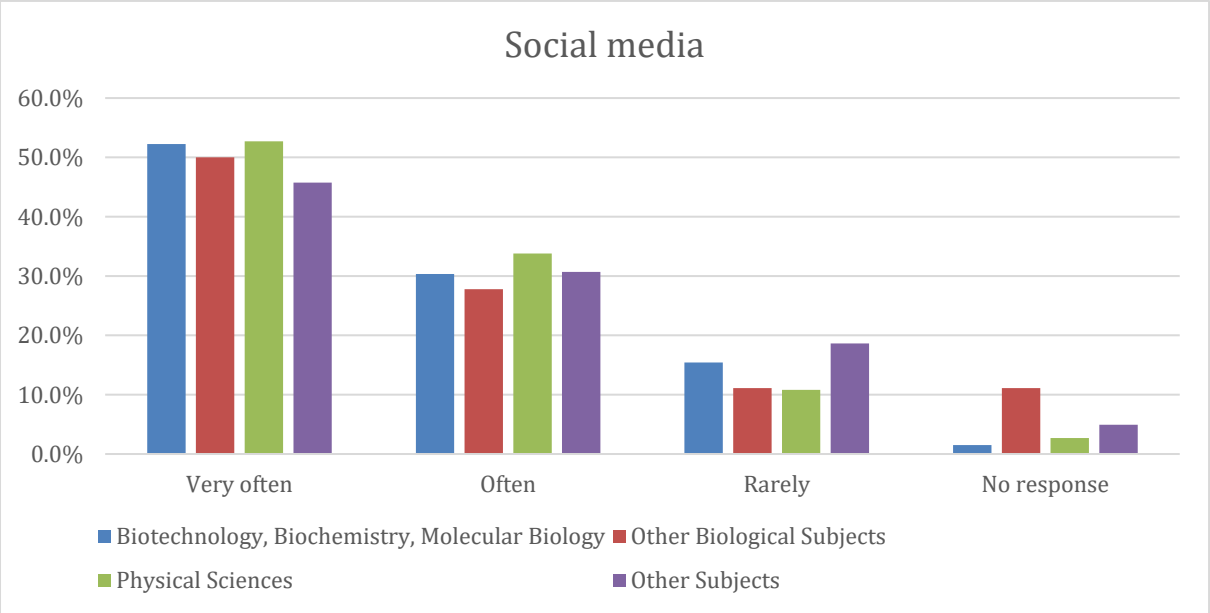

Figure 20: Participants' obtaining information related to biotechnology from social media.

DISCUSSION

4. Discussion

This was a cross-sectional study. Undergraduate students of different educational majors from different universities were the target population of the current study. A minimum sample size of 88 from each center was calculated. Overall, 784 students participated through simple random sampling. In this study, compilation of data, descriptive analysis, and Chi-square tests were done using SPSS 29. Also, for graphical representations, Microsoft Excel was used. According to the objective of the study, the following observations were made. For the study, data was collected from both from private and public universities. Among them, the percentages of the participants from the four categories based on the educational major were for Biotechnology, Biochemistry and Molecular Biology, other biological sciences, physical sciences and for the other subjects. In this study, from the 1st, 2nd, 3rd and 4th year subsequently. Among these respondents, the majority were from Bangla medium schools and colleges. The numbers of students from the English version and English medium school and college. A previous cross-sectional study was carried out among almost equal participants of 750 in Golestan province in Iran. During the study, the participants were investigated through cyberspace, and the data was analyzed using Mplus 7 and SPSS 16 (Shahnazi, et al., 2020). The current study was conducted targeting only tertiary-level students, while the previous study targeted people over the age of 18 from any educational background.

In the present study, participants were asked about their familiarity with biotechnology. In response to the question, respectively from biotechnology, other biological subjects, and physical sciences were familiar with biotechnology. Moreover, 4th-year students have a better understanding than 1st and 2nd-year students as they study different sources and come across the term. In a study conducted in the UAE undergraduate students were asked to complete an internet survey. The study included questions on literacy, the environment, society, and the economy as they relate to biotechnology to collect data. Students' responses (n = 1,104) were compiled and statistically examined. The study's findings showed that student academic success and the institution they were enrolled in greatly affected their levels of educational awareness in the literacy on biotechnology and natural domains. Overall, it was determined that the students' knowledge performed poorly. Educated populations most likely accepted reputable sources of correct biotechnology information supplied through lectures or the internet. As a secondary source, the students learned what was going on around them (AbuQamar et al., 2015). Here, it is visible that the majority of the participants had familiarity with the term Biotechnology, while in the previous study in the UAE, students showed poor

performance in knowing about biotechnology. In the case of being familiar with genetic engineering and GMOs, of the participants were familiar, few were unfamiliar, and some were uncertain. The maximum of the participants from the four educational majors were familiar with the terms genetic engineering (GE) or genetically modified organisms (GMOs). Besides, there were very less differences between the groups that believed and did not believe that hybrids and GM crops are similar. In this question, of biotechnology students believed that hybrids and GM crops are similar whereas said these are not similar. This raised questions about their depth of knowledge of the subject. On the other hand, of other subjects believe hybrids and GM crops are not similar while some believed in the similarity. As there is a significant difference ($p = <0.001$), it should be taken into account as a proportion of the students have this misconception that hybrids and GM crops are similar even studying subjects like biotechnology, biochemistry, and molecular biology. During the literature review, numerous studies have investigated pupils' understanding of genetic engineering. Students from a minimum of 15 different countries were assessed for their knowledge between 2012 and 2022. According to the review's findings, the focus of the items requested was mostly connected to the principles, procedures, advantages, and hazards of genetic engineering, even though the elements of the tool were not precisely the same. Additionally, most studies included respondents from more than one secondary school grade while collecting data, meaning the study of school students' opinions or understanding of genetic engineering (Purbosari & Astuti, 2023).

