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Empowering Futures: Biotechnology Education in Bangladeshi High Schools

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Abstract- **The advancement of formal education propelled scientific knowledge, emphasizing the need for curiosity, critical thinking, problem-solving, and adaptability in an increasingly technological world. In Bangladesh, a strong foundation in technology, particularly biotechnology, is crucial for development. Biotechnology combines biology and engineering to create products and services that address challenges in food security, disease management, and environmental sustainability. This study examines the current state of biotechnology education at the higher secondary school (HSC) level in Bangladesh, assessing the awareness and understanding among students and teachers, identifying barriers, and suggesting strategies for improvement. The study reveals a significant gap in awareness and understanding of biotechnology products and services among HSC science students and teachers. Current biotechnology curricula and teaching methodologies are inadequate, contributing to partial awareness of biotechnology's usefulness. Findings indicate that educational awareness significantly influences students' and teachers' perceptions of biotechnology. The inclusion of biotechnology courses in the biology curriculum is essential to bridge this gap. Comprehensive strategies for biotechnology education will equip students with the necessary knowledge to differentiate between biotechnological and non-biotechnological products and services, fostering a deeper appreciation and understanding of biotechnology. Implementing these strategies will better prepare students for the demands of a knowledge-driven economy and the rapidly advancing biotechnology industry.**

Keywords- Biotechnology, education, awareness, secondary school, strategies

I. INTRODUCTION

Life on earth has been around for more than 3.7 billion years. Humans have survived by using other organisms [1]. Initially, humans were wanderers and hunters, then they became shepherds and farmers, which led to stable communities and early civilization. This stability helped humans explore their surroundings and make progress in science and the arts, improving their quality of life [2]. The development of formal education further advanced human knowledge, especially in science. Education systems everywhere aim to teach people the knowledge and skills they need to be curious, think critically, solve problems, and adapt to a scientific and technological world [3]. Bangladesh is no exception to this trend. For any country, including Bangladesh, to develop, it needs a strong foundation in technology, which uses scientific knowledge to improve life. One rapidly growing area of science and technology is biotechnology. As the world advances towards an increasingly knowledge-driven economy, the importance of biotechnology education cannot be overstated [4].

Biotechnology is a scientific field that combines biology and engineering to use living organisms or their parts to create products and services that improve people's lives [5]. In Bangladesh, the potential benefits of biotechnology are immense. The country faces numerous challenges that biotechnology could address, such as food security, disease management, and environmental sustainability [6]. To capitalize on these opportunities, it is essential to cultivate a skilled workforce well-versed in biotechnological concepts and techniques. This journey begins with robust biotechnology education at the higher secondary school (HSC) level. Integrating biotechnology into the curriculum at this stage can spark interest and provide foundational knowledge that students can build upon in their higher education and professional careers. It is at this formative stage that students are most impressionable and capable of developing a keen interest in scientific fields. It is essential for preparing students for

the demands of the modern world and the rapidly advancing biotechnology industry. However, this integration comes with its fair share of challenges and opportunities. Identifying and addressing these challenges, while capitalizing on the opportunities presented, is critical for the effective implementation of biotechnology education in the local government area of Bangladesh.

Problem Statement

From the beginning of creation, humans have been meant to dominate other creatures. To achieve this, they have used and improved microorganisms for new production processes. This involves biotechnology, which uses living organisms and processes to produce goods and services for humans.

Despite the growing significance of biotechnology in addressing global challenges in healthcare, agriculture, and environmental sustainability, there is limited research on the integration and impact of biotechnology education at the higher secondary level in Bangladesh. While some studies have focused on biotechnology education in developed countries, and a few have touched upon tertiary education in Bangladesh, there is a noticeable lack of comprehensive studies examining how educational awareness of biotechnology at the higher secondary school level affects students' knowledge, attitudes, and potential career choices in this field. Additionally, the effectiveness of current biotechnology curricula, teaching methodologies, and resource availability in Bangladeshi schools has not been extensively explored. This lack of knowledge creates a gap, as few studies address educational awareness in this area.

This study aims to fill that gap by exploring ways to educate teachers and students about biotechnology and its products and services as well as to investigate the current state of biotechnology education in higher secondary schools in Bangladesh, assess the level of awareness and understanding among students, identify barriers to effective teaching and learning, and suggest strategies for improvement.

