19. Trial for Setting-up of Biotechnology Laboratory in SUCs in the Philippines for Kuroshio Science Research Network

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1. Collaborative Research under Kuroshio Science Network

After a Memorandum of Understanding (MOU) was signed between the University of the Philippines System, Bicol University in the Philippines, and Kochi University in Japanese FY2007 (November 24, 2005 and March 31, 2006, respectively), many joint research projects have been conducted, mainly in the natural and social sciences with a focus on fieldwork. Phylogenetic classification based on DNA sequence analysis is an important technique for providing basic information for such kind of research on biological resources; however, no researcher from the partner universities in the Philippines has published papers using this technique in “Kuroshio Science” journal and “Kuroshio Symposium.” When Satoshi Kubota (first author) visited the Bicol University Tabaco Campus (BUTC) for the first time in March 2017, Plutomeo M. Nieves (last author), a professor from College of Fisheries, was planning to submit an application titled "Upgrading of Research Facilities/Laboratories of the Bicol University Tabaco Campus PCARRD Building" to Department of Science and Technology - Philippine Council for Agriculture, Aquatic, and Natural Resources Research and Development (DOST-PCAARRD), and we discussed about the equipment and reagents required for biotechnological experiments. In August 2017, the application was accepted and funded by the DOST-PCAARRD. To strengthen research collaborations in the Kuroshio Science Network, we set up a biotechnology laboratory and conducted seminars for young faculty and students; we published the first paper on outcomes from these activities in April 2021[1]. In this chapter, we summarize the history and current status of biotechnological research, policy of conversion to Outcome-Based Education (OBE) for higher education in the Philippines, and current status of biotechnology-related seminars at the University of the Philippines Diliman. In addition, details of the setting up of the biotechnology laboratory and seminars for young faculty and students in BUTC are presented. Finally, we propose improvements for the stable implementation of biotechnological research in State Universities and Colleges (SUCs) in the Philippines.

2. History and Current Status of Biotechnological Research

Biotechnology, a life science research field, has a significant impact on the society because it is an important applied science. Even if we focus only on "Next-Generation Sequencing," which has made rapid progress in the 2000s, its market size was about 500 million USD in 2018 and is expected to reach 1 billion USD by 2024[2].

Mendel's law of heredity (Mendel, 1866) was rediscovered in 1900 in independent papers by three botanists: de Vries, Hugo, von Tschermak, E., and Correns, C. The search for the identity of hereditary material began in the early 20th century. Since the beginning of the 20th century, it had been speculated that the genetic material could likely be proteins or nucleic acids. However, it was not until Avery *et al*. showed in 1941 that inoculation of the DNA from a highly virulent strain of *Streptococcus pneumoniae* into mice caused transformation, which strongly suggested that the DNA was the genetic material[3]. Many biochemists, organic chemists, and physical chemists have been trying to understand the mechanisms underlying DNA replication and conversion of genetic information into proteins during inheritance and reproduction, but the details remain unclear.

Watson and Crick integrated many related discoveries by other researchers and found that DNA strands have a double-helical structure and that the pairing of bases in these strands is pre-determined (complementarity). They also suggested that this structural feature allows DNA to make an exact copy of itself and pass the genetic instructions to the next generation[4]. In addition, Crick advocated for the existence of "central dogma," a scheme for the flow of genetic information (DNA → RNA → Protein)[5]. In 1961, the first evidence of a triplet code was presented through experiments using T4 bacteriophages[6]. In the same year, Nirenberg and Matthaei showed that polyuridylic acid contains information for the synthesis of poly L-phenylalanine[7], and subsequently deciphered the entire genetic code, thus winning the 1968 Nobel Prize in Physiology or Medicine along with Holley and Khorana. On the other hand, for proteins, which are functional macromolecules, such as enzymes as biocatalysts, the amino acid sequence of insulin was deciphered for the first time in the early 1950s[8-11]. From the late 1960s to the 1970s, DNA ligase[12], which has DNA binding activity, and restriction enzymes[13,14], which cleave specific sequences of DNA strands, were discovered, and "recombinant DNA," a chimeric DNA constructed from DNAs obtained from different organisms, was successfully produced in vitro for the first time[15]. On the other hand, a specific strain of E. *coli* was found to take up DNA in the presence of $CaCl_2$[16]; using this phenomenon, a cyclic plasmid was successfully introduced into the bacterium and the drug resistance gene encoded in the plasmid was successfully expressed[17]. By combining these techniques, in 1974, plasmid DNA artificially inserted with eukaryotic (*Xenopus laevis*) ribosomal DNA was successfully transformed into *E. coli* (the first report of recombinant DNA)[18]. Subsequently, recombinant protein synthesis of mouse dihydrofolate reductase in 1978 and human growth hormone in 1979 was reported in *E. coli*[19,20]. Because this recombinant DNA technology could provide bacteria with abilities that they did not originally have, there were concerns about various dangers that could arise due to the advancement of biotechnology. In 1976, the National Institute of Health, USA, established guidelines that severely restricted development beyond what was necessary[21]. However, since 1978, the guidelines have been revised to be more appropriate from the viewpoint of scientific development[22], and recombinant DNA experiments can now be performed in ordinary laboratories. In 1979, the postgraduate training course, "Molecular Cloning of Eukaryotic Genes," was held at the Cold Spring Harbor Laboratory, and the technology was widely introduced to young scientists who would lead life sciences in the future. The

manuals used in this training course were revised and published as “Molecular Cloning: A Laboratory Manual” in 1982[23]. This series has become a best seller, selling more than 200,000 copies in all editions[24]. The topics in this manual, which is intended for the beginners, include “isolation of single colonies of bacteria,” “verification of strains through genetic markers,” and “recovery of purified bacteriophages from a cesium chloride gradient.” However, molecular cloning of eukaryotes, whose genome is hundreds of times larger than that of bacteria, is still not easy. The polymerase chain reaction (PCR) technique was developed to specifically amplify and analyze a portion of the DNA sequence of a large genome sequence[25], however, because the reaction employed Klenow fragment, enzymes had to be added after each cycle. The usage of Taq polymerase, a DNA polymerase produced by the thermophilic bacterium *Thermus aquaticus*, eliminated the need for the addition of enzymes during the reaction, thus opening the way for reaction simplification and automation[26]. Immediately after the publication of the PCR method, the cycle sequencing method, which is still used today, was established by combining it with the enzymatic DNA sequencing method described by Sangar *et al*. in 1977[27]. In addition, various application methods, such as the detection of mutations and length polymorphisms in DNA sequences[28] and quantification of mRNA[29], have also been published. A PubMed search using the two keywords "PCR" and "polymerase" yielded 264 hits in 1989, but the number of hits increased rapidly to over 7,200 in 1999. As a subsequent development of the technique, real-time PCR was reported in 1996[30] and digital PCR was reported in 1999[31], and the number of hits exceeded 15,000 in 2012. In the human whole-genome sequencing data published in 2001[32], the old Sanger method[27] was used. However, with the increasing demand for processing large amounts of DNA sequencing data, various parallel sequencing analysis methods with completely different principles have been developed[33,34], which has led to the development of “next-generation sequencing” as described above.

3. Introduction of Outcomes-Based Education (OBE) in Higher Education and Current Status of Biotechnology Education in the Philippines

In the Philippines, where traditional education (input-based and process-based education) has been the mainstream, “Policy-Standard to Enhance Quality Assurance (QA) in Philippine Higher Education thorough an Outcome based and Typology-based QA (Committee of Higher Education [CHED] Memorandum Order, No. 46, 2012)” was released in 2012 with the aim of improving the quality of higher education by shifting the educational system to “outcome-based education”[35]. The goal of this policy is to increase productivity through human resource development and enhance international competitiveness. Higher education institutions are required to provide educational services that meet the needs of academia and industry, as well as to develop high levels of academic skills, thinking, and behavior that meet international standards. In the field of biotechnology, it is essential to provide not only knowledge-based lecture-based education, but also practice-based experimental education. To achieve this, a systematic curriculum must be established, many instructors with sufficient abilities to conduct practical training must be trained, and the facilities and equipment in universities and colleges must be improved. In 2017, CHED presented the Policy, Standards, and Guidelines (PSG) in the Biology Department at the undergraduate level[36].

Based on CMO No. 46, series of 2012, the PSG specifies the “core competencies” expected of biology department graduates. Regardless of the type of university or college, it is necessary to develop a system that meets the minimum requirements set forth in this standard. Table 1 shows the components of the bachelor's

curriculum and number of credits. Of these, “Biology Tool Courses” and “Specialization Courses,” which are related to biotechnology education, are excerpted (Tables 2 and 3).

In biology tool courses, the requirement is to offer half or more of the lecture credits or laboratory courses (Table 2). In specialization courses, more than 30 courses in fields such as cellular and molecular biology, microbiology, systematic biology, biotechnology, and genetics are listed. It is expected that each university will establish its own bachelor’s degree.