The present survey shows that most of the students are familiar with vaccines and antibiotics, as these are the common biotechnology products used in regular life. For instance, a total of participants is familiar if not extremely familiar, while some had slight familiarity with vaccines. There were very few respondents were found to be not at all familiar with vaccines. Regarding familiarity with antibiotics, the same familiarity trend was observed (>80%) and a minimal number of participants were moderately and slightly familiar with antibiotics. The data shows that students are less familiar with insulin than that of vaccines and antibiotics. In cases of Bt brinjal and golden rice, the majority of the students were not familiar with the products. Some biotechnology students responded moderately to not being at all familiar. The reason might be the students were in their 1^{st} or 2^{nd} years of university. A study examined five such products and their perceived benefits and risks to gauge public opinion and regulatory preferences in the United States. Surprisingly, a significant portion (70%) of respondents exhibited consistent support or opposition across all five products, suggesting that early

experiences with GM products may influence opinions on newer biotechnologies. The study identified five common opinion patterns about biotechnology and employed machine learning models to predict respondents' opinion groups (Azodi & Dietz, 2019). The findings depicted that a major group of customers were unaware of the items being developed from biological materials. The study showed that overall awareness was poor (Ruf et al., 2022). The present study reveals that students from different educational majors have varying levels of familiarity with biotechnology products. Participants from biological sciences majors show higher familiarity due to the more accordance with biotechnology-related products. In contrast, students in the non-biological majors have less connectivity with biotechnology-derived products resulting the limited exposure. This indicates the need for interdisciplinary education and communication to bridge knowledge gaps. Targeted educational initiatives to increase understanding of GM crops are needed.

A significant proportion of participants expressed positive attitudes toward GM technology. Notably, more of the participants are in agreement that GM technology is useful in ensuring food security. This positive sentiment was spread across various academic categories, suggesting a general optimism regarding the potential of GM technology. Regarding the statement that genetic engineering can enhance the nutritional quality of food, a majority either agreed or strongly agreed. This suggests that a substantial portion of the respondents acknowledge the potential benefits of GM technology in improving the nutritional content of food. The data reveals that many participants supported the statements that genetic engineering helps reduce the use of pesticides, GMOs are used in medicine, and GM technology aids in treating diseases. These findings indicated a generally positive perception of the roles and applications of GM technology. The primary findings indicated that students' views on GMOs are significantly influenced by their educational backgrounds. Specifically, students pursuing technical and natural science programs (comprising 60.90% of the sample) hold more favorable opinions about GMO products compared to their counterparts in Social Sciences programs (constituting 22.63% of the respondents). Consumers tend to have a less favorable perception of GMOs (Palmieri et al., 2020).

A small percentage of respondents expressed concerns about the safety of GMOs for health and their potential to cause environmental pollution. However, the majority either remained neutral or did not express strong disagreement. The findings suggest that while some individuals are more uncertain about these issues, others have doubts. The statement about GM

food labeling affecting consumers' buying decisions indicated that a substantial portion of respondents believed that labeling influenced buying choices, with around either agreeing or strongly agreeing. A study investigated the significance of scientific reliability, shedding light on the factors contributing to shaping public perceptions about the impact of GM foods on both the food supply and human/environmental health. The research also emphasized the value of a comprehensive definition of source credibility which encompassed attributes like understanding, integrity, concern, and trust. In the analysis, scientific goodwill was identified as a distinct element associated with source credibility. The findings indicated that people's perceptions of scientific credibility and understanding were strongly divided. There was potential to impact how they view the principle of scientific findings related to GM foods ("The Role of Scientific Source Credibility and Goodwill in Public Skepticism Toward GM Foods," 2020). In a previous study, it was found that most consumers are unfamiliar with labeling and brands. Additionally, some people have false assumptions about how bio-based items would affect the environment. Although consumer preferences differ across product categories, bio-based materials are sometimes overshadowed by other considerations like cost or usefulness. High intentions to buy and a greater readiness to pay are observed, for example, for disposable goods, plant pots, and products with bio-based packaging (Ruf et al., 2022).

The present study reveals that the preferences and uses of media and information technology vary in terms of educational majors and academic years. Because these preferences differ as students grow academically. There was an obvious result that depicted the frequent use of scientific articles was higher among the students of life sciences than that of the other subjects. Additionally, the use of scientific articles was also impacted by the participants' academic year. The responses to the use of electronic media were also influenced by the educational majors of the participants. There was a good response to coming across biotechnology-related information from social media regardless of the educational major and academic year. The result of the present study highlighted those exceptions that occurred in the case of using printed media. The notable inequalities were because the students preferred reading the various scientific papers. Most of the students tend to use more social media these days resulting in them coming across information related to biotechnology and GMOs from social media. Students generally lack awareness of biotechnology advancements. To enhance their understanding, they require accessible learning materials that incorporate the latest research across various biotechnology domains. Moreover, assigning them international journal readings can broaden and update their insights. In summary, it's crucial to create updated

learning materials on evolving biotechnology topics to facilitate their education (Kurniati & Ahda, 2019).

The overall survey revealed that participants' educational majors influenced their responses to the questions. The study indicates the need for updates in learning materials. Reading and connecting more with journals, electronic, and printed media will enhance the knowledge of biotechnology. Also, educating biological science students and creating a bridge between life science students and other subjects' students will help spread awareness of biotechnology and its uses.

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