Purpose of the Study

The impact of teaching biotechnology in higher secondary schools in Bangladesh is greatly affected by the lack of knowledge for both students and teachers. Since biotechnology is a fast-growing field, not having the right training and awareness makes it hard for education to keep up with modern science demands. The main objective of the study was to investigate the impact of educational awareness regarding biotechnology, its products, and services among students and teachers in Higher Secondary Schools within a Local Government Area in Bangladesh. Specifically the purpose was:

- To evaluate the impact of current biotechnology curriculum on students' understanding and attitudes towards biotechnology.
- To assess the availability and adequacy of resources and materials related to biotechnology education in higher secondary schools.
- To find out the extent higher secondary school students were aware of the usefulness of biotechnology and its products and services.
- To examine the role of educational awareness on biotechnology products and services as perceived by students.
- To explore the influence of educational awareness on biotechnology products and services from the perspective of teachers.
- To identify the strategies for implementing biotechnology education.

II. THEORETICAL FRAMEWORK AND LITERATURE REVIEW

Concept of Biotechnology

Technology is the application of science to practical human purposes, aiming to increase productivity, provide more leisure time, and improve quality of life. Technology has been developing since ancient times and is used in all areas of human activity, such as agriculture, electricity, medicine, biology, and drugs [7].

Biotechnology is a term combining biology and technology. Biotechnology is a multidisciplinary field that combines engineering and natural sciences to use organisms and their parts to create products and services. The term was first used in 1919 by Hungarian engineer Karl Ereky to refer to the use of living organisms to produce products from raw materials [8]. According to the United Nations (1992), biotechnology is any technological application for specific uses. Despite the varying definitions of biotechnology, they all share common elements: the use of biological entities (like microorganisms and cells, whether living or dead) and their components (such as enzymes) to produce products or services that enhance human welfare [9].

Current Status of Biotechnology Education in HSC in Bangladesh

Biotechnology, which involves applying technology to biological systems to develop practical solutions, holds immense potential in addressing challenges across various sectors such as health and agriculture [7]. Despite Bangladesh's significant advancements in agricultural biotechnology through conventional methods, other areas like industry and healthcare are yet to see similar progress. This discrepancy in progress highlights the need for a comprehensive educational approach to raise awareness about biotechnology products and services, especially in higher secondary schools. However, there is only a

chapter included in the book with little information which does not even fulfill the basic information about biotechnology where its products and services descriptions are so far away [10]. Biotechnological experiments in the classroom limited to yoghurt production, lactic acid production in sour dough, citric acid production, comparative protein analysis, restriction digestion of DNA and separation by gel electrophoresis etc. Even students have very little idea about the occurrence of bacteria in the body, outside the body, and in food and their beneficial role in the body [11]. By integrating biotechnology education into the secondary school curriculum, students can gain a foundational understanding of this field, paving the way for a more informed and skilled workforce in the future. Moreover, educational initiatives focusing on biotechnology products and services in higher secondary schools can enhance students' awareness of the diverse applications of biotechnology in different industries and fields. This educational emphasis on biotechnology not only enriches students' learning experiences but also equips them with the knowledge and skills needed to contribute to agricultural development, biological research, and other crucial areas in Bangladesh's evolving landscape of science and technology.

Students' Interest in Biotechnology Topics

Students' curiosity and perspectives on the subjects they study greatly influence their educational achievements [12]. Prokop and colleagues undertook a study to assess students' engagement and attitudes towards biotechnology, employing questionnaires. Their findings suggest that around the age of 16, students generally become interested in biotechnology. Notably, girls tend to focus more on the social and ethical aspects, whereas boys gravitate towards its economic and technical facets. This interest stems primarily from curiosity and receptiveness to new technologies rather than deep knowledge [13]. It's noteworthy that students' interest in biotechnology often aligns with their concern for broader societal issues, with media exposure playing a significant role in shaping this interest compared to formal science education. Students are particularly keen on understanding the benefits, drawbacks, and risks associated with biotechnology, especially its applications in healthcare and global food security, along with ethical considerations [14]. They express optimism about genetic engineering's potential in environmental conservation and diagnosing hereditary diseases but harbor apprehensions regarding its use in agricultural production and the release of genetically modified organisms. Additionally, students' express concerns about potential misuses of genetic technology and its implications across research and various application domains [15].