The requirements for human resources, laboratories, and facilities are also presented in this PSG. As for human resources, unit heads are required to have a doctoral degree and department heads are required to have a master's degree. Each faculty member in charge of specialized subjects is also required to have a master's degree. In terms of laboratories and facilities, appropriate maintenance is required to achieve program outcomes; however, no specific conditions have been specified. In practice, it seems difficult for faculty members who have little experience in biotechnology experiments to provide adequate education in the Department of Biology, which consists only of master’s degree graduates. In addition, many of the reagents and tools required for biotechnological experiments are expensive; even a simple series of experiments, such as DNA extraction without genetic recombination, fragment amplification by PCR, and species estimation by restriction fragment polymorphism (RFLP), requires a budget of several hundred thousand pesos, which cannot be maintained easily if sufficient budget is not secured.

Table 4 shows a list of biotechnology-related seminars conducted at the University of the Philippines Diliman in 2018-2019. Since the University of the Philippines is a leader in the academic field in the Philippines, there is a need to update the information pertaining to advanced technologies and their applications, which can be obtained from a variety of sources. Many of these are expected to be useful for the education of faculty members in charge of state universities. Table 5 shows a list of laboratories in the Philippines that require extensive equipment for biotechnological research. Although researchers and collaborators in these institutes can conduct biotechnological research, they are unlikely to have the capacity

Table 1 Components of the BS Bio Curriculum and Their Corresponding Units

COMPONENTS	UNITS
a. General Education Curriculum	36
b. Biology Tool Courses	18
c. Fundamental Courses	50
d. Specialization Courses	25
e. Free Electives	6
f. Undergraduate Thesis	6
g. Practicum or On-The-Job Training or equivalence or apprenticeship	3
h. Physical Education (PE)	8
i. National Service Training Program (NSTP)	6
Total	158

Table 2 Biotechnology Related Courses in Biology Tool Courses (Selected)

Area	Course	Lecture	Laboratory	Units
Chemical Biology	Chemical Biology I (Organic Molecules)	2	1	3
	Chemical Biology II (Analytical Methods for Biology)	2	1	3
	Chemical Biology III (Biomolecules)	3	2	5
BioPhysics	Biophysics	2	2	4

to collaborate with faculty members in biology departments across the country; therefore, it is essential to invest heavily in state universities as regional hubs or to establish biotechnological research institutes with facilities that can be shared.

Table 3 Biotechnology Related Suggested Courses in Specialization Courses (Selected)

Field of specialization	Suggested courses
Cellular and Molecular Biology	Immunology Recombination DNA Techniques Radiation Biology Molecular Genetics Molecular Systematics Bioinformatics Genomics and Proteomics
Microbiology	Virology Microbial Taxonomy Microbial Physiology Microbial Ecology Microbial Genetics Industrial Microbiology Food Microbiology Pathology Epidemiology
Systematic Biology	Molecular Systematics Phylogenetics Population Genetics Bioinformatics Evolutionary Systematics
Biotechnology	Health Biotechnology Agricultural Biotechnology Industrial Biotechnology Food Biotechnology Molecular Genetics Bioprocessing Tissue Culture Bioinformatics Genomics and Proteomics
Genetics	Cytogenetics Molecular Genetics Human Genetics Microbial Genetics Population and Quantitative Genetics Developmental Genetics Biosocial Genetics

Table 4 list of biotechnology-related seminars conducted at the University of the Philippines in 2018-2019 (Selected)

Biotechnology
CRISPR-Cas and Genomics. Institute of Plant Breeding, UPLB (Jan 23, 2018)
Establishment and Management of BRCs/Biobanks: a case of KNRCC. Philippine Genome Center, UP Diliman (Jul 17, 2018)
Molecular and Phenotypic Characterization of Mechanically-Stimulated Transgenerational Arabidopsis. Institute of Biology, UP Diliman, and Philippine Genome Center (Sep 17, 2018)
Genomics on the road: From Agriculture to Health and Beyond. PCARI-SGCL, NUAL-PH, and Philippine Genome Center, UP Diliman (Dec 8, 2018)
CRISPR-CAS9: Principles, Applications, & Related Issues. Institute of Biological Sciences, UPLB (Mar 25, 2019)
Cracking the genomes of marine & non-model organisms: novel approaches for correcting, assembling, and scaffolding genomic data using Brujingraphs and Hi-C contact maps. Philippine Genome Center, UP Diliman (Apr 8, 2019)
Biosafety Seminar. Philippine Genome Center-Mindanao Satellite Facility, UP Mindanao (Jul 30, 2019)
NGS Data Management and Bioinformatics Challenges, Basic Concepts and Considerations in Omics Analysis. Philippine Genome Center-Visayas Satellite Facility (Aug 30, 2019)
Gene editing and Biotechnology trends. Institute of Biology, UP Diliman, and Rautaki Solutions (Sep 9, 2019)
1st National Genomics Conference. Philippine Genome Center, UP Diliman (Oct 10, 2019)
Mindanao Wide Genomics Seminar: Accelerating Omics Research. Philippine Genome Center-Mindanao Satellite Facility, UP Mindanao (Oct 29, 2019)
Structural Biology of Scaffolds: from phages to RNA. Institute of Biology, UP Diliman, and University of Manitoba (Nov 20, 2019)
Applying Emerging Trends: Developmental Biology in Health, Agriculture and Species Conservation. Philippine Society for Developmental Biology (Nov 29, 2019)
Bioscience
Novel proteins in the oxidative stress response. Institute of Biology, UP Diliman, and Vanderbilt University (Nov 26, 2018)
Development of a functional screen for bacterial gene clusters involved in the biosynthesis of fungicides. Philippine Genome Center, UP Diliman (Aug 3, 2019)
Newton Agham Seminar on Bioactive Natural Products. National Institute of Molecular Biology and Biotechnology, UPLB (Aug 20, 2019)

Enzyme Engineering: Directed Evolution and Rational Protein Design for the generation of efficient and highly selective biocatalysts.

Institute of Chemistry, UP Diliman (Sep 16, 2019)

PSCB's 10th Annual Meeting and Scientific Convention: Unboxing the Cell: Organelles and Sub-cellular Structures.

Philippine Society for Cell Biology (Oct 7, 2019)

Technology

Molecular delimitation of species using haplowebs and conspecificity matrices: Examples from amphipods, corals and plants.

Philippine Genome Center-Visayas Satellite Facility (Apr 10, 2019)

Assembling genomes into complete chromosomes using Bwise and chromosome conformation capture.

Philippine Genome Center-Visayas Satellite Facility (Apr 10, 2019)

Medical Science

Illuminating Chikungunya Virus proteins through Microscopy.

Institute of Molecular Biology and Biotechnology-National Institutes of Health, UP Manila (Jan 11, 2018)

Medical Records in the Genomic Era.

Philippine Genome Center, UP Diliman (May 29, 2018)

Integrating Microbial Genomics in Public Health and Environment, From Antibiotic Production to Antibiotic Resistance.

National Institute of Molecular Biology and Biotechnology, UPLB (Jul 31, 2018)

Lessons from the Eye and the Race to Finding a Cure for Alzheimer's Disease.

Philippine Genome Center, UP Diliman (Dec 5, 2018)

Molecular Genetic Approaches to the Studies of Freshwater Biodiversity and Dengue Eco-epidemiology.

Institute of Biology, UP Diliman, and Ehime University (Jan 18, 2019)

Cell signaling pathways during thyroid follicle development.

Institute of Biology, UP Diliman, and Mindanao State University-IIT (Apr 29, 2019)

Institute of Biology, UP Diliman, and Orentreich Foundation for the Advancement of Science (OFAS) (May 24, 2019)

Mesenchymal actomyosin contractility is required for androgen-driven urethral masculinization in mice.

Institute of Biology, UP Diliman, and Wakayama Medical University (Aug 13, 2019)

Pleiotropic Effects of Methionine Restriction.

Agriculture

Forum on Locally Developed Genetically-Modified Products.

Institute of Biology, UP Diliman (Apr 29, 2019)

Genomics and Proteomics of Onion Armyworm.

National Crop Protection Center, UPLB (Jun 4, 2019)

Application of CRISPR-Cpf1 System in Increasing Yield Components of Rice (var Samba Mashuki). Institute of Chemistry, UPLB (Oct 28, 2019)
The Genomics of Date Palms. Philippine Genome Center, UP Diliman (Nov 11, 2019)
"Oh, my Genes": Lessons from Plant Genetics and Genomics for Trait Development. Philippine Genome Center, UP Diliman (Nov 18, 2019)
Cytogenetics in Plant Breeding: Conservation and Evolution in the Post-Genomic era. Central Mindanao University, and Philippine Genome Center-Mindanao Satellite Facility, UP Mindanao (Dec 16, 2019)

Table 5 list of laboratories in the Philippines that have large equipment needed for biotechnological research (selected)

Philippine Genome Center: UP Diliman, UP Visayas (Satellite Facility), UP Mindanao (Satellite Facility) (pgc.up.edu.ph)
Institute of Biology UP Diliman (https://biology.science.upd.edu.ph/)
Marine Science Institute UP Diliman(http://www.msi.upd.edu.ph/)
National Institute of Molecular Biology and Biotechnology - UP Diliman (nimbb.science.upd.edu.ph)
Institute of Biological Sciences UPLB (cas.uplb.edu.ph)
National Institute of Molecular Biology and Biotechnology (BIOTECH) - UPLB (biotech.uplb.edu.ph)
National Institutes of Health - Institute of Molecular Biology and Biotechnology UP Manila (http://nih.upm.edu.ph/institute/institute-molecular-biology-and-biotechnology)
College of Fisheries and Ocean Sciences UP Visayas (upvcfos.wordpress.com)
Institute of Environmental and Marine Sciences Siliman University, Dumagete City, Negros Oriental (http://su.edu.ph/schools-colleges/institute-of-environmental-and-marine-sciences/)
National Science Research Institute UP Diliman (nsri.upd.edu.ph)

4. Setting-up of the Biotechnology Laboratory at BUTC and Suggestions for Operational Improvements

BUTC was established in 1949 as the Bicol School of Fisheries. In 1969, it was integrated into Bicol University and became an important college of fisheries representing the Bicol region. It now offers six courses: Bachelor of Secondary Education and Science in “Secondary Education,” “Entrepreneurship,” “Nursing,” “Social Work,” “Food Technology,” and “Fisheries”. When Satoshi Kubota (first author) visited BUTC for the first time in March 2017, Plutomeo M. Nieves (Last author) has just submitted an application titled “Upgrading of Research Facilities/Laboratories of the Bicol University Tabaco Campus PCARRD Building” to DOST-PCAARRD. It was to elucidate the species composition of glass eel by DNA barcoding

for the research project, "The Eel Fishery in Tributaries along the Lagonoy Gulf: Implication to Management and Conservation (Eel Project)" funded by the DOST-PCAARRD. We shared information on the requirements for the establishment of a biotechnology laboratory at the campus and agreed to set up a functional biotechnology laboratory not only for the development of research and education at BUTC but also for the enhancement of the Kuroshio Science Network. In addition, Satoshi Kubota presented "Analysis of Stony Coral with Advanced Life Science Technologies," where we discussed the methods used in biotechnology (e.g., PCR, Restriction Fragment Length Polymorphism (RFLP), and amino acid sequencing by LC-MS/MS) on March 7, 2017. After the application was officially accepted by DOST-PCAARRD, Satoshi Kubota presented the results of our research titled "New Approach for Scleractinian Coral Analysis (DNA sequencing and phylogenetic analysis)" at the "Research Proposal Write-Shop and RDE Management Forum" and "Multiple clades of zooxanthellae" at the "Bicol Region Aquatic Resource Management Forum (Metagenomic analysis)" held at BUTC and BU Legazpi East Campus on August 31 and October 25 and 26, 2017, respectively. In November 2017, we received a notification regarding the delivery of expected equipment and reagents for DNA analysis, and hence, we planned a Conference on Biotechnology Research [ConBio] (Organizer: Assistant Professor Alex P. Camaya, graduated from Kuroshio Science Program, Kochi University) on December 7 and 8, 2017. We organized lectures and hands-on seminars for young researchers and graduate students not only from Bicol University but also from other state universities. However, the renovation of the biotechnology laboratory in the BUTC-PCAARRD building was still in progress, and the equipment and reagents necessary for DNA extraction and subsequent PCR amplification, except for micropipettes, thermal cycler, and image analyzer (Photos 1 and 2), did not arrive as of the first week of December. Therefore, Satoshi Kubota made a video of the experimental procedures, including sample pulverization by liquid N_2, DNA extraction, and DNA amplification by PCR, before leaving Japan; the movie was shown and explained in the lecture "Virtual Demo: Molecular Phylogenetic Analysis for Marine" (Photo 3).

Photo 1 Biotechnology Laboratory in PCAARRD building of BUTC (Dec. 7, 2017)

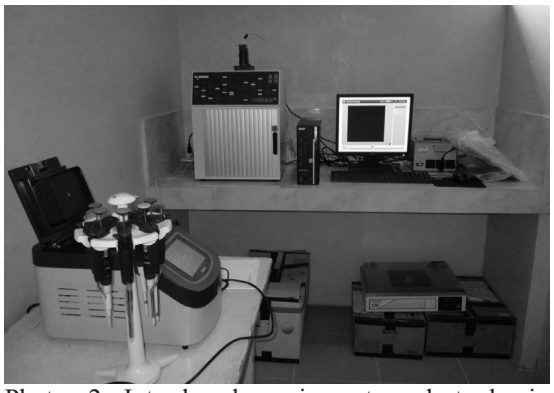

Photo 2 Introduced equipment and tools in PCAARRD building of BUTC (Dec. 7, 2017)

Photo 3 Virtual Technical Seminar in BUTC (Dec. 7, 2017)

To promote research projects using biotechnological experiments, it is necessary to develop human resources that can devote themselves to research. After Katrina Canon (5th author) applied for the MEXT Special Program in January 2018, we discussed the target organisms to be analyzed for her doctoral course research; we also discussed the research plan, including DNA extraction and PCR amplification, to be carried out in the BUTC biotechnology laboratory in February 2018. On August 30, 2018, Katrina Canon and Satoshi Kubota instructed about the research on DNA extraction, quantification, and computer analysis of DNA sequences to the research assistant of the Eel Project; however, they could not analyze their major samples because some equipment and kits had not been delivered even though it had been more than one year since the acceptance of the research project. Since the DNA extraction kit was delivered in December 2018, we were able to extract glass eel samples that needed to be analyzed in the Eel Project for the first time in this biotechnology laboratory on January 4, 2019. Subsequently, the research assistants prepared DNA extracts for DNA amplification by PCR from many glass eel samples. A hands-on seminar on PCR amplification was conducted at the BUTC biotechnology laboratory by Katrina Canon on September 4, 2019, however, the PCR amplification reaction stopped due to the failure of the new thermal cycler despite that was the first time it was used. It took more than a month to discover that the failure was caused by the program due to insufficient support from the supplier. Ultimately, it took more than half a year to introduce the updated program. Therefore, the DNA extraction was carried out at BUTC, and with the permission of the Bureau of Fisheries and Aquatic Resources, Department of Agriculture, the samples were sent to Kochi University for PCR amplification, RFLP analysis, and DNA sequence analysis[1]. As described here, it was not easy to carry out even the basic biotechnological experiments involving DNA extraction from biological samples and the amplification of DNA fragments by PCR. However, there are few facilities in the Bicol region where such experiments can be performed at present. Therefore, the sample preparation for the degree research of Teresa Avila (4th author), who is working on the dried fish “Abo” in the neighboring state of Camarines Sur, was also performed at BUTC[37]. Thus, it would be of great benefit to other campuses and universities if a biotechnology laboratory could be established in a local state university. Unfortunately, on November 1, 2020, Super Typhoon Goni hit the Bicol region and damaged many buildings in BUTC, leaving not only the biotechnology laboratory, but also many other facilities still unusable.

Through the ongoing trials pertaining to the setup of our biotechnology laboratory since 2017, some problems have become apparent. Three possible improvements are suggested below. The first is shortening the approval period. In our experience, there have been cases where research projects have been conducted and orders for equipment and reagents have been submitted, but orders to the supplier have been delayed. The reagents required for biotechnological experiments are expensive, and many have short expiration dates. While waiting for the reagents to be delivered, reagents that have already been purchased may become unusable rendering it as a waste of government resources. To avoid this, the existing procurement system must be improved to enable prompt approval, processing, purchase and delivery, at least for reagents that have been requested for the project use. The second suggestion is to improve the infrastructure of the university, BUTC in particular. The frequent arrival of large typhoons and unstable energy supplies have caused frequent power outages on the campus, as such, its mandated functions and delivery of services greatly disrupted to the detriment of its target clients it serves. This kind of investment may be huge but the benefits are of paramount importance to the vision, mission and goals of the University. Therefore, it is essential that the government should invest heavily in State Colleges and Universities (SUCs) in Bicol to create a more responsive, relevant and innovative R&D in the region. The third suggestion pertains to systematizing the human resource

development. It is sufficient to attend short-term courses or technical seminars offered by universities in Metro Manila, such as UP, UST, DSLU to learn specific experimental techniques. However, to support the smooth progress of biotechnological research at the university, it is necessary to acquire the ability to create a comprehensive staff development plan and biotech roadmap in the region. It may be difficult for a single university to implement these three suggestions. We hope that the national and local government support and assistance for higher education, research, and development will be given utmost attention and priority.

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