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A publication of the Philippine Physics Society committed to the advancement of physics and physics education in the Philippines.

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THE PHILIPPINE PHYSICS SOCIETY: A STORY OF HALF A CENTURY OF DREAMS, GROWTH, COMMUNITY, AND SERVICE

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Maxino College, Bagacay, Dumaguete City

I. NATURE AND COMPOSITION

The Philippine Physics Society (PPS) is an organization of physicists, physics professionals, physics teachers, physics students and physics enthusiasts. It is a national organization originally based in the southern part of the Philippines and focused to the south. Thus, its activities have been initially concentrated in the Visayas and Mindanao.

During the International Conference on Physics Education for Development held in Manila on December 1-5, 1992, about 150 conference participants coming from Luzon sought membership in PPS. They were consequently admitted to the society.

After a decade of having initial activities in Northern Luzon (Physics regional seminars in Vigan City in 1990 and Bangued, Abra in 1999), the PPS, in 2002, has extended its service to underserved areas in Luzon, as well. The main concern of the PPS is the improvement of its members in their respective fields of research and teaching and the advancement of Physics and Physics Education. Thus, PPS hopes that the members, having learned more, can serve better.

II. BRIEF HISTORY

The Philippine Physics Society (PPS) was born in Cebu City in 1974 from an awareness of a need for an organization of physics people as a vehicle for pooled resources, efforts and concerns by a group of less than 10 young physics graduates from the University of San Carlos. It had its initial meetings at the National Science Development Board (NSDB) Regional Office. It was subsequently admitted as a member of the Science and Technology Forum, an association of scientific and technological organizations in Cebu and Region VII. Professor Gerardo Maxino, its founder, was designated as the Chairman of the Society. In its formative stage, PPS enjoyed the strong support of the NSDB Region VII Director, Mrs. Amalia V. Rodriguez.

Later on, in 1979, the word "Southern" in parentheses was attached to its name to underline the focus of its interest. In 1987, the members voted to remove "(Southern)" and return the original name: Philippine Physics Society.

Although the founding members originally intended the PPS to be exclusively for physics professionals, it was decided during the First Convention in 1979 to open the membership to all those interested in physics. The PPS was admitted as member of the Philippine Science and Mathematics Council in the 1980s.

The PPS intended originally to focus its attention to the Visayas and Mindanao, which it considered as underserved areas. This explains why its activities were mainly in these two geographical divisions during its first 25 years of existence. At the closing years of the Millenium, however, incontrovertible evidence convinced the PPS that there were many areas in Luzon, even sectors in Metro Manila, that were underserved too. Thus, PPS has taken since the Year 2000 the entire Philippines as its area of service. For the Philippine Physics Society is an embodiment of the ideal of service to physics and peoples. The Luzon Conference was started in 2002. This conference is held only if the venue of the subsequent annual national convention is in Mindanao or the Visayas. The Luzon Conference hosts have been Adamson University (Manila, 2002), Mapua Institute of Technology (Manila, 2003), Technological University of the Philippines (Manila, 2005) and Colegio de San Juan de Letran - Calamba (Calamba City, Laguna, 2007).

III. MEMBERSHIP

The members of PPS are grouped into:

A - College physics teachers
B - Graduates of professional physics degrees like BS (Physics), BS Physics, MS Physics, PhD Physics
C - High School physics teachers
D - Physics enthusiasts
E - Physics students
F - Research and development practitioners in industry

These groupings are mainly due to interests and members may belong to several groupings if they qualify for them. All the members, regardless of their groups, have the same rights and privileges in the Society. Certain qualifications, however, are required for election to some offices in the Society. For instance, members of the Governing Board should preferably be graduates of professional degrees in Physics.

To become a member of PPS, a person simply applies for membership through any member or officer of the Society. Also, for this purpose, an interested person may contact the PPS President through the society's official email address. The second PPS convention in 1980 decided to collect yearly membership fees starting 1980.

PPS is also organized by areas. This is a grouping on the basis of geographical proximity and accessibility of transportation. The aim here is to keep the members in close contact with each other. The first area to be formally organized was the Negros - Siquijor area. Some of the chapters that have been formed are: (1) Bacolod, (2) Bukidnon, (3) Butuan, (4) Cebu, (5) Iloilo province, (6) Iloilo City, (7) Negros Oriental, (8) Southern Negros, (9) Tacloban, (10) Tagbilaran, (11) Cagayan de Oro-Camiguin, (12) Iligan City, (13) Agusan del Norte, (14) Surigao del Norte, (15) Northern Samar, (16) Samar, (17) Siquijor, (18) Region I, (19) Region II, (20) Region III, (21) Region IV, (22) Bicol, (23) NCR, (24) Aklan, (25) Boracay, and (26) South Central Mindanao (2011).

IV. GOVERNING BODY

PPS is governed by a National Board and a National Assembly. All members who have previously attended at least one PPS National Convention are entitled to attend the National Assembly. The National Assembly is held at the start of the annual PPS convention. It is the National Assembly that elects the members of the National Board from among themselves and decides on the major policies that govern the society. The 1991 National Assembly decided that Prof. Dr. Gerardo Maxino, Prof. Dr. Vicenta Maxino and Prof. Dr. Fr. Herman van Engelen, SVD, shall be permanent members of the National Board to provide continuity and that seven members from the National Assembly shall be elected to the Board to serve a one-year term. Subsequently, the National Assembly allowed expansion of membership to accommodate representatives from the different regions.

The members of the National Board should have the widest geographical distribution possible and should preferably be physics degree holders. Initially the members of the National Board elected from among themselves a President, Secretary-Treasurer, and Auditor. They continue to serve in office until replaced by majority vote of the National Board and such action ratified by the National Assembly of the subsequent National Convention. This arrangement provides continuity and reliability.

From 1974 to 1979, Professor Gerardo Maxino served as Chairman of PPS. Fr. Francisco Glover, PhD, SJ, was the Chairman of (S) PPS from 1979-1980. The present PPS President is Prof. Gerardo Maxino, the Secretary-Treasurer is Prof. Vicenta Maxino and the Auditor is Ms. Judith Dianson.

The different PPS chapters elect their own sets of officers. The members of the National Board are disqualified from holding positions at the chapter or group level.

The Philippine Physics Society follows a flat structure and avoids as much as possible unnecessary layering. Thus, a chapter should encompass not more than a province. In some cases, a region may organize into a chapter; however, as soon as conditions allow, the regional chapter should break up into provincial/city chapters. Neighboring towns/cities may also form a chapter. This structure is more responsive to local needs.

The PPS adheres to and encourages the practice of servant-leadership among its officers and members.

PPS observes and honors the traditions of the society while it continues to evolve the best possible structures and processes as it moves along in time. Only the National Assembly on a majority vote may decide to change the observed traditions of the society.

