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Challenges in Teaching Biotechnology in the Philippine STE Program

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Abstract. To develop the full potential and enhance the science skills, mathematical abilities, and English proficiency among Filipino learners, the Department of Education implemented a special program in science, technology, and engineering at the basic education level. The students are taught based on an enhanced science-technology-oriented curriculum to prepare them for college and science, technology, engineering, and mathematics-related careers. Since the focus of this program was on science, technology, mathematics, and research, the inclusion of biotechnology subjects is integral in supporting the learners to develop an interest and aptitude in these fields. This study looked into the challenges that schools and educators face in teaching biotechnology using the qualitative research design, specifically a phenomenological approach. Interviews were conducted to obtain data. A multi-step method was employed when interviewing the 11 public high school science teachers about the challenges they encountered in teaching biotechnology. They were interviewed based on how they teach the subject, their teaching approaches, the depth of their understanding of the subject, and their specific teaching challenges. Results identified five essential themes: (a) Expertise Mismatch, (b) Abstract Nature of the Subject, (c) Deficiency in Foundation Knowledge, (d) Lacking Teaching Strategies, and (e) Lack of Learning Resources. A multi-faceted approach can be adopted to approach these identified challenges proactively. This should encompass (a) improvement in teacher training, (b) curriculum overhauling, (c) provision of essential resources, and (d) implementation of innovative teaching methodologies.

Keywords: Biotechnology education; Philippines; science technology engineering program; science teachers; teaching challenges; qualitative

1. Introduction

The recent global health crisis has increased public cognizance of the critical function of science and technology in solving societal issues (Han, 2020). We are now in the primacy of biology in the twenty-first century, emphasizing new post-digital–bio-digital reconfigurations (Jandric & Hayes, 2023). Regarding the educational sector, the pandemic has produced the most significant switch to homeschooling and blended learning modalities in human history (Jandric et al., 2020; Greenhow & Lewin, 2021). It has had a significant effect on the ways learners learn, and teachers teach. These developments prompt new social practices, such as producing and disseminating knowledge needed to address these challenges (Peters et al., 2021).

Biotechnology as an Elective Course in the Special Science Program

Science education in the Philippines continuously develops and has undergone reforms (Macaranas & Robles, 2023) to remain relevant and fulfill the needs of the fourth industrial revolution (Camara, 2020). Cognizant of the country's educational and economic development, the Philippines' basic education curriculum has a specialized class program called the Science, Technology, and Engineering (STE) program to cultivate scientific, technological and engineering competencies among young learners (Department of Education [DepEd], 2019). This program is intended for the DepEd to produce ready-for-higher education or ready-for-workforce students through Special Curricular Programs (SCPs), infusing them with the right values and equipping them with 21st-century skills that would support nation-building while upholding Filipino culture and identity (Albert et al., 2020; Camara, 2020). The advanced science-technology curriculum is designed for students interested in science, technology, mathematics, and research. It follows DepEd Order No. 55, and has been revised in the K–12 Curriculum under DepEd Order No. 31 s. 2012, with more radical courses for the specialized science program.

The core subjects that are part of the Secondary Education Curriculum and the K to 12 Basic Education Curriculum have been enhanced by adding the disciplines identified for inclusion in the Revised Curriculum of the Engineering and Science Education Program of the science and technology-oriented high schools. Complex courses that were added include chemistry, electronics, biotechnology, research, advanced statistics, and consumer chemistry. These courses are anchored on the nuance that science education catalyzes the knowledge economy. Biotechnology is one of the most promising and innovative applications of science in the 21st century (Hodge, 2023), and it is reflected in the amount of investment various countries, including the Philippines, have allocated to training human resources equipped with relevant knowledge and values in biotechnology. While concepts, principles, and applications of biotechnology are covered in the instruction, actual exposure and field-based experiences are critical yet missing components of biotechnology education. Fernando et al. (2019) report evidence of outcome, claiming that those STEM senior high school graduates who took the test are only marginally ready for baccalaureate engineering programs.

Elsewhere, few studies have examined biotechnology literacy among students, such as in Malaysia (Bahri et al., 2014), where students have a typical level of knowledge, perception, and attitude toward this field. The same observation was made by Kurniati and Ahda (2019), who attributed students' inadequate understanding of the latest advancements in biotechnology to the fact that they seldom peruse research findings that have been published in journals and other reading materials. Acarli (2016) also revealed that nearly half of the aspiring educators in Turkey had accurate and relevant associations for biotechnology. However, many of them did not have adequate conceptual associations and had misconceptions regarding biotechnology.

According to the K-12 Science Curriculum Guide (DepEd, 2013), the educational program in the Philippines is designed to develop individuals who possess a thorough understanding of science. This understanding will enable them to make informed decisions and utilize scientific knowledge to address community issues effectively. In the Philippines, there is a dearth of systematic investigation focusing on the status of biotechnology education (Gutierez, 2015). Moreover, in the context of the STE Program, only the research instruction among secondary schools under this program was investigated (Ramirez & Formalejo et al., 2017), but none in biotechnology instruction. Science education is crucial to any country's development, and the Philippines is no exception. However, the country has consistently performed poorly in international science assessments such as the Program for International Student Assessment (PISA).

This study aimed to address this issue by investigating the challenges, gaps, and implications relevant to the teaching and learning of biotechnology in the Philippine STE Program. The research emphasized the importance of biotechnology as a promising and innovative application of science in the 21st century. It highlighted the need for a thorough understanding of this field to address societal issues effectively. The study particularly focused on the STE Program, which aimed to develop science, technology, and engineering competencies among young learners, preparing them for higher education or the workforce. By contributing to the development of strategies to optimize biotechnology education and address the issues confronted by teachers and students in this domain, this research can help enhance science education outcomes in the Philippines.

Research Objectives

This study sought to achieve the following:

1. To identify and analyze the issues confronted by teachers in teaching biotechnology within the Philippine STE Program and
2. To address the issues raised and enhance the standard of biotechnology education in the Philippines by making suggestions and possible solutions.

2. Methodologies

Research Design

The study employed a phenomenological approach with a qualitative research design. It details the real-world experiences of teachers teaching junior high school students in biotechnology subjects. Additionally, this research aims to explore and highlight the challenges teachers face in the educational context. This study used a qualitative design, and one of its methodologies is phenomenology, which investigates how various people interpret the meaning of a term or phenomenon based on their personal experiences. The main objective is to synthesize unique encounters with a phenomenon to portray its universal essence and provide a combined representation of the experience's essence (Cohen et al., 2000; Patton, 2015).

Research Locale and Participants

The study was administered at public schools in the provinces of Leyte and Cebu in the Philippines, with special science programs that included biotechnology subjects in the curriculum. Purposive sampling was used to select 11 full-time junior and senior high school science teachers with three years of experience teaching during the 2023–2024 academic year for the study. Owing to their various educational backgrounds, science teachers found it difficult to teach biotechnology subjects. As a result, the study's focus was limited to science teachers. They were chosen for their experience and the subject of the research. Participants who have previous experience with the phenomenon were chosen.

The research participants were obtained using the following selection criteria:

1. Having been a public school science teacher teaching biotechnology as a subject;
2. Having worked as a teacher for three years during the school year 2023–2024;
3. Having already had difficulties with the subject;
4. Being able to discuss significant and relevant concepts regarding the aforementioned difficulties in teaching biotechnology; and
5. Being ready to take part in the study.

Research Instruments

With an emphasis on their experiences and difficulties teaching biotechnology, the researchers created a series of interview questions for science teachers. The questions were specifically designed to uncover information about the tactics teachers employ, what they know about the subject, and how they teach biotechnology. The goal was to educate teachers with an in-depth understanding of all aspects of education by highlighting the specific challenges they face when teaching students in biotechnology. The questions were created to promote in-depth and transparent conversations, which will aid in collecting important data for a comprehensive examination of the difficulties science teachers face when teaching students in biotechnology. The crafted interview questions are as follows:

1. What challenges did you encounter when teaching biotechnology at your school?
2. What are your approaches in teaching complex biotechnological concepts to students with varying levels of prior knowledge?
3. Can you describe a specific experience where you encountered a significant challenge in teaching biotechnology?
4. How do you overcome the challenges you experience in teaching biotechnology?
5. Which of these issues, in your opinion, will have the most effect on the quality of science education in the Philippines as a whole?

Data Collection

When interviewing science teachers on their challenges with teaching biotechnology, a multi-step procedure was used to ensure the rigor and reliability of the data-gathering process. Initially, university experts in science education validated the researcher-crafted interview questions. These experts are assistant and associate professors at the university. Their feedback was used to improve the clarity and relevance of the questions. After conducting focus group talks with a diverse group of science educators, the interview technique was fine-tuned to reflect teachers' experiences across educational contexts. The completed interview instrument was then used as a guide in interviewing the participants via Zoom meeting, allowing for the generalization of challenges experienced in various educational settings. The interviews were conducted over the course of one week.

Data Analysis

The participants' responses to the interview questions were analyzed using Braun and Clarke's (2006) thematic analysis, which included six stages: being familiar with the collected data, obtaining preliminary codes, looking for themes, evaluating themes, defining and labeling themes, and creating the report. Transcription, repeated reading, and taking note of the basic concepts are all methods of becoming acquainted with the data. The process of creating initial codes involves gathering information for each code and methodically coding significant data points throughout the whole data set. Sorting codes into potential topics and gathering all pertinent information for each possible theme are the steps involved in searching for themes. In order to create a thematic map of the study, reviewing topics means figuring out whether the themes apply to the coded extracts (Level 1) and the entire data set (Level 2). To provide precise definitions and labels for each theme, it is necessary to do ongoing research to refine the specifics of each theme and the overall narrative the analysis presents. Finally, the last opportunity for analysis is during report production. After choosing compelling, vivid extract examples, analyzing a final subset of extracts, and making a relationship between the analysis and the research subject and literature, a scholarly analysis report is generated (Braun & Clarke, 2006). The researchers carefully identified and bracketed their prejudices and biases to avoid any potential influence on the interpretation of findings. This guaranteed that the investigation into science teachers' challenges in teaching biotechnology remained neutral and impartial, increasing the credibility of the study's findings.

Ethical Considerations

All of the participants provided the researcher with their informed consent before the study started. The purpose, methodology, potential risks and advantages, and guarantees of confidentiality and anonymity were all explained in detail to the participants. Additionally, participants were informed that they could withdraw from the study at any moment and without penalty. To assure ethical standards, the researcher obtained prior clearance from the applicable ethics committee for data collection, demonstrating adherence to recognized ethical criteria in human subjects research. The researcher remained polite and open with participants throughout the study, prioritizing their well-being and rights.

3. Results and Discussions

After thoroughly and rigorously examining the data, researchers delved into eight themes and findings extracted from the initial dataset. They honed in on a central concept, streamlining the information by eliminating redundancies. This meticulous process distilled the research into five essential themes, as shown in Table 1. These themes drawn out from the interview conducted with each participant are Expertise Mismatch, Abstract Nature of the Subject, Deficiency in Foundation Knowledge, Lacking Teaching Strategies, and Lack of Learning Resources.

Table 1. List of Themes, Sub-themes, and Number of Codes for the Challenges

Theme	Sub-themes	Frequencies
Expertise Mismatch	1. Mismatch of the subject taught in the field of specialization	10
	2. Lack of mastery of the content	8
Abstract Nature of the Subject	1. Lack of concretization of the subject	8
	2. Reductionist approach in teaching biotechnology	10
Deficiency in Foundation Knowledge	1. Lack of foundational knowledge and skills	9
	2. Teaching approach to cognitive load subjects	8
Lacking Teaching Strategies	1. Lack of training on effective strategies in teaching the content	9
	2. Lack of laboratory experiences on the application of biotechnology concepts	10
Lack of Learning Resources	1. Lack of physical resources/ facilities	9
	2. Lack of print or digital resources	8

Theme 1: Expertise Mismatch

Findings revealed that expertise mismatch is one of the challenges encountered among teachers in teaching biotechnology. One participant admitted, "*I'm trained in chemistry, not biotechnology, and while there may be some overlap, it's not the same. I often feel out of my depth.*"(I6). Particularly, sub-themes included a mismatch of the subject taught with the field of specialization and a lack of mastery of the content.

Mismatch of the Subject Taught in the Field of Specialization

Teacher competency is a multifaceted predictor of student performance across academic domains (Carlson et al., 2013). Mastering the subject matter, often linked to relevant academic specialization, is particularly critical to effective instruction (Reyes et al., 2014). Although the significance of teacher quality in educational outcomes is widely acknowledged (Elliot, 2015), there are still concerns about subject misassignment across different grade levels (Weldon, 2016). This situation where teachers are assigned to teach subjects in which they are not adequately trained, has yet to receive enough attention despite its potential consequences (Hobbs, 2012). Importantly, assigning teachers, who are highly qualified, to subjects outside their areas of expertise could make them functionally unqualified, which may negatively affect student achievement and undermine the educational process (Ingersoll et al., 2014).

Teachers in the Philippines are concerned about teaching subjects other than their field of expertise. When teaching biotechnology to high school students, teachers encounter tremendous challenges due to the mismatch between their expertise and the subject matter. In the interview, high school science teachers in the Philippines shared their experience teaching biotechnology despite not having a specialized background in the subject. "*It's definitely been a challenge,*"(I2) they admitted. "*I've spent countless hours trying to familiarize myself with the content, but there's only so much I can do without a strong foundation in biotechnology.*"(I5). Another teacher echoed similar sentiments, saying "*Teaching outside my specialization has been tough. I often find myself struggling to come up with engaging activities that can truly capture the essence of biotechnology. It's a constant battle between wanting to provide the best education for my students and feeling like I'm not fully equipped to do so.*"*(*I9*)*

Meanwhile, the introduction of senior high school in the current K-12 Program has faced significant obstacles due to a teacher shortage. Science instructors are challenged to teach subjects outside of their area of interest or experience. This difficulty also affects senior high school science teachers as there is a shortage of qualified teachers, particularly among new school teachers.

Nowadays, teachers often do not have the opportunity to teach in their specialized field, which results in a lack of mastery of the content. Rebucas (2022) conducted a study that showed that teachers who teach subjects outside their specialization face several challenges, including difficulty in familiarizing themselves with the subject matter and choosing appropriate teaching strategies. Similarly, Picardal and Picardal (2023) found that non-biology science instructors teaching biology struggled with inadequate foundational knowledge and misconceptions regarding fundamental concepts. Some teachers felt hampered by the mismatch between their expertise and the subjects they were assigned to teach. "*I believe in lifelong learning,*"(I7*)* one teacher remarked, "*but there's a difference between expanding your knowledge base and being thrust into unfamiliar territory without adequate support.*"(I7) Co et al. (2021) also found that teachers who teach outside their expertise struggle owing to their limited knowledge of the subject, which can affect their teaching and learning methods. According to Du Plessis (2020), out-of-field teaching approaches significantly impact the quality of teaching and learning in scientific classrooms. This phenomenon posed obstacles that may impede future STEM development and improvement efforts.

Teachers who teach outside of their specialty suffer significant hardships and difficulties that impair their ability to prepare and teach successfully. These difficulties are mostly caused by their lack of subject matter knowledge (SMK), which impacts their pedagogical content knowledge (PCK). As a result, these teachers may need assistance in developing new activities, as well as more originality. When they lack confidence, they rely on traditional teaching approaches. To ensure student learning, teachers must devote significant time and effort to understanding the subject matter and carefully organizing activities appropriate for their students' skills. The education system's teaching and learning process is at risk when teachers teach outside their expertise. If teachers need to be better aligned, it is recommended that they be assigned to appropriate assignments, ideally in their unique and specialized disciplines, and get support (Co et al., 2021).

Expertise mismatch significantly impacts the educational system, affecting students, coworkers, parents, governing bodies, and school administrators. It puts additional strain on school staffing management and lowers the quality of teaching and learning (Zhou, 2013). This tendency lowers instructional quality, thereby lowering students' academic achievement (Childs & McNicholl, 2007). The government, politicians, and administrators should be aware of this issue and give enough support, training, and funding to help teachers become competent and effective (Nixon et al., 2017). As a result, it is critical to understand teaching outside one's area of competence to deliver practical, competent instruction and excellent education.

Lack of Mastery of the Content

A teacher's knowledge of a subject can greatly affect how well their students learn. Charalambous et al. (2019) posited that teachers with a strong grasp of mathematical knowledge tend to have students who perform better in math in elementary school. "*I want to provide the best education possible,*" one teacher confessed, "*but it's challenging when I don't feel like I have a strong grasp on the material myself.*" (I8). Similarly, Blomeke et al. (2016) found that more experienced teachers taught students who scored higher on mathematics tests, while teachers with more experience reported higher instructional quality across all countries. Conversely, when teachers do not have a thorough grasp of the subject, they may need help to explain it to their students or provide appropriate feedback to avoid confusion and poor student outcomes. Another teacher shared his frustration, saying, "*I worry that my lack of mastery in the content hinders my ability to support my students effectively. When they ask questions that go beyond my understanding, I feel like I'm failing them.*"(I11). There are a few reasons why this happens. Sometimes, teacher training programs need to give teachers more knowledge in certain subjects, especially in fields such as STEM that are constantly changing (Darling-Hammond & Bransford, 2005). Schools may also have to assign teachers to subjects in which they are not experts owing to a lack of resources or staff (Ingersoll, 2012).

Theme 2: Abstract Nature of the Subject

Owing to the role of biotechnology in modern science education and its benefits in modern life, the issues around teaching it need to be addressed (Nordqvist & Aronsson, 2019). This observation can be attributed to the abstract nature of the subject, which requires concrete instructional materials such as laboratory tools and equipment to teach the subject effectively. The abstract nature of the subject emerged as a significant hurdle among teachers interviewed. "*Biotechnology is such a vast and abstract field,*" one teacher reflected. "*It's challenging to make it tangible for students, especially without access to the necessary laboratory equipment.*" (I2). Subthemes for this major theme included (a) lack of concretization of the subject and (b) a reductionist approach in teaching biotechnology.

Lack of concretization of the subject

Early theorists posited that children can learn abstract thought through interactions with concrete objects, a notion applicable to teaching challenging subjects such as biotechnology (Bahri et al., 2014; Nguyen & Siegel, 2015). Biotechnology, often perceived as abstract (Kidman, 2009), requires concretization for comprehension (Ndikumana et al., 2024). Practical work is integral to science education, providing students with the opportunity to interact with scientific phenomena (Hofstein, 2017; Isozaki, 2017; Mercado & Picardal, 2023; Putri et al., 2022; Selco, 2020; Snetinova et al., 2018) and transform abstract thoughts into concrete experiences (Kolb et al., 2001).

Gallagher and Savage (2020) found that teaching biotechnology faces challenges due to a lack of concrete activities involving concepts beyond immediate tactile and visual perceptions (Borgerding et al., 2012), leading to student misconceptions. This challenge emerged in the interview with a participant who said, "*Biotechnology is inherently abstract; without concrete examples and hands-on experiences, it's difficult for students to grasp the concepts.*" (I8) Hence, to grasp the subject fully, biotechnology involves the five senses (Teodiano, 2014). A teacher explained that "*Students need to interact with scientific phenomena, and it's through these tangible experiences that abstract concepts become more understandable.*" (I4) Thus, teachers' hands-on exposure to practical work in biotechnology, whether in physical or virtual settings, enhances effective teaching and positively influences their interest and attitude toward the subject (Orhan & Sahin, 2018).

In the study of Bonde et al. (2014), the prevalence of traditional teaching strategies such as memorization and lecture methods challenges the biotechnology industry as it relies on skilled and up-to-date professionals. Competent science professionals who are expected to address current and future challenges can only be developed by exposing them to concrete models of abstract concepts for them to observe, investigate, and evaluate the scientific phenomena (Mueller et al., 2015; Sypsas & Kalles, 2018). Teachers teaching biotechnology expressed concerns about the absence of laboratory work and deemed it as a hurdle to the effective teaching of biotechnology (Steele & Aubusson, 2004). Thus, to cultivate students' proficiency in learning biotechnology, the curriculum should prioritize hands-on activities to enhance their comprehension of abstract concepts through tangible experiences (Yasin et al., 2018). This is amplified by the statement of a participant, namely *"Hands-on activities are crucial for cultivating students' proficiency in biotechnology, and without them, I am doing a disservice to our students and the future of the industry.*" (I1)

Addressing the need for concretization in teaching biotechnology requires a shift towards prioritizing hands-on activities and tangible experiences in the curriculum. This approach enhances students' comprehension of abstract concepts and prepares them for the demands of the biotechnology industry.

Reductionist approach to teaching biotechnology

Biotechnology, a naturally complex and difficult subject, typically demands technical skills to facilitate effective teaching (Halverson et al., 2010; Mazzocchi, 2011). The challenging nature of biotechnology often results in teachers using a reductionist approach to teaching the subject. Reductionist methods in teaching strive to dissect complex systems into individual digestible components, often an attempt to make an abstract concept comprehensible (Hantula, 2018; Van Regenmortel, 2004). However, to simplify complex ideas to the level of student understanding, teachers and textbooks employ loose terms or statements that may result in relying on individual interpretations (Duda et al., 2021). This is supported by the statement of a participant mentioning that "*Biotechnology is inherently complex, but often, I am forced to simplify it to the point of losing its depth and authenticity.*" (I8*)* Furthermore, a teacher explained that "*This strategy is a balancing act to make the subject accessible to students, but in doing so, I risk oversimplifying it.*"(I10) This observation extends beyond educational institutions, as communicating reductionist biology rather than presenting accurate information is also prevalent among biologists and the media (Watts, 2019). Implementing a reductionist approach in teaching tends to result in oversimplification, where ideas that are too complex and abstract are excessively simplified, potentially departing from the authenticity of the subject matter (Saputri & Widyaningrum, 2016). Thus, teachers must emphasize the need for a balanced approach to teaching biotechnology that simplifies complex ideas without sacrificing depth and authenticity.

Theme 3: Deficiency in Foundation Knowledge

Many domains are involved in the study of biotechnology, and for the learners to fully grasp its scope, they must possess strong foundational knowledge and skills. Students who lack the necessary background knowledge about subjects usually perceived to carry a high cognitive load may find the biotechnology subject too complex and difficult to comprehend. This deficiency poses a significant challenge to both the teachers who are teaching biotechnology and those who are also teaching foundation subjects. Creating a more comprehensive biotechnology curriculum is the first step in addressing this challenge.

Foundational Knowledge and Skills in Science

As students progress in their learning journey, they learn different/various? science subjects according to the learning competencies appropriate to their grade level. The complexities of the concepts and skills increase as they move up grade levels. They learn the uniqueness of each discipline and acquire knowledge and skills that allow them to learn in a wider and deeper scope.

There is an observed decline in students' interest in learning science subjects such as physics (Potvin & Hasni, 2014). According to Erinosho (2013), the nature of the subject matter, the instructors and their role in the classroom, and the evaluation process account for most of the challenges. Students perceived the course as challenging because of its computational and cumulative nature. One of the participants stated, "*My students do not know the basic math operations. How can I teach them more advanced concepts in this case?*" (I11) In the study of Sarabi and Gafoor (2018), they found that students feel that physics, chemistry and biology are all equally difficult. There are more unfamiliar terms and they find difficulty in understanding challenging and abstract concepts. Moreover, mathematical skills are needed to conduct problem-solving assessments. The majority of the teacher participants agreed. A response from a teacher emphasized, "*The students do not know simple science vocabulary words, even the simple concepts like the parts of the cell and the basic processes in Biology*." (I6)

The demand for basic science subjects that require high cognitive skills is usually translated into poor student performance. The results of PISA 2018, a global assessment measuring students' ability to engage in science-related issues, exemplify this. Filipino learners' average scientific literacy scores ranked second last among the 78 countries tested, as seen in the data posted by the National Center for Education Statistics (Schleicher, 2019). Suppose the students have not fully grasped the essential concepts and have weak analytical and inquiry skills. In that case, this will create learning gaps that hinder their understanding of more advanced and integrated subjects such as biotechnology.

Teaching Approach to Cognitive Load Subjects

Teaching subjects that are prerequisites in learning biotechnology, which has a high cognitive load, should be approached at the level of course designing, student-friendly language in textbooks and classroom instruction, incorporating socially and culturally relevant sciences that can be related to each other, and encouraging relevant learning through reforms in assessment practices (Sarabi & Gafoor, 2018). Teaching an integrated subject such as biotechnology now requires more than just the strategies employed in the classroom. It also requires preparation, exposure to biotechnology-related issues, and up-to-date with socioscientific challenges. A key consideration in course design is student relevance, which helps students retain and grasp the material more easily. It has been shown by earlier studies, as cited by Tidemand and Nielsen (2016), that students who work with socioscientific problems can learn some of the sophisticated skills and competencies associated with scientific literacy. However, an increasing amount of research on the comprehension and application of socioscientific issues by science teachers has revealed a number of obstacles to these subjects' general acceptability. Participating teachers concurred that they require more confidence in their expertise. Responses included, "*I am not really sure if what I know is correct or updated*" (I2), "*I do not have any outlet or ways on how to update my knowledge with the recent developments in STEM*," (I8), and "*I need more guidance in developing lessons that are applicable to real-life so that it will be relevant to my students*." (I10)

Individuals are limited when it comes to genetic and biotechnology-related concerns. Research has been conducted on the methods used to teach these subjects in classrooms and laboratories. Hasni's study, for example, revealed that one study involving science teachers found that employing models and animations regarding the concept of DNA resulted in longer-lasting learning than simple lecturing (Orhan & Sahin, 2018). This study also showed that new teaching strategies, such as web-based interdisciplinary learning approaches, problem-solving, research inquiry, projects, and argumentation, positively impacted the participants' experiences in the laboratory. The participants' level of proficiency has increased as a result of the "Introduction to Biotechnology Laboratory" activity, which focuses on research inquiry. They are now able to formulate hypotheses, recognize variables, carry out experiments, modify data, and analyze findings. It has been shown that assignments generated with a comparable instructional technique improved students' conceptual knowledge and capacity to pose questions, solve issues, and draw conclusions. Therefore, a teacher's self-efficacy is crucial to improving biotechnology learning. Bandura's social-cognitive theory of behavioral change is the source of the concept of self-efficacy. According to Barni et al. (2019), this pertains to a teacher's confidence in handling duties, responsibilities, and challenges associated with their work as a professional. Owing to its consequences for instructional strategies, student academic achievement, and teaching efficacy, teachers' self-efficacy has increasingly established an increasing importance in school psychology research.

Mueller et al. (2015) looked into how biotechnology and genetics were perceived by teachers and learners in high school introductory science and agricultural science classes when using active versus passive learning units. After completing the unit, students in the passive learning classes and those participating in the active learning sessions for the Apple Genomics project showed a notable increase in their knowledge. Additionally, this study found that when applying their knowledge of genetics and biotechnology, students enrolled in the Apple Genomics project active learning classes outperformed those enrolled in passive learning programs.

Incorporating 21st-century skills into biotechnology education is also important since it can help students become more scientifically literate as they study the field (Yasin et al., 2018). Teachers require more support to implement this. Teaching biotechnology topics can be challenging; however, a successful learning outcome is achievable with the comprehensive curriculum translated into strong teacher support, intensified teaching expertise, and effective classroom strategies.

Theme 4: Lacking Teaching Strategies

The disparity in pedagogical techniques within the larger framework of the STE program is one of the complex issues which educators face when teaching biotechnology. This theme had two subthemes, based on the analysis of the participant responses: (a) lack of training on effective strategies in teaching biotechnology content and (b) lack of laboratory experience in applying biotechnology concepts.

Lack of Training on Effective Strategies in Teaching Biotechnology Content

Various factors must be considered to ensure the effectiveness of the teaching-learning process. In their study, Sy et al. (2022) emphasized that to perform the teaching-learning process effectively—especially when teaching science—students' motivation and interest must be directed toward making the lessons engaging and informative. Educators must be equipped with effective methods for students to learn science topics more effectively. According to the 2022 PISA, the Philippines ranked third from the bottom in science. The result showed no significant improvement from the 2018 PISA, where the Philippines ranked second from the bottom. The low performance in science puts a heavy toll on the country's public science teachers.

Palines and Ortega-Dela Cruz's (2021) study found that students' development of scientific literacy skills is influenced by their teachers, the learning environment, and the support of the school administration. Furthermore, their research pointed out the significance of localization, contextualization, and differentiated instruction since effective pedagogical practices promote high-quality learning (Biku et al., 2018). Also, effective instruction results in effective learning, and students may learn everything and anything, including how to think more deeply (Yen & Halili, 2015). Bidabadi et al. (2016) and Mariano-Dolesh et al. (2022) also illustrated that a successful teaching strategy encourages learners to learn and challenges their assumptions as they perceive themselves as problem solvers and agents of change. However, students' interest will only become evident if the teachers are well-trained in the various teaching strategies that would develop the teachers' competence in teaching the subject (Fauth et al., 2019). However, this is not the case. Most of the participants in this study confirmed that they hardly even have professional development that can support their teaching. Their common responses were, "*Our school does not have the resources to send us to training or seminars"(I*3), "*Our school has many priorities other than giving us professional development opportunities*" (I7), and "*Our administrator does not know any opportunities for us to be trained so we just do what we can do from our end*." (I9)

Teachers' development and progress depend on their training. Sy et al. (2022) suggest that teachers need to improve classroom management techniques, instructional tactics, and student interactions. The most recent educational developments, including constructivism; multiple intelligences; multicultural education; inquiry-based, brain-based, interactive, reflective, and integrative learning; and authentic assessment, are necessary to improve the teacher. In the educational set-up, teachers must undergo training through in-service training (INSET), seminars, and conferences to help them become more competent in their areas of expertise. A trained teacher has more skills and techniques to be applied to improve learners' academic achievements (Ulla, 2018). A study by Biku et al. (2018) found that teachers need proper pedagogical training to teach the subject, rather than relying only on personal teaching methods. This study also revealed a shortage of trained teachers, contributing to factors affecting the teaching-learning process. Furthermore, quality teaching is strongly associated with successful pedagogical strategies for delivering learning to students. Orhan and Sahin (2018) found that teaching biotechnology courses using innovative teaching methodologies improved laboratory experiences, technical abilities, and participants' knowledge and awareness.

Lack of Laboratory Experiences in the Application of Biotechnology Concepts

Mastery of science contents and concepts and an in-depth understanding of their application can be achieved through laboratory experiences. Teachers must ensure that laboratory experiences are part of the teaching-learning process since they are an integral part of science education and nurture students' curiosity. Laboratory work must be strongly interwoven with theory rather than taken separately or as an extra experience (Prabha, 2016). Chan et al. (2021) identified four fundamental skills that students could acquire during laboratory experiments: (a) skills linked to science education, (b) scientific skills, (c) practical skills, and (d) general skills. Several distinct strategies are used in laboratories to help students learn. Teachers' capacity to succeed in laboratory activities is mostly determined by their technical knowledge and performance in the laboratory. However, based on the participants' responses in the study of Orhan and Sahin (2018), it was found that teachers lack knowledge and practice. This could result in limited exposure of learners to laboratory activities, affecting their understanding. This claim is supported by the study of Khalil and Elkhider (2016), in which the researchers noted that some science teachers lack experience in using science teaching materials (laboratory materials) because they lack training in using them. Moreover, the low knowledge of some teachers results in their not using these facilities for fear they might damage the learning resources.

Theme 5: Lack of Learning Resources in Teaching Biotechnology
The lack of learning resources in teaching biotechnology is a significant challenge educators face. Teachers often feel underprepared and uncomfortable teaching biotechnology, leading to limited time spent on these topics (Mueller et al., 2015). This section discusses the lack of learning resources in teaching biotechnology in secondary schools, namely (a) lack of physical resources/facilities, and (b) lack of print or digital resources.

Lack of Physical Resources/Facilities
The science laboratory is essential to learning meaningful scientific concepts and acquiring scientific skills by implementing theories. Hands-on learning experiences help learners improve their problem-solving and critical-thinking abilities. The laboratory encourages students to be more creative while solving real-life problems.

In Philippine public schools, most high schools barely have functional laboratories and adequate laboratory equipment, hindering the teachers from having the learners perform science experiments (Hadji Abas & Marasigan, 2020). Some schools have the equipment but lack the standard laboratory room, therefore teachers would opt to bring apparatus and materials into the classroom to use (Duban et al., 2019). However, for schools with no equipment, teachers improvise and provide materials for the students to perform experiments or show experiments that illustrate the science concepts discussed (De Borja & Marasigan, 2020). This challenge emerged as many of the participants share similar perspectives; *"I would use education videos to supplement what could have been done in actual laboratories, but the experience is for sure different."*(I2) This dilemma in public schools results in poor scientific skills among learners and decreases their interest in science subjects.

Biotechnology education often relies on laboratory-based learning, which requires specialized equipment and resources (Orhan & Sahin, 2018). The availability and accessibility of these resources can significantly impact the quality of biotechnology education. The lack of learning resources in teaching biotechnology is a significant challenge that educators face. Teachers often feel underprepared and uncomfortable teaching biotechnology, leading to limited time spent on these topics (Mueller et al., 2015). Following Mangubat and Picardal's (2023) recommendations, funding for books, glassware, heating tools, fire extinguishers, and other chemistry teaching supplies should be given top priority to protect students during experiments. This recommendation is relevant to experiments involving biotechnology.

Lack of Print or Digital Resources

Learning resources play a pivotal role in aiding the process of teaching and learning. It serves as a tool to deliver content and enhance learners' engagement, visualization, and experiential learning. A study revealed that teachers who use learning materials stimulate learners' interest in actively engaging in activities, an essential part of the learning process (Kija & Msangya, 2019). Using various instructional materials, such as printed materials, digital resources, Internet facilities, and models, greatly helps learners visualize abstract scientific principles and concepts (Ordu, 2021). These many materials help to foster scientific skills, including problem solving, critical thinking, and investigation. Accessing, selecting, and effectively applying high-quality learning resources leads to superior learning outcomes.

However, one of the challenges public schools face in delivering quality science instruction is the insufficiency of these learning resources (Pacala & Cabrales, 2023). A study found that teachers had insufficient learning materials, an issue which educational institutions should investigate to improve learning (Magallanes et al., 2022). Moreover, available printed resources such as textbooks in schools need to be updated and cater to the population of learners in school. Information and communications technological (ICT) equipment that aids visual presentation and allows simulations, such as TV, computers, and tablets, are hardly available in every classroom. It was found that increased usage of e-learning materials and technologies, such as manipulatives and simulations, improves teaching efficiency and learner performance (Alenezi, 2020). According to the research conducted by Aguanta et al. (2024), the use of digital resources such as instructional videos in the teaching and learning process has received positive feedback. This is because the learning process predominantly depends on the experiences of the students. However, Internet access for learners is even more difficult as participants shared that *"There is a limitation on the supplementary or take-home activities that may be given to the students as some of their homes would have limited access to Wifi or mobile data."* (I7)

As a result, the lack of learning resources in the Philippines limits students' knowledge, effectiveness, and resourcefulness over time. It impacts learners' interest in science, resulting in a cycle of low achievement and disinterest in pursuing science-related careers and low performance of learners in international assessments.

4. Conclusion

Teaching biotechnology in secondary schools faces several obstacles that have considerable influences on education, teaching methods, and the learning process. These include the lack of teacher expertise, complex and abstract subject matter that is difficult for students to understand, students' needing more foundational knowledge, limited teaching strategies, and inadequate educational resources. A comprehensive and diverse approach to address these issues effectively is necessary. This strategy should involve improving teacher-training programs, revising educational curricula to make them more relevant and accessible, ensuring adequate resources are available, and integrating innovative teaching approaches. By implementing these measures, future generations of students from diverse disciplines can excel in their studies and contribute to advancing STEM knowledge which may lead to societal progress.

5. Recommendations

To ensure students' success in biotechnology in the Philippines, the approach should involve improving teacher expertise through targeted training, adapting the curriculum to incorporate hands-on activities and local applications, and providing adequate resources such as cutting-edge laboratory equipment and accessible digital tools. Innovative teaching methods, such as inquiry-based learning and multidisciplinary approaches, will give students the confidence and develop their critical thinking abilities they need to succeed in their area. Future research could overcome limitations by undertaking a larger-scale study with a more varied sample and investigating the influences of cultural and socioeconomic factors on student achievement.

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