Material for Teaching Biotechnology in Schools

Studies in Bangladesh show that people doubt whether their governments can handle the risks of biotechnology. They think this is because there isn't enough good information available. In response, some European countries have started teaching biotechnology in schools [16]. One project, called IBEA, funded by the National Institute of Biotechnology, aims to educate the public, especially students, about biotechnology. They've made teaching materials available online, covering various topics and including information for teachers and activities for students. These materials don't just focus on science but also discuss ethical, social, legal, and economic aspects of biotechnology. Examples of the materials that are dealing with a wide range of biotechnological issues are included DNA Fingerprinting, novel food, fermentation technology, DNA model, practical immunology, transgenic plat etc [17].

Biotechnology Products and Services

Biotechnology products and services are created using technology that involves microorganisms and cells, both living and dead. These products range from ancient times, like wine, beer, and leavened bread made between 6000 BC and 4000 BC, to modern-day products [18]. Biotechnology is used in four main areas: (a) medical, (b) crop production and agriculture, (c) manufacturing organic products like beer and dairy, and (d) recycling, waste treatment, and cleaning up polluted sites [19]. According to Wikipedia (2009), biotechnology has five branches: (a) green biotechnology for agricultural processes, (b) red biotechnology for medical processes, (c) white biotechnology for industrial processes, (d) bioinformatics, an interdisciplinary field essential for biotechnology, and (e) blue biotechnology for marine and aquatic applications [20]. Among these, green and white biotechnology are the most important in terms of Bangladeshi economy.

Green biotechnology focuses on agriculture and has led to advancements such as plant selection and propagation through micropropagation, the creation of transgenic plants that can thrive in specific conditions with or without chemicals, and engineering plants to produce pesticides. Examples include BT corn, cassava, rice, wine, beer, and soy milk. White biotechnology is used in industrial processes. It involves designing organisms to produce useful chemicals, such as using enzymes as industrial catalysts to create valuable chemicals or eliminate hazardous pollutants [21].

Role of Educational Awareness

The main goal of the education system is to prepare young people with the knowledge, problem-solving abilities, and values needed to navigate a world that relies heavily on technology [22]. Science education plays a crucial role in helping students gain a deeper understanding of their

surroundings. It's essential for students to develop scientific literacy so they can critically evaluate information, especially in scientific matters, and make informed decisions about their environment and health [23]. Educational efforts are necessary to help students and the public understand biotechnology issues, enabling them to distinguish biotechnology products from others and understand their effects on the body [22]. Creating awareness among students about biotechnology products and services is crucial for them to differentiate between genetically modified foods and those produced through traditional breeding methods. Some emphasize the importance of students being knowledgeable about the social, ethical, and economic implications of genetic engineering, cloning, genetically modified foods, and other aspects of biotechnology [24]. Given the impact of biotechnology on human health, agriculture, and the environment, it's vital for secondary school students to have a solid scientific foundation in genetics, cell biology, and an understanding of the associated risks and benefits, so they can make informed decisions [25]. This awareness will enable senior secondary school students to form well-informed opinions about the risks and benefits associated with biotechnology products and services.

Strategies for Implementing Biotechnology Education

Strategies are essential for effectively managing any endeavor. When it comes to creating educational awareness about biotechnology, several key strategies need to be considered. Firstly, biotechnology should be incorporated into the current biology curriculum for senior secondary schools, as this has not been done previously [26]. This curriculum should be carefully designed and evaluated to ensure its adequacy for teaching purposes. Both formal and non-formal school programs can be employed as part of these strategies. While the formal school program presents fewer challenges since students are already in secondary schools, the non-formal program, targeting secondary school dropouts, may face more hurdles [27]. It's advocated that the formal school program is the best strategy. Recruiting expert teachers in biotechnology is crucial, and they should be provided with proper incentives to ensure their dedication to teaching [28]. Mass media, including print and electronic platforms, should be utilized for educational purposes, with TV and radio programs, discussions, demonstrations, and documentaries on biotechnology made available to schools. Additionally, newspapers and magazines should feature articles on biotechnology. Excursions to biotechnology industries can provide practical exposure, while projects in biotechnology can be undertaken by students under the guidance of specialist teachers. Equipping secondary schools with well-equipped biotechnology laboratories is essential for facilitating hands-on experiments and better understanding of the subject.

Scope of the Study

The research covered higher secondary schools in North-East Local Government Area, Bangladesh. In terms of content, the study was on the role of educational awareness of biotechnology and its products and services among higher secondary school students and teachers.

III. METHODS

Research Questions

1. To what extent are the Higher Secondary School students (HS1 and HS2) and teachers in North-East Local Government Area of Bangladesh aware of biotechnology products and services?

2. To what extent are Higher Secondary School students (HS1 and HS2) and teachers aware of the usefulness of biotechnology products and services?

3. How does educational understanding of biotechnology products and services affect Higher Secondary School Students in Bangladesh's North-East Local Government Area?

4. What is the role of educational awareness of biotechnological products and services in respect to teachers in North-East Local Government Area?

5. What are the best available strategies for implementing biotechnology education in Higher Secondary School Students in North-East Local Government Area?

Hypotheses

H_1: There is no significant difference between the means responses of teachers and students on the role of educational awareness on biotechnology products and services.

H_2: There is no significant difference in the means responses of HS1 and HS2 students on the role of educational awareness on biotechnology products and services.

Data Collection

The study employed a descriptive survey design. A convenient sampling technique was utilized to select 9 out of twenty higher secondary schools in the North-East Local Government area. Stratified sampling procedures were then employed to select 20 HS1 and 20 HS2 science students, as well as 10 science teachers, from each of the 9 secondary schools sampled, resulting in a total sample size of 450, comprising 200 HS1 science students, 200 HS2 science students, and 50 science teachers. To gather data for addressing research questions 1 and 2, response categories included "Very High Extent," "High Extent," "Low Extent," and "Very Low Extent." Experts in Measurement and Evaluation at Bangladesh Agricultural

University and lecturers in the Faculty of Biomedical Sciences at Khulna Agricultural University reviewed and approved the questionnaire. The researchers distributed 400 copies to students and 50 to teachers. They were assisted by five trained research helpers. All 450 questionnaires were fully filled out and returned, achieving a 100% response rate.

Data Analysis

The mean and standard deviation were employed to address the five research questions, while a t-test of difference in means using SPSS statistical analysis software (version 26) was utilized to test the two null hypotheses. A mean value of 2.50 was designated as the midpoint for acceptance. The decision criterion for each hypothesis was the rejection of the null hypothesis (H_0) if the calculated T-value exceeded the tabulated T-value, and the acceptance of the null hypothesis (H_0) if the calculated T-value was less than the tabulated T-value.

IV. FINDINGS

Research Question 1: To what extent are the Higher Secondary School Students in North-East Local Government Area aware of biotechnology products and services?

Table 1: The extent of student's awareness of biotechnology products and services.

SN	Items	VHE	HE	LE	VLE	N	MR	SD	DEC
1	Genetic engineering products and services	11	27	286	126	450	1.90	0.88	Disagree
2	Agriculture produces and services	26	44	267	113	450	2.11	0.76	Disagree
3	Marine products and services	10	22	307	111	450	1.70	0.81	Disagree
4	Medical products and services	47	36	310	57	450	2.08	0.60	Disagree
5	Industrial products and services	40	50	294	66	450	2.20	0.72	Disagree
Grand mean rating							1.9		Disagree

*VHE = Very High Extent, HE= High Extent, LE= Low Extent, VLE= Very Low Extent, N= Total Response, MR= Mean Rating, DEC= Decision.

The data presented in Table 1 indicate that science students responded to 5 items to a very low extent, with mean scores of 1.90, 2.11, 1.70, 2.08, and 2.20 respectively. This suggests that higher secondary school students have limited awareness of biotechnology products and services. The overall grand mean score further confirms these findings.

Research question 2: To what extent are Higher Secondary School Student aware of the usefulness of biotechnology products and services?

Table 2: The extent which the higher secondary schools are aware of the usefulness of biotechnology products and services.

SN	Items	VHE	HE	LE	VLE	N	MR	SD	DEC
6	BT-cotton, corn, brinjal, rice, soybean, tomatoes, tobacco etc.	67	58	209	116	450	2.70	1.04	Agree
7	Vaccine (COVID-19, HPV, HBV, Influenza), therapeutic proteins (insulin, erythropoietin, monoclonal antibody), intravenous solutions.	47	55	287	61	450	2.60	0.93	Agree
8	Diagnostic kits, genetic testing kits, PCR kits, ELISA kits, scanning kits.	17	21	203	209	450	1.80	0.78	Disagree

9	Synthetic DNA, recombinant DNA, plasmid DNA.	27	38	318	67	450	1.70	0.66	Disagree
10	Enzymes, amino acids, vitamins, nucleoxide etc.	32	24	277	117	450	1.80	0.71	Disagree
11	Chemicals of all sorts-ethanol, butanol, organic acids, acetone, etc.	51	38	269	92	450	0.90	0.86	Disagree
12	Genetically modified sheep, chicken, goats, cows, pigs, mice, processed fish etc.	11	34	252	153	450	2.70	1.3	Agree
13	DDT, camphor, xylene etc.	8	13	356	73	450	1.90	1.3	Disagree
Grand mean rating							2.01		Disagree

*VHE = Very High Extent, HE= High Extent, LE= Low Extent, VLE= Very Low Extent, N= Total Response, MR= Mean Rating, DEC= Decision, HBV= Hepatitis B Vaccine, HPV= Human Papillomavirus Vaccine, PCR= Polymerase Chain Reaction, ELISA= Enzyme-linked Immunosorbent Assay.

The data presented in Table 2 indicate that items numbered 6, 7, and 12 received positive mean scores of 2.70, 2.60, and 2.70 respectively, indicating that students are aware of the usefulness of these items. However, items numbered 8, 9, 10, 11, and 13 received mean ratings of 1.80, 1.70, 1.80, 0.90, and 1.80 respectively, indicating that students have very limited awareness of the usefulness of these biotechnology products and services. The overall grand mean of 2.01 suggests that both students and science teachers have a low level of awareness regarding the usefulness of biotechnology products and services.

Research Question 3: What is the role of educational awareness of biotechnological products and services among Senior Secondary School Students and science teachers?

Table 3: The role of educational awareness of biotechnological products and services among Higher Secondary School students

SN	Items	VHE	HE	LE	VLE	N	MR	SD	DEC
14	Deepen understanding of biotechnology influence in the environment	120	170	72	38	400	3.00	0.83	Agreed
15	Acquire scientific literacy that will help students acquire knowledge of biotechnology products	96	115	109	80	400	2.90	0.65	Agreed
16	Help them to make informed scientific decision and choices of biotechnology products and services	130	170	72	28	400	2.90	0.74	Agreed
17	Become aware of biotechnology products and services and to differentiate them from others produced through other means	113	189	51	47	400	3.20	0.53	Agreed
18	Become knowledgeable about ethical, social, and economic implications of cloning and other biotechnology products and services	124	189	56	31	400	3.00	0.80	Agreed
19	Have knowledge and awareness of associated risks and benefits of these products and services	148	188	35	29	400	3.23	0.56	Agreed

Grand mean rating	3.04		Agreed

*VHE = Very High Extent, HE= High Extent, LE= Low Extent, VLE= Very Low Extent, N= Total Response, MR= Mean Rating, DEC= Decision.

The data presented in Table 3 indicate that all items received positive responses, with mean scores ranging from 2.90 to 3.23 and a grand mean score of 3.04. This suggests that respondents agree with all the items. Furthermore, it indicates that educational awareness would significantly contribute to assisting secondary school science students and their teachers in becoming aware of biotechnology products and services, as well as their associated risks and benefits.

Research Question 4: What is the role of educational awareness of biotechnological products and services in respect of science teachers' responses?

Table 4: The role of educational awareness of biotechnological products and services among Higher Secondary science teachers' response.

SN	Items	VHE	HE	LE	VLE	N	MR	SD	DEC
14	Deepen understanding of biotechnology influence in the environment	15	25	5	5	50	3.00	0.75	Agreed
15	Acquire scientific literacy that will help students acquire knowledge of biotechnology products	12	26	7	5	50	2.90	0.89	Agreed
16	Help them to make informed scientific decision and choices of biotechnology products and services	12	24	2	12	50	2.78	0.80	Agreed
17	Become aware of biotechnology products and services and to differentiate them from others produced through other means	20	18	3	9	50	3.03	0.62	Agreed
18	Become knowledgeable about ethical, social, and economic implications of cloning and other biotechnology products and services	20	25	0	5	50	3.02	0.78	Agreed
19	Have knowledge and awareness of associated risks and benefits of these products and services	18	22	7	3	50	2.90	0.87	Agreed
Grand mean rating							2.93		Agreed

*VHE = Very High Extent, HE= High Extent, LE= Low Extent, VLE= Very Low Extent, N= Total Response, MR= Mean Rating, DEC= Decision.

Similarly, the responses of teachers, as depicted in the above table for items 14–19, were positive regarding the role of educational awareness in assisting secondary school students in understanding biotechnology products and services, including their associated risks and benefits.

Research Question 5: What are the strategies for implementing biotechnology education in Higher Secondary School in North-East Local Government Area?

Table 5a: Strategies for implementing biotechnology education- student's response

SN	Items	VHE	HE	LE	VLE	N	MR	SD	DEC
20	Designing and development of biotechnology as a tool for teaching	80	220	67	33	400	2.80	0.68	Agreed

	biology and agriculture education in the senior secondary schools and incorporated into biology curriculum								
21	Non-formal education for out-of-school youths	55	264	71	10	400	3.02	0.73	Agreed
22	Well trained biotechnology teachers to be provided	100	223	32	45	400	3.00	0.86	Agreed
23	Well-articulated incentives to be given to the teachers and those detailed to teach the students on special arrangement	82	251	56	11	400	2.90	0.87	Agreed
24	Print and electronic media-television, radio, video tapes, teaching programmes – as well as written articles in newspapers and magazines made available to senior secondary schools	112	137	89	62	400	2.65	0.63	Agreed
25	Use of excursions and other programmes such as biotechnology workshops, seminars for both science students and teachers	134	143	77	46	400	2.91	0.56	Agreed
26	Taking on biotechnology projects when appropriate or necessary	121	152	88	39	400	2.87	0.80	Agreed
27	Availability of well-equipped biotechnology laboratories and centers for experiments	138	186	43	33	400	3.00	0.76	Agreed
Grand mean rating							2.89		Agreed

*VHE = Very High Extent, HE= High Extent, LE= Low Extent, VLE= Very Low Extent, N= Total Response, MR= Mean Rating, DEC= Decision.

Table 5a indicates that the data on strategies for implementing educational awareness of biotechnology products and services have mean scores ranging from 2.65 to 3.02, with a grand mean of 2.89. This positive response from students suggests that the strategies can be effectively applied at the appropriate time.

Table 5b: Strategies for implementing biotechnology education- teacher's response

SN	Items	VHE	HE	LE	VLE	N	MR	SD	DEC
20	Designing and development of biotechnology as a tool for teaching biology and agriculture education in the senior secondary schools and incorporated into biology curriculum	9	31	6	4	50	2.92	0.71	Agreed
21	Non-formal education for out-of-school youths	10	23	7	10	50	3.22	0.80	Agreed
22	Well trained biotechnology teachers to be provided	10	20	10	10	50	3.01	0.82	Agreed
23	Well-articulated incentives to be given to the teachers and those	7	27	10	6	50	2.86	0.78	Agreed

	detailed to teach the students on special arrangement								
24	Print and electronic media-television, radio, video tapes, teaching programmes – as well as written articles in newspapers and magazines made available to senior secondary schools	6	22	17	5	50	2.95	0.65	Agreed
25	Use of excursions and other programmes such as biotechnology workshops, seminars for both science students and teachers	11	24	10	5	50	2.90	0.77	Agreed
26	Taking on biotechnology projects when appropriate or necessary	7	22	13	8	50	3.07	0.80	Agreed
27	Availability of well-equipped biotechnology laboratories and centers for experiments	10	26	6	8	50	3.01	0.79	Agreed
Grand mean rating							3.00		Agreed

*VHE = Very High Extent, HE= High Extent, LE= Low Extent, VLE= Very Low Extent, N= Total Response, MR= Mean Rating, DEC= Decision.

In Table 5b, displaying data on the response of science teachers regarding the strategies for implementing educational awareness of biotechnology products and services, the items have mean scores ranging from 2.92 to 3.22, with a grand mean of 3.00. This indicates that teachers responded positively to the effectiveness of the suggested strategies.

H_1: There is no significant difference between the means responses of science teachers and science students (HS1 and HS2) on the role of educational awareness of biotechnology products and services.

Table 6: The difference in the mean responses of science teachers and science students in HS1 on the role of educational

Respondents	**SA**	**A**	**D**	**SD**	**Total**	**T-table**	**T-cal**	**Decision**
Science teachers	15	25	5	5	50	-2.30	0.58	Accept
Science students (HS1)	45	189	14	2	250			
Total	60	214	19	7	300			

*SA- Strongly agree, A- Agree, D- Disagree, SD- Strongly disagree, HS1- Higher secondary level 1

The result indicates that H1, which suggests that there is no significant difference between the responses of science teachers and HS1 science students regarding the role of educational awareness on biotechnology products and services in the North-East Local Government area, failed to be rejected, as the calculated T-value (0.56) is less than the tabulated T-value (2.31).

H_2: There is no significant difference in the means responses of science teachers and HS2 on the role of educational awareness on biotechnology products and services.

Table 7: The difference in the mean responses of science teachers and science students in HS2 on the role of educational awareness

Respondents	**SA**	**A**	**D**	**SD**	**Total**	**T-table**	**T-cal**	**Decision**
Science teachers	15	25	5	5	50	-2.31	0.56	Accept
Science students (HS1)	49	194	6	1	250			
Total	64	219	11	6	300			

*SA- Strongly agree, A- Agree, D- Disagree, SD- Strongly disagree, HS2- Higher secondary level 2

V. DISCUSSION

The study findings suggest that senior secondary school science students and teachers have limited awareness of biotechnology products and services. Including biotechnology elements in the senior secondary school biology curriculum could enhance student awareness of these products and services. However, it's noted that respondents are only partially aware of the usefulness of biotechnology products and services. For instance, white biotechnology involves industrial processes using organisms to produce beneficial chemicals [20]. Therefore, it's imperative to educate higher secondary school science students about these aspects of biotechnology. The results in tables 3 and 4, reflecting student and teacher responses, underscore the significant role of educational awareness in understanding biotechnology products and services. This aligns with the views of some researcher who emphasize the importance of the education system in equipping young people with knowledge and problem-solving skills to navigate a technological society and gain a deeper understanding of the world [22]. Moreover, as highlighted in tables 5a and 5b, both teachers and students responded positively to the strategies for implementing educational awareness of biotechnology products and services. This resonates with the recommendations of Chidobi and colleague for designing science curricula in secondary schools [23]. Additionally, the similarity between the responses of science teachers and students in tables 5a and 5b underscores the effectiveness of the strategies. Finally, the results in tables 6 and 7 indicate that there is no significant difference between the mean responses of science teachers and both HS1 and HS2 science students regarding the role of educational awareness on biotechnology products and services. This suggests a consensus among respondents regarding the importance of educational awareness in understanding biotechnology.

VI. CONCLUSION

The study reveals a significant gap in awareness and understanding of biotechnology products and services among Higher Secondary School science students and their teachers. The inclusion of biotechnology courses in the biology curriculum is essential to bridge this gap. Enhanced educational awareness will equip students with the necessary knowledge to differentiate between biotechnological and non-biotechnological products and services. Consequently, implementing comprehensive strategies for biotechnology education will foster a deeper understanding and appreciation of biotechnology among students and teachers alike.

VII. RECOMMENDATIONS

The findings of the study support the following recommendations:

1. Biotechnology-trained teachers are expected to teach in higher secondary schools.
2. Higher secondary schools will have fully functioning biotechnology laboratories and centers for educational purposes.
3. Considering biotechnology as a teaching tool for biology and agriculture, some aspects of biotechnology should be included in biology and agriculture science curricula.
4. Higher secondary schools should have access to appropriate biotechnology educational resources, including print and electronic media.
5. Science students can benefit from periodic excursions to biotechnology manufacturing plants.
6. The government should provide appropriate financial incentives to individuals who major in teaching biotechnology. There ought to be additional biotechnology training sessions and conferences for biotechnology educators.

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