V. ACTIVITIES

PPS holds yearly its national convention. The first one was held in Dumaguete City on March 31 to April 1, 1979. It was attended by 96 participants including almost all the PhD Physics degree holders in the country. The themes and hosts of the national conventions are:

YEAR	THEME	HOST (S)
1979	Physics Research and Teaching in the Context of National Development	Silliman University Foundation University *Dumaguete City*
1980	Redirecting Physics for the Filipino	University of San Carlos *Cebu City*
1981	Physics in the Classroom and Industry	MSU-Iligan Institute of Technology *Iligan City*
1982	Physics and Energy	Silliman University Foundation University *Dumaguete City*
1983	Physics and Rural Development	Xavier University *Cagayan de Oro City*
1984	Physics and the Environment	University of Negros Occidental-Recoletos *Bacolod City*
1985	Communicating Physics	St. Paul University – Dumaguete *Dumaguete City*
1986	Physics and Social Responsibility	Central Philippines University *Iloilo City*
1987	Physics and Total Human Development	Fr Saturnino Urios University *Butuan City*
1988	Physics in the Classroom and Community	Divine Word University *Tacloban City*
1989	Physics, Ecology and the Development of Community	Central Mindanao University *Musuan, Bukidnon*
1990	Physics and Agricultural Technology	Visayas State University *Baybay, Leyte*
1991	Physics and Information Technology	University of San Carlos *Cebu City*
1992	Physics and Education	Holy Name University *Tagbilaran City*
1993	Physics Literacy for People Empowerment	University of Negros Occidental-Recoletos *Bacolod City*
1994	Physics, Ecology and Sustainable Development	University of Eastern Philippines *Catarman, Samar*
1995	Physics in the Philippines in the Year 2000	Central Philippine University *Iloilo City*
1996	NIChood through Quality Physics Education	Ateneo de Davao University *Davao City*
1997	Quality Physics Education through Networking	Silliman University *Dumaguete City*
1998	20 Years of Shared Service	University of San Carlos *Cebu City*

1999	PPS Silver Jubilee Revisiting our Roots	Liceo de Cagayan University *Cagayan de Oro City*
2000	Physics Para sa Mahirap	Fr Saturnino Urios University *Butuan City*
2001	Physics and Culture	Holy Name University *Tagbilaran City*
2002	Becoming a Physics Community of Competence and Service	Silliman University *Dumaguete City*
2003	A Silver Jubilee Celebration of Community and Mission	Samar State University *Catbalogan, Samar*
2004	PPS Pearl Anniversary: A Tribute to Fr. Francisco "Kiko" Glover, SJ	Ateneo de Davao University *Davao City*
2005	Physics, Appropriate Technology and the Development of Peoples	University of Baguio *Baguio City*
2006	Physics, Tourism and Ecology	Aklan State University *Banga, Aklan (with Boracay as 2nd venue)*
2007	Physics and Indigenous Technology	Fr. Saturnino Urios University (lead host) *Butuan City*
2008	Physics and Magic, Mystics and Wizardry	Siquijor State College *Larena, Siquijor*
2009	Physics and Natural Disasters	Central Bicol State University of Agriculture *Pili, Camarines Sur*
2010	Physics and Climate Change	Xavier University *Cagayan de Oro City*
2011	Physics and Environmental Well-Being	Silliman University *Dumaguete City*
2012	Physics, Nationalism, and Development	Colegio de San Juan de Letran-Calamba *Calamba City, Laguna*
2013	Physics and Caring for the Earth in the Specter of Climate Change	Ateneo de Davao University *Davao City*
2014	PPS@40: Physics and Servant Leadership	Maxino College *Bagacay, Dumaguete City*
2015	Physics, Light, Culture, and Life	University of Northern Philippines *Vigan City, Ilocos Sur*
2016	Physics and Indigenous Culture and Develoment	Central Mindanao University *Musuan, Bukidnon*
2017	Physics, Urbanization and Inclusive Growth	University of San Carlos *Talamban, Cebu City*
2018	Physics and the Development of Indigenous Communities	Ateneo de Davao University *Davao City*
2019	PPS@45: Physics and Social Transformation	Maxino College *Bagacay, Dumaguete City*

2020	Physics and Livable Future *(Covid 19 Pandemic)*	(Central Philippine University) *Jaro, Iloilo City*
2024	PPS@50: Facing Global Challenges with Physics and Sustaining Services for God, Country, Community, and Persons	Siquijor State College *Larena, Siquijor*

During the annual convention, papers on physics research and teaching are presented by the members of the Society and by invited scientists and educators. Short courses which treat a particular topic in physics in depth, along with shorter lectures and workshops on a variety of topics, are also conducted during the convention to meet the needs of the members. The PPS National Convention incorporates the National Physics Olympics and the National Physics Fair. During the group meetings, the members discuss their concerns, elect their officers and share their expertise on particular topics in physics. Merit awards are given for exemplary commitment to physics education through active participation in the PPS annual conventions, according to the following category:

ORDER OF GALILEO - at least 5 PPS annual conventions
ORDER OF NEWTON - at least 10 PPS annual conventions
ORDER OF MAXWELL - at least 15 PPS annual conventions
ORDER OF EINSTEIN - at least 20 PPS annual conventions

The members of the National Board are also elected during this time and recognition is given to deserving physicists. The *Golden Service Award* is the highest honor and distinction given by the PPS. It is conferred on one who has spent a lifetime of commitment and passion for service and community towards the development of physics and physics education in the country, as an offering to the Filipino people. Those who have made significant contributions in Physics are conferred the Outstanding Achievement Award. Those who have served the society and the struggle to improve physics and physics education in the Philippines for many years through lectures, workshops, and other worthy activities are given the Outstanding Service Award. Those who for years painstakingly labor in physics education – caring for, nurturing, and mentoring the youth – even at times, or always in the case of some, bring their students to attend the PPS conventions are given the National Physics Educator Award. Administrators who faithfully support and allow their teachers and students to attend the activities of the society are conferred the Outstanding Administrative Service Award. Through the years, the PPS awardees have been:

Golden Service Awardees:

2004 Fr. Francisco "Kiko" Glover, PhD, SJ
2006 Fr. Herman van Engelen, PhD, SVD
2011 Mr. Narciso F. Mefragata
2013 Fr. Daniel J. McNamara, PhD, SJ
2015 Br. Joseph Scheiter, PhD, FSC
2022 Hope Maxino Bandal, PhD
Vicenta Cabahug Maxino, PhD
Teresita Dinal Taganahan, PhD

Outstanding Achievement Awardees:

1980 Casimiro del Rosario, PhD
1981 Fr. Francisco Glover, PhD, SJ
1982 Zoilo M. Bartolome, PhD
1983 Posthumous awards to:
Fr. Philip van Engelen, SVD
Fr. Hubert Lorbach
Fr. Franz Oster, SVD
Fr. Michael Richartz, PhD, SVD
1984 Venancio Alcantara, Jr., PhD
1985 Jack John Brennan, PhD
1986 Robert Wild, PhD
1988 Fr. Herman van Engelen, PhD, SVD
1989 Manuel Eugenio, PhD
2024 Vangeline Kinilitan Parami, PhD

Outstanding Service Awardees:

1989 Gerardo C. Maxino, PhD
Vicenta C. Maxino, PhD
1993 John D. Brule, PhD
1995 Aida D. Eugenio
1998 Nila Sabal
Judith Dianson
2000 Dr. Pelagia Joven
2001 John L. Holdsworth, PhD
Ed van den Berg, PhD
Christopher Bernido, PhD
Victoria Bernido, PhD
Remedios Cardino
Josefina Clarete
2002 Leopoldo Millamena
Ms. Teresita Taganahan
2003 Dr. Remigio G. Tee
Narciso F. Mefragata
2005 Dr. Perla Funa
Dr. Raymund Vizcarra
2007 Dr. Hope M. Bandal
Dr. Loreto B. Feril, Jr.
Dr. Asonita Parmisana
2010 Dr. Gil Nonato C. Santos
2014 Dr. Angela Kho Payongayong

National Physics Educator Awardees:

2005 Jose Caberte
Jose Luna
Vicente Simplicio Villegas
2006 Lottie Dingding
Esperanza Caballero
2007 Myrna Genandoy
Romulo Sopeña
Dr. Roel Taroc
2008 Dr. Veneranda Rizon
2009 Rene B. Cabrera
Susana C. Cahig
2010 Jaime H. Rillorta
Marlyn G. Jover
Dr. Mario P. Obrero
2011 Grethel A. Mende
Felix L. Nistal
Roberto A. U. Dangkulos
2012 Shirley T. Palisoc, PhD
Severino C. Cupida
2014 Michelle T. Natividad, PhD
2016 Elmer E. Galang
Nestor Sienes
2018 Emil C. Alcantara
Theresa O. Corcoro
2019 Aris Larroder
Mariquit M. Obrero
Cherile O. Yap
2020 Michael Nalitan
Josefina Sinaon
Jose M. Barlis Jr.
2021 Andy Nestor Ryan Pazon
Ryan G. Tubog
2024 Brando A. Piñero

Outstanding Administrative Service Award:

2007 Dr. Saturnina Chenfoo
Dr. Dominador. Cabanganan
Supt. Ponciano Joven

PPS publishes the *Philippine Physics Journal* [formerly *The (S)PPS Proceedings*], for articles on physics research and teaching. From the manually typed paper-bound mimeographed sheets of manuscripts in 1979, the *Philippine Physics Journal* is now a better-looking journal, electronically processed, and stitch-bound with a printed cover. In her study in 2000 in Central Visayas, Dr. Asonita J. Parmisana found that in the period 1989 to 1999, of the physics articles published in the national level, 60 percent were in the *Philippine Physics Journal.* This is indicative of the important role of the *PPJ* in physics education in the country. The PPJ, by tradition, is published by the labor of love of its faithful staff. Starting with the 2008 issue, the *Philippine Physics Journal* has been processed at Maxino College, Dumaguete City with the assistance of its BS Physics students and those of its other physics-related courses.

PPS also publishes the *PPS Newsletter*, as need arises, to keep contact with its members. Originally a printed newsheet, it has been electronically incorporated in the PPS official website. Since January 2006 PPS has maintained a website (http://philippinephysicssociety.com or http://philippinephysicssociety.org) where news and information can be shared readily with all members who have access to the internet. There is also a Facebook account: Philippine Physics Society.

PPS also holds Physics Summer Institutes for upgrading physics education. The first Physics Summer Institute was conducted free of charge in cooperation with Foundation University which granted the bureau credits for the given courses during the summer of 1980. The teachers taught without compensation.

In Summer 1981, STEP in Physics (Southern Teachers Enrichment Program in Physics) replaced the Physics Summer Institute. STEP in Physics was funded by FAPE (Fund for Assistance to Private Education) and offered scholarships for a Bachelor of Science in Physics degree or a Master of Science in Physics degree at the University of San Carlos for three consecutive summers to qualified physics teachers. More than 50 physics teachers enrolled in the BS Physics program and more than ten took the MS Physics program. None of the teachers, however, decided to finish the BS Physics degree, it being a second degree for them at the baccalaureate level. Many of those who participated in the program, both at the undergraduate and graduate levels, eventually finished masteral and doctoral degrees.

In Summer 1986, PPS, as a member of the Philippine Science and Math Council, was one of the organizations that conducted the FAPE-sponsored Physics Summer Science Institute at the University of San Carlos.

In October 1986 to March 1988, PPS cooperated with Silliman University in conducting the Certification Program for Physics Teachers in Secondary Schools sponsored by the Science Education Institute of the Department of Science and Technology.

In Summer 2003, a cooperative program among Siquijor State College, the Philippine Physics Society, the Silliman University Center of Development in Physics and Ateneo de Davao University Physics Department was initiated. The program offered a three-summer course leading to Master of Arts in Science Teaching (Physics) which required thesis. About 20 Physics teachers participated in the program. In June 2005, a special graduation ceremony held at Siquijor State College granted the degree Master of Arts in Science Teaching (Physics) to ten of the participants and the degree Master in Teaching (Physics) to three of the participants. A second run of the program, this time with the inclusion of the Master of Science in Science Education (Physics) was held in Summers 2011-2013 through the collaboration of Siquijor State College, the Philippine Physics Society, and Maxino College, with the latter as instructional venue. Eight graduated with the degree Master of Science in Science Education (Physics) and one with the degree Master in Teaching (Physics). The former requires a thesis. Both require 26 graduate units of Physics content courses, four units of research, and six units of thesis. Teaching methodology is integrated into the courses. The third and final run of the Tri-Summer Graduate Physics Program was conducted from 2015 to 2017. Of the six initial enrolees, four graduated with the degree of Master of Science in Science Education (Physics Teaching).

The year 1986 illustrates the vitality of PPS: upgrading seminars on various topics in Physics held in Cebu City (2); Binalbagan, Negros Occidental; Dumaguete City; Iloilo City; Butuan City; Musuan, Bukidnon; Bacolod City; Sta. Catalina, Negros Oriental; and Kabankalan, Negros Occidental. At present, with many active PPS chapters, upgrading seminars have become regular yearly activities in many provinces and cities of the Visayas and Mindanao areas. In 1990, PPS held the very first Physics Seminar in Vigan City at the Divine Word College of Vigan under the sponsorship of the UNESCO University Physics Project in the Philippines.

To cite another example, from the renewed vitality of community life emerging from the 24th PPS Convention at Silliman University in April 2002, a Regional Upgrading Seminar On Electricity, Optics and Modern Physics was held for the first time in Siquijor in August 2002. This resulted in the formation of the PPS -- Siquijor Chapter. In October 2002, at the invitation of Adamson University, PPS held its first upgrading Physics seminar in Electricity, Optics and Modern Physics in Metro Manila, indeed, the First Luzon Conference. The seminar was well attended by physics teachers from schools all-over Luzon and resulted in the formation of six new chapters. Not to be outdone, the Negros Oriental Chapter had its own Physics upgrading seminar on Electricity and Optics in Tanjay City in November 2002. In July 2005, a similar physics upgrading seminar was conducted at Aklan State University resulting in the establishment of the Aklan PPS Chapter and Boracay PPS Chapter.

Although many PPS conventions and seminar-workshops had been conducted in Region VIII, the first PPS seminar-workshop cum regional convention in Southern Leyte was held on October 22, 2013 at St. Joseph College, Maasin City. This was the Region VIII Convention and Seminar-Workshop on Physics Laboratory Instrumentation for All. This was also the maiden public presentation of some apparatus from the Technology Incubation Unit of Maxino College.

In 1980, PPS started its Laboratory Extension Assistance Program (LEAP) in the Negros- Siquijor Area. In LEAP, any Physics teacher who has difficulties in his laboratory may request for assistance from PPS. Requests for such assistance must be made in writing to the PPS National President. A LEAP team will then visit the physics teacher. The LEAP team repairs equipment when possible and shows the teacher how to use the equipment found in the school's laboratory. LEAP services are free. The expenses of the LEAP team are supported by the PPS membership fees. A physics teacher of Sacred Heart Academy of Bais City was the first to avail of this service. The LEAP is now being reinvigorated with the support of the Physics Education Center of Maxino College, Bagacay, Dumaguete City. On account of financial limitations, however, services are restricted at the moment to areas near the serving station, unless of course travel expenses will be shouldered by a sponsor**.** An example of this was the seminar-workshop conducted by PPS and Maxino College at Trinity Christian Academy, Bacolod City. The workshop involved experiments using pieces of apparatus produced by the Technology Incubation Unit of Maxino College. These laboratory equipments enhanced the Physics Labratory of the host schools.

Since many schools have poorly equipped physics laboratories, PPS encourages capable physics teachers to make low cost physics equipment to be sold at cost to their fellow PPS members after they have undergone a short course using the equipment. PPS provides seed money for this construction but requires that no teacher will be allowed to buy unless he has undergone the short course associated with this equipment.

In 2017, PPS and Maxino College worked with the Schools Division of Negros Oriental in conducting the Physics Teachers Enhancement Program of Negros Oriental Division which was held for six Saturdays or a total of 48 hours. PPS and Maxino College provided the trainors, resource persons, and training materials. Participants went back to their schools with a number of free physics laboratory equipment.

PPS has initiated and propagated the Physics Olympics in the Philippines, if not in Asia. The first Physics Olympics was held in Dumaguete City in December 1983. Now, the Physics Olympics is held in many places in the Philippines. The first National Physics Olympics for teachers was held during the 10th PPS Convention at the Divine Word University of Tacloban in Tacloban City on April 6-9, 1988. Since then, the National Physics Olympics has been a regular feature of the annual PPS Convention. PPS conducts training in organizing the Physics Olympics. For example, a well attended Physics Olympics Congress was held on September 19, 2007 at La Consolacion College in Bacolod City.

In 1997, PPS handled the technical aspects of the First TRITECH Inter-Regional Physics Olympics sponsored by the Tri-Sectoral Forum for Technology Excellence (TRITECH) at SM, Cebu City. The 2nd TRITECH Inter-Regional Physics Olympics was held on July 26, 2000 under the sponsorship of TRITECH and DOST-Visayas Cluster (led by Region VII).

The Physics Olympics has really taken roots in the country. Now, during this annual national event, three categories are kept: high school students, college students, and professionals/teachers.

Since 1993, at the University of Negros Occidental - Recoletos, Bacolod City, PPS has conducted the National Physics Fair during the annual PPS Convention. Here, investigatory projects, inventions, and exhibits are presented by teachers and students in all levels. Mentoring in research is done during the Physics Fair.

Through the efforts of Dr. Robert Wild, PhD, PPS received a donation of about 3600 volumes of books and journals which were shipped to the Philippines free of charge from the United States of America through the Operation Handclasp of the U.S. Navy. These books and journals were turned over to requesting schools, among which was Silliman University, on a first come-first served basis after sharing the costs of transporting the books from Subic Bay to the recipient's place.

PPS feels a sense of honor when at its 45th Year, at the 41st Annual National Physics Seminar-Convention at Maxino College, the Secretary of the Department of Science and Technology (DOST) generously served as the honored Guest Speaker, speaking on "DOST and the Three Pillars: Malasakit, Pagbabago, at Kaunlaran". His parting words to the PPS members are very inspiring: "It is therefore my fond hope that the members and prime movers of the Philippine Physics Society, on the occasion of its 41st Annual National Physics Seminar- Convention, shall be forever committed to develop lifelong learners who are logical, analytical, creative, and critical thinkers who can share their talents and skills toward national development and inclusive growth. May the PPS continue to advocate effective educational practices in Physics. Most of all, may you accompany the quest for nature's fundamental laws with the concerted search for relevant applications benefiting the whole of Philippine society."

VI. CONCLUSION

Founded in 1974, the Philippine Physics Society now stands gratefully and proudly on fifty years of service for the improvement of Physics and Physics Education in the country, as well as the growth and development of its thousands of members. Spread throughout the country -- in Luzon, Visayas, and Mindanao -- PPS is not only the longest existing but also the largest Physics association in the country today. Such is no mean accomplishment. Now we can proudly claim that the Philippines has have a long lasting Physics organization with concrete accomplishment, including a Physics journal that has outlasted many in similarly placed countries. The praise should fall on all PPS members who have spent time, effort, and resources to build up a community of service-oriented and friendly persons. To this also belongs the affirmation and confirmation and validation of a philosophy by which the PPS has lived since its moment of birth:

1. Self-reliance -- meaning we have the capability to succeed and that the improvement of Physics and Physics Education in the country depends on us; that there is nobody else more interested than us in the improvement of Physics and Physics Education in the Philippines.
2. Sharing -- This means that by putting together the little that each of one has, we can make significant, relevant, and appropriate changes.
3. Indigenization -- This means that we sould not blindly copy, that we should look at problems, needs, resources, and solutions with Filipino eyes.
4. Hominization -- This means that in our pursuit and journey, we should not be confined only to material things,

that we should also imprint the human spirit into our tasks; that man, as matter and spirit, reflects his unity in the pursuit, application, and communication of Physics.

5. Community Building -- This means that we can accomplish better the task we have set for ourselves if we let grow the Physics and larger communities; that community leads us to the accomplishment of our aims and goals.

Thanks to all members of the Philippine Physics Society for their devotion to the improvement of Physics and Physics Education in the Philippines and for their firm resolve to be together as a community for years and years to come!

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AN ECO-FRIENDLY AND COST-EFFECTIVE SENSOR FOR THE DETERMINATION OF CAFFEINE

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ABSTRACT

Graphite rods, extracted from waste zinc-carbon batteries, were used as the working electrode in differential pulse voltammetry (DPV) to detect caffeine. The electrode surface was modified with multiwalled carbon nanotubes (MWCNT) and Nafion to enhance its sensitivity. The effects of the amount of MWCNT in the electrode modifier and the DPV parameters on the anodic peak current were investigated. Results show that the optimum amount of MWCNT is 3 mg and the optimum DPV parameters are: pulse potential of 200 mV and pulse time of 25 ms.

INTRODUCTION

The quantity of electronic waste or e-waste is rising rapidly all over the world. The accumulation of this waste has negative effects on the environment as well as on human health. A potentially dangerous form of e-waste is the zinc-carbon battery. This type of battery is commonly used in household products such as clocks, flashlights, TV remote controls, toys, and other products. Since it does not contain mercury, it is not considered as hazardous waste and can be disposed of with ordinary trash. Most zinc carbon batteries end up in landfills where they decay and leak. When the casing of these batteries corrodes, the chemicals inside leach into the soil and make their way into groundwater and surface water. Eventually, they enter the food chain. Some of the batteries also get burnt in landfills releasing toxic chemicals into the air.

Due to the potential threat of waste batteries to health and the environment, several approaches have been adopted to reduce and reuse them. One of these approaches is the dismantling and recovering of valuable materials such as zinc, steel, manganese, and graphite rod from zinc carbon batteries. In previous studies, the zinc case, graphite rod and carbon paste (a mixture of carbon, MnO_2, and NH_4Cl) were utilized as a biogas desulfurizer [1-3] and the graphite rod, which possesses good electrical conductivity, was used as the working electrode in voltametric detection of myricetin [4], heavy metals [5], and tannic acid [6].

In this study, graphite rods from waste zinc-carbon batteries were modified with multiwalled carbon nanotubes (MWCNT) and Nafion and were used as the working electrode in differential pulse voltammetry (DPV) to detect caffeine.

METHODOLOGY

Preparation of graphite electrodes

Graphite rods were extracted from spent AA zinc-carbon batteries. The extracted graphite rod was cleaned by submerging it in ultrapure water and was sonicated for 20 minutes using a Bandelin Sonorex sonicator. After the graphite rod was cleaned, it was dried in an oven at 130 °C. Once dried, the tip of the rod was polished with emery paper of grade P130, then with grades of P1000 and P2000. The rods were wrapped with a Teflon tape for the insulation of the exposed sides of the rod. The graphite electrodes were polished with alumina slurry which consists of 1.0 µm particles, and then with particle sizes of .30 and 0.05 µm on a polishing cloth. After polishing was done, the electrodes were washed by sonicating in ethanol for 5 minutes, and then with ultrapure water. The graphite electrodes were then stored at room temperature until further use.

Preparation of the MWCNT-Nafion coating solution

The MWCNT-Nafion coating solution was prepared by weighing the MWCNT at 1 mg, 2 mg, 3 mg, 4 mg, and 5 mg using a Bosch SAE200 analytical balance. The weighed MWCNT was mixed into 0.5 mL 15 wt% Nafion and 4.5 mL ethanol solution. The mixtures were sonicated in an ultrasonicator for 2 hours. The prepared graphite electrode was then drop-coated with the MWCNT-Nafion solution and was allowed to dry at room temperature.

Differential Pulse Voltammetry

A PalmSens4 potentiostat was used for the DPV measurements. The modified graphite electrode was used as the working electrode, Ag/AgCl electrode as the reference electrode, and a platinum wire as the counter electrode. The electrolyte solution in the electrochemical cell was composed of 0.1 M H_2SO_4 and deionized water. A known amount of caffeine was dissolved in the electrolyte solution.

RESULTS AND DISCUSSION

Effect of MWCNT

The effect of the MWCNT content of the electrode modifier on the anodic peak current was investigated by varying its amount at 1 mg, 2 mg, 3 mg, 4 mg, and 5 mg while the concentration of the Nafion-ethanol solution was kept constant at 0.33 mL of 15 wt% Nafion and 4.67 mL of pure ethanol. The modified electrodes were then used in the detection of 10 ppm of caffeine via differential pulse voltammetry. The DPV parameters were held constant; a pulse potential of 0.5 V, a pulse time of 0.01 s, and a scan rate of 0.3 V/s. The electrodes were also pretreated for 30 s with a pretreatment potential of 2.0 V.

Figure 1 shows the voltammograms obtained for the varied amounts of MWCNT. It can be seen from the figure that using 3 mg of MWCNT in the electrode modifier gives the highest current peak. Also shown that past this amount, further increasing the concentration of MWCNT will lead to lower current peaks. It can be inferred that an excess of MWCNT on the electrode surface could be hindering the effective detection of caffeine.

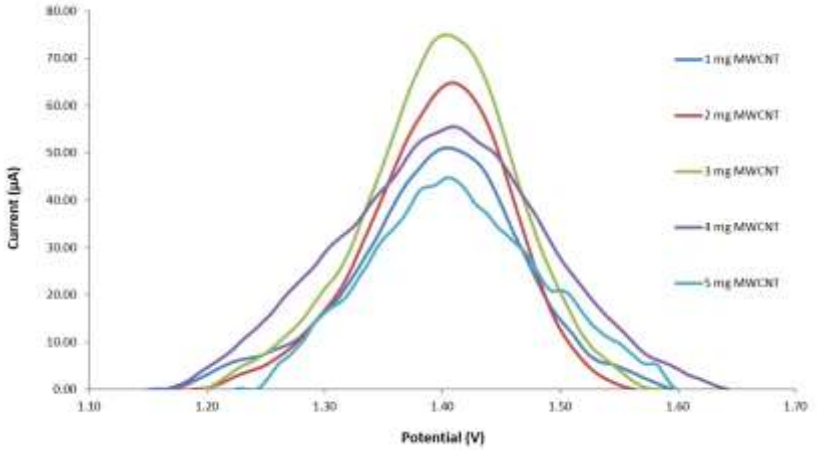

Figure 1. *Voltammograms obtained for varied amounts of MWCNT in the electrode modifier.*

Effect of Pulse Potential

The pulse potential was varied at 0.01 V, 0.1 V, 0.2 V, 0.25 V, and 0.3 V to determine its effect on the anodic peak current. The other DPV parameters were held constant; a pulse time of 0.01 seconds, and a scan rate of 0.3 V/s. The electrodes were also pretreated for 30 s with a pretreatment potential of 2.0 V. The pulse potential. The electrolyte solution used had 0.1 M H_2SO_4.

Figure 2 shows the voltammograms obtained for the different pulse potentials. It is seen in the figure that there is an increase from the lowest value, 0.01 V, up until 0.2 V, where it drops afterward. This means that the best pulse potential value for the detection of caffeine is 0.2 V.

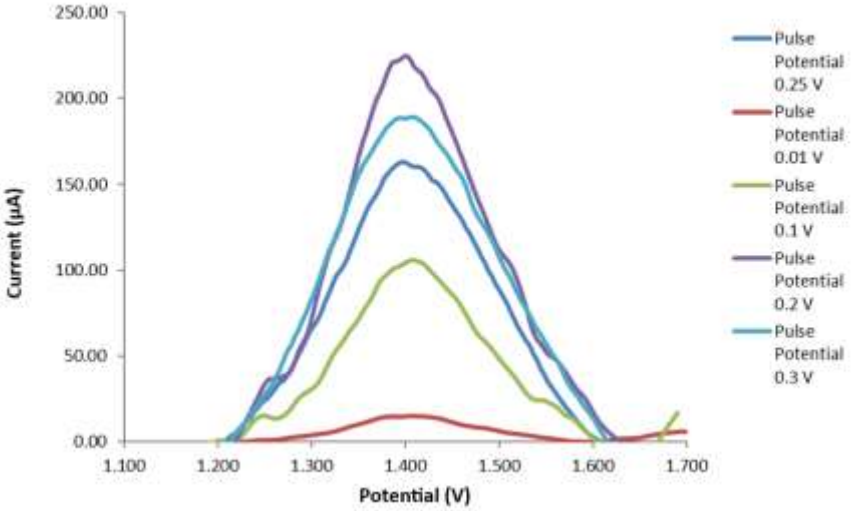

Figure 2. *Voltammograms obtained for varied pulse potentials.*

Effect of Pulse Time

The pulse time was varied at 5 ms, 10 ms, 25 ms, and 50 ms to determine its effect on the anodic peak current. The other DPV parameters were held constant; a pulse potential of 0.5 V, and a scan rate of 0.3 V/s. The electrodes were also pretreated for 30 s with a pretreatment potential of 2.0 V. The electrolyte solution used had 0.1 M H_2SO_4.

Figure 3 shows the voltammograms obtained for the different pulse times. It can be seen in the figure that the peak current increased when the pulse time was increased from 5 ms to 25 ms. Past 25 ms, there is a big drop in the peak current. This indicates that 25 ms is the best pulse time for the detection of caffeine.

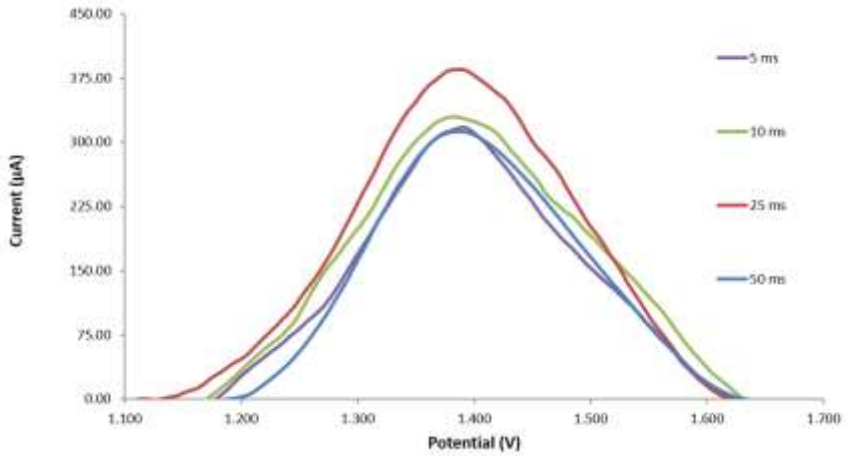

Figure 3. *Voltammograms obtained for varied pulse times.*

CONCLUSION

The fabricated MWCNT/Nafion modified graphite electrode was successful in detecting caffeine via differential pulse voltammetry. The optimum amount of MWCNT used as electrode modifier was found to be 3 mg. The highest anodic peak current was obtained at a pulse potential of 200 mV and pulse time of 25 ms. The fabricated sensor is not only cost-effective but environment-friendly as well.

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TRANSFORMING IDEAS TO PRODUCTS: DESIGN THINKING ON LEARNERS' CONCEPTUAL UNDERSTANDING AND PERFORMANCE TASK RATING IN PHYSICS

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INTRODUCTION

The emergence of technology and the increase in knowledge are noted to be some of the products of Physics. Gadgets including laptops, mobile phones and tablets are made possible under the principles of Physics on Electromagnetism. The use of car airbags as life saving device can be explained by Mechanics. The common Filipino misconception like "Pakisara ng pinto, lalabas ang aircon." can be corrected after reviewing the laws of Thermodynamics. The occurrence of rainbows and the production of sounds by human voice and musical instruments can be simplified by Optics and Acoustics, respectively. Furthermore, the life-changing invention, Global Positioning System (GPS) that makes every traveler's journey easy and stress-free is in lined with the concept of Relativity.

Despite the countless applications of Physics in the society, most high school and college students hate Physics. In fact, Tan (2017) in his article, mentioned that students hate Physics because it covers topics that are difficult, boring and uninteresting like spending day after day calculating forces and velocities for problems which they think have no real-life application. In 2015, Yatra mentioned in his writing that Physics is portrayed as unethical to Arts so people who write, paint or make music are naturally turned off by it. He hypothesized that Physics is taught poorly in school killing the interests of students towards the subject.

One way to solve the problem is to use a methodology which is human-centered. In this methodology, students will be exposed to real-life problems which will require them to design a solution to solve the problem hence, the term Design Thinking.

Design Thinking is a design methodology that provides a solution-based approach to solving problems. It's extremely useful in tackling complex problems that are ill-defined or unknown, by understanding the human needs involved, by reframing the problem in human-centric ways, by creating many ideas in brainstorming sessions, and by adopting a hands-on approach in prototyping and testing (Dam and Siang, 2017).

In education, design thinking is a structured framework for identifying challenges, gathering information, generating potential solutions, refining ideas, and testing

solutions. Design thinking can be flexibly implemented, serving equally well as framework for a course design or a roadmap for an activity or group project (Luka, 2014).

Figure 1 graphically illustrates the Framework of the study.

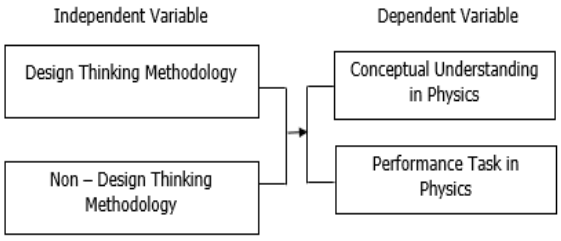

Figure 1. *The effect of Design Thinking Methodology and Non – Design Thinking Methodology on the Conceptual Understanding in Physics and Performance Task Rating in Physics*

STATEMENT OF THE PROBLEM AND HYPOTHESES

This study aimed to determine the effect of design thinking methodology on the conceptual understanding and performance task rating in Physics of Grade 8 students.

Specifically, the study aimed to answer the following specific concerns:

1. What is the conceptual understanding in Physics of the Grade 8 students before and after exposure to design thinking methodology and non-design thinking methodology?
2. What is the mean gain on the conceptual understanding in Physics of students after exposure to design thinking methodology; and non-design thinking methodology?
3. What is the performance task rating in Physics of Grade 8 students after exposure to design thinking methodology; and non-design thinking methodology?
4. Is there a significant difference in the conceptual understanding in Physics of Grade 8 students before exposure to design thinking methodology and non-design thinking methodology?
5. Is there a significant difference in the conceptual understanding in Physics of Grade 8 students after exposure to design thinking methodology and non-design thinking methodology?
6. Is there a significant difference in the conceptual understanding in Physics of Grade 8 students before and after exposure to design thinking methodology and non-design thinking methodology?
7. Is there a significant difference in the mean gain on the conceptual understanding in Physics of students after exposure to design thinking methodology and non-design thinking methodology?
8. Is there a significant difference in the performance task rating in Physics of the Grade 8 students after exposure to design thinking methodology and non-design thinking methodology?
9. What are the learnings and challenges of students after undergoing design thinking methodology and non-design thinking methodology?

In view of the aforementioned problems, the following hypotheses were advanced:

1. There is no significant difference in the conceptual understanding in Physics of the Grade 8 students before exposure to design thinking methodology and non-design thinking methodology.
2. There is no significant difference in the conceptual understanding in Physics of the Grade 8 students after exposure design thinking methodology and non-design thinking methodology.
3. There is no significant difference in the conceptual understanding in Physics of the Grade 8 students before and after exposure to design thinking methodology and non-design thinking methodology.
4. There is no significant difference in the mean gain on the conceptual understanding in Physics of students after exposure to design thinking methodology and non-design thinking methodology.
5. There is no significant difference in the performance task rating in Physics of the Grade 8 students after exposure to design thinking methodology and non-design thinking methodology.

METHODOLOGY

Research Design

This study ascertained to determine the effect of design thinking methodology to students' conceptual understanding and performance task rating in Physics. The study adopted Fraenkel and Wallen's Quasi Experimental - Matching Only Pretest-Posttest Control Group Design. Comparisons were made between groups receiving different treatments.

The Subjects

The subjects of the study were the 60 selected Grade 8 students of Passi National High School in the Division of Passi City who were officially enrolled for school year 2019-2020.

Two sections were selected as the subjects of the study. Thirty students were selected from each section using match pairing technique. Students' sex and Grade 7 Science final grade were the bases for pairing.

By tossing a coin, the 2 groups were assigned to either control group (not exposed to design thinking methodology) or the experimental group (exposed to design thinking methodology).

Instrumentation

In terms of conceptual understanding, the main source of data of this study was the result of the Pretest-Posttest scores from the duly validated teacher-made test with Table of Specifications (TOS) that encompassed the Grade 8 Science concepts based on the K-12 Science module guide provided by the Department of Education. The topics covered were Heat, Sound and Light only. Prior to pilot testing, 70-item test was constructed by the researcher. The test underwent reliability testing retaining 50 items with a Cronbach alpha of 0.747.

For the performance task rating, students' outputs were evaluated using a teacher-made rubric checked and validated by experts

Data Gathering Procedure

The data gathering procedure was done in three experimental stages: the pre-experimental stage, the experimental stage, and the post-experimental stage.

Pre-experimental Stage. Permission to conduct the study was secured from the Schools Division Superintendent of the Division of Passi City and the Principal of Passi National High School. Prior to the actual experimentation, students together with their class advisers were called for an orientation regarding the purpose of the study as well other matters concerning the conduct of the study. A permission letter was sent to the parents seeking approval for allowing their children's participation in the study. Further, the letter explains the intention of the teacher for conducting the study.

Research instruments such as 70-item test with Table of Specifications (TOS), Lesson Plans, Rubrics and Activity Sheets were prepared by the researcher. These instruments underwent validation. The copy of 70-item test was distributed to different Physics experts for face and content validation. Lesson plans, rubrics and activity sheets were also distributed to Design Thinking experts for checking and validation. Revision of these instruments was done incorporating experts' comments and suggestions.

The validated 70-item test underwent pilot testing. Prior to that, a letter to conduct a pilot test was secured from the Principal of Passi National High School. One section from Grade 8 other than the subjects of the study took the test. After the test, results were gathered and underwent reliability testing. The final test was composed of 50 multiple choice questions only with a Cronbach alpha of 0.747.

Experimental Stage. Before the experimental and the control groups were exposed to different treatments, a pretest was given. The researcher prepared advanced lesson plans and activities for every objective of the lesson in the study. The researcher taught the students about Science lessons specifically heat, sound and light and employed design thinking methodology in some of the selected topics under this unit. Students under non-design thinking methodology was exposed to instruction following the 7E's lesson plan format. On the other hand, students under design thinking methodology were exposed to an instruction following the DrSHIRLEY lesson plan format which was anchored on the idea of Dam and Siang (2017) about design thinking. At the end of each lesson, the students created a prototype of the solution they had to solve the problem. Each prototype was assessed using a duly validated rubric which served as the performance tasks in Physics. Students exposed to design thinking used the design thinking manual to create their outputs while non-design thinkers were given with the teacher-made activity sheets to create their outputs.

Post-Experimental Stage. After the experimentation, a posttest was given to both groups using the instrument parallel to the pretest. The results from both groups was analyzed for comparison of their conceptual understanding. In addition, the performance task ratings of both groups were also compared.

Data Analysis Procedure

Giving of Pretest to determine the Pre-Conceptual Understanding in Physics
‖
Intervention Proper
‖
Giving of Post Test to determine the Post-Conceptual Understanding in Physics
‖
Evaluation of Outputs to determine the Performance Task Rating of the Students
‖
Gathering of Students' Learnings and Challenges through their Journals
‖
Analysis of Data

The data gathered were subjected to appropriate data analysis.

Mean. The 50-item test was given 1 point per item. Individual scores were counted. The total scores for each group were divided by the number of cases in order to get the mean performance of the Pretest-Posttest of the group exposed to design thinking methodology and the group not exposed to design thinking methodology.

Standard Deviation. To determine the dispersion of the students' scores from the mean obtained for two groups in the study, the researchers used the standard deviation.
Inferential Statistics

Paired Sample t-test. This test was used to determine the significant difference in the conceptual understanding of the Grade 8 students in Physics before and after exposure to design thinking methodology and non-design thinking methodology as based on the results of their pre and posttests.

Independent Sample t-test. This test was used to determine the significant difference in the conceptual understanding of the Grade 8 students in Physics before and after exposure to design thinking methodology and non-design thinking methodology. The Pretest and Posttest scores of the students belonging to the experimental group (exposed to design thinking methodology) were compared to the Pretest and Posttest scores of students belonging to control group (not exposed to design thinking methodology) to determine the significant difference between them. Furthermore, the significant difference in the performance task rating in Physics after exposure to design thinking methodology and non-design thinking methodology as evaluated using the teacher-made rubric was also determined. The 0.5 level of significance was used for all statistical tests.

Students' Learnings and Challenges. Science journal was the main source of data to determine the learnings and challenges of the learners for every problem. The learnings and challenges were classified into themes with similar thoughts or ideas.

RESULTS AND DISCUSSION

Descriptive Data Analysis

Table 1. *Conceptual Understanding of Non-Design Thinkers and Design Thinkers obtained from Pretest Scores*

Methodology	N	SD	Mean	Descriptive Rating
Non-Design Thinking	30	3.55	14.37	Very Low
Design Thinking	30	3.10	13.70	Very Low

Legend: 8.00 – 16.20 (Very Low); 16.21 – 24.50 (Low); 24.51 – 32.8 (Average); 32.81 – 41.10 (High) and 41.11 - 49.40 (Very High)

Table 2. *Conceptual Understanding of Non-Design Thinkers and Design Thinkers obtained from Posttest Scores*

Methodology	N	SD	Mean	Descriptive Rating
Non-Design Thinking	30	10.54	26.57	Average
Design Thinking	30	10.63	34.73	High

Legend: 8.00 – 16.20 (Very Low); 16.21 – 24.50 (Low); 24.51 – 32.8 (Average); 32.81 – 41.10 (High) and 41.11 - 49.40 (Very High)

The results of data analysis revealed that initially, students both under non-design thinking methodology and design thinking methodology had a "Very Low" conceptual understanding. After six weeks of intervention, students under non-design thinking methodology had an "Average" conceptual understanding while students under design thinking methodology had "High" conceptual understanding.

Table 3. *Mean Gain for Conceptual Understanding of Non-Design Thinkers and Design Thinkers*

Methodology	N	Mean Gain	SD
Non-Design Thinking	30	12.20	8.97
Design Thinking	30	21.03	10.44

The results of data analysis revealed that students under design thinking methodology had higher mean gain in conceptual understanding than students belonging to non-design thinking methodology.

Table 4. *Performance Task Rating of Non-Design Thinkers and Design Thinkers*

Methodology	N	SD	Mean	Descriptive Rating
Non-Design Thinking	30	6.34	78.26	Fairly Satisfactory
Design Thinking	30	3.70	90.35	Outstanding

Legend: Below 75 (Did Not Meet Expectations); 75.00-79.49 (Fairly Satisfactory); 79.50-84.49 (Satisfactory); 84.50-89.49 (Very Satisfactory) and 89.50-100.00 (Outstanding)

Results showed that students under non-design thinking methodology had "Fairly Satisfactory" rating while students under design thinking methodology had an "Outstanding" rating.

Inferential Data Analysis

Table 5. *Differences in the Preconceptual Understanding*

	Df	Mean	t-value	Significance	D	Confidence Level	
						Lower	Upper
Pretest	29	13.70	11.04*	.000	2.69	-24.93	-17.14
Posttest		34.73					

**p < .001*

There is no significant difference noted in the conceptual understanding of students from both groups prior to the intervention. The result was probably the effect of match-pairing technique of the respondents prior to the experiment proper. The respondents were paired according to sex and Grade 7 Physics grades.

Table 6. *Differences in Post Conceptual Understanding*

Methodology	Df	Mean	t-value	Significance	Confidence Level	
					Lower	Upper
Non-Design Thinking	58	26.57	2.99*	.004	-13.64	-2.70
Design Thinking		34.73				

*p < .05

A significant difference in the post conceptual understanding in Physics of both groups was revealed. The conceptual understanding in Physics of design thinkers was significantly higher than the non-design thinkers.

Table 7. *Differences in Pre and Post Conceptual Understanding of Non-Design Thinkers*

	Df	Mean	t-value	Significance	D	Confidence Level	
						Lower	Upper
Pretest	29	14.37	7.45*	.000	1.55	-15.55	-8.85
Posttest		26.57					

*p < .001

Table 8. *Differences in Pre and Post Conceptual Understanding of Design Thinkers*

Methodology	Df	Mean	t-value	Significance	Confidence Level	
					Lower	Upper
Non-Design Thinking	58	14.37	.775	.441	-1.05	2.39
Design Thinking		13.70				

Results revealed that there is a significant difference in the conceptual understanding in Physics before and after exposure to design thinking methodology and non-design thinking methodology. Though the results showed a significant difference for both groups, the effect size of design thinking methodology was higher compared with non-design thinking methodology in terms of conceptual understanding in Physics.

Table 9. *Differences in the Mean Gain for Conceptual Understanding*

Methodology	Df	Mean	t-value	Significance	Confidence Level	
					Lower	Upper
Non-Design Thinking	58	12.20	3.52*	.001	-13.86	-3.81
Design Thinking		21.03				

*p ≤ .001

There is a significant difference in the mean gain on conceptual understanding in Physics of students belonging to both non-design thinking methodology and design thinking methodology. Design thinkers had higher mean gain compared to non-design thinkers.

Table 10. *Differences in Performance Tasks*

Methodology	Df	Mean	t-value	Significance	Confidence Level	
					Lower	Upper
Non-Design Thinking	46.71	78.26	9.02*	.000	-14.77	-9.41
Design Thinking		90.35				

*p < .001

A significant difference in the performance task rating in Physics of the Grade 8 students after exposure to design thinking methodology and non-design thinking methodology was revealed.

Learnings and Challenges

For six weeks, students learned about Heat, Sound and Light. Since Design Thinking can only be applied to topics where output is an end product, the researcher decided to apply design thinking methodology in one lesson for every topic. Thus, for six weeks, three topics were discussed and three outputs were made by the students. Students under non-design thinking methodology made use of the teacher-made activity sheets with instructions and materials while students under design thinking methodology were given a problem only and underwent several stages of design thinking to come up with their outputs. Their learnings and challenges in every output making were written in their Science journals.

Non-Design Thinkers' Learnings

- A Guided Construction of Knowledge
- Cooperating without Questioning
- Learning after Doing

Non-Design Thinkers' Challenges

- Guide but not well Interpreted

Design Thinkers' Learnings

- An Avenue for Active Learning
- Developing Scientific Skills and Attitudes
- Learning while Doing
- Cooperating through Brainstorming

Design Thinkers' Challenges

- An Opportunity worth the Risk

Exposing students to both non-design thinking methodology and design thinking methodology allowed learners to experience different learnings and challenges while performing the activities. Since non-design thinkers were guided during the problem solving and project making, students were provided with activity sheets for them to follow to construct an output. This led them to learn the value of obedience. It was noted that non-design thinkers tend to master the topic right after the construction of outputs. This was contrary to the learnings gained by design thinkers who had a wide range of learning in their quest to solve the problem posed by the teacher. Design thinkers exposed themselves to different workplace to deeply understand the problem. Understanding the problem led them to come up with a very good solution which in turn, was transformed into tangible products. Another notable learning from design thinker was the honing of creativity. The use of design thinking methodology allowed the students to design their products in such a way that it answered the question. Design thinkers were noted to have mastered the topic during and after the construction of the outputs. Allowing the students to explore led them to understand what the problem was all about.

While students continued to construct their outputs with guidance and independence, several challenges arose while doing the activity. Analysis of students' science journal revealed that non-design thinkers found it difficult to interpret the procedures even if the activity sheets were already provided by the teachers. Difficulty in interpreting the procedure of the activity resulted to students being bored and lose interest in continuing the project. These actions meant that non-design thinkers have lower GRIT for they have no commendable patience in pursuing the activity. Design thinking methodology, on the other hand, developed students' patience and passion in solving problem despite several challenges. To name some of these challenges, design thinkers experienced conflict among group members during the Ideate stage of the

process as they were brainstorming about the possible solutions to the problem. Though it appeared to be a problem for most of design thinkers, brainstorming is actually a sign that learners were actively engaged and shared responsibility in providing solutions to the problems. It was also realized that the process of problem solving through design thinking was long and hard for design thinkers. However, positive attitude about students' determination on undergoing these difficult processes made them appreciate success after hard work. This gave the researcher a conclusion that design thinking was indeed an opportunity worth the risk.

CONCLUSION

In view of the preceding findings, the following conclusions were drawn:

Prior to the intervention, both non-design thinkers and design thinkers were noted to have low conceptual understanding in the topics Heat, Sound and Light. Since an insignificant difference was noted between the conceptual understanding of the learners prior to the intervention, it was concluded that both groups have comparable level of intelligence with regards to the selected topics making it a very good springboard to objectively assess the effectiveness of design thinking in terms of conceptual understanding and performance task rating in Physics.

After the intervention, a significant difference between the conceptual understanding of both groups was revealed. Since the conceptual understanding of design thinkers was noted to be higher than that of non-design thinkers, it can be concluded that design thinking was a very effective methodology in improving the conceptual understanding in Physics of students. This methodology allowed the learners to be actively involved in problem solving and project making. As properly introduced, design thinking as a methodology enabled the learners to deeply understand the problem by gaining useful insights through engaging, experiencing and interviewing experts.

Comparing the conceptual understanding of learners prior and after exposure to non-design thinking methodology, a significant difference was also noted. Further analysis revealed a large effect size in terms of conceptual understanding of learners. The increase in conceptual understanding of non-design thinkers could have been the effect of a six-week actual teaching and learning process. Since, non-design thinking methodology adopted the inquiry-based approach to learning, it was concluded that this methodology was still effective in improving the understanding of learners on selected Physics topics. A significant difference was also noted between the conceptual understanding in Physics before and after exposure to design thinking methodology with a large effect size in terms of conceptual understanding of learners. As compared to non-design thinking methodology, design thinking methodology had higher effect size which signified that design thinking had greatly improved the conceptual understanding of learners under this methodology with a higher magnitude effect than the non-design thinking methodology. From this, it was concluded that the use of an innovative teaching methodology, Design Thinking, was proven effective in improving the conceptual understanding of the learners.

Although both groups have shown significant difference between their pre and post conceptual understanding, the differences between their mean gains were found to be

statistically significant. As mentioned before, design thinkers had higher mean gain for conceptual understanding compared to the non-design thinkers. From this alone, it can be concluded that design thinking was a more effective strategy in improving the conceptual understanding in Physics than the non-design thinking methodology. Since design thinking promoted hands-on, mind-on learning, design thinking served as an avenue for learning as well as an opportunity to improve scientific skills and attitudes. Moreover, design thinking supported the idea that learners learn best by doing which simply proved that design thinking is a way of learning where learners learn by doing.

Aside from improving learners' conceptual understanding, design thinking was proven to improve the performance task rating in Physics. Results revealed that design thinkers had higher performance task rating than non-design thinkers. This supported the idea that the use of this methodology in project making and problem solving can improve the performance task rating of learners. This methodology allowed the learners to brainstorm possible solutions to the problem and required them to come up with an output as solution to the problem, thus the phrase "Transforming Ideas to Products". Since this methodology enabled the learners to test-retest their outputs prior the final presentation and testing, the outputs were more likely to be effective and successful than those outputs which have not undergone such process. From all of these, it was concluded that design thinking and the use of design thinking manual as a guide were key processes which contributed a lot in the success of project making.

Implications

For theory. The findings of the study proved the Constructivist Theory of Jerome Bruner grounded on the fact that learning was an active process where learners constructed new ideas or concepts based on their current and previous knowledge. Upon observation and analysis of students' science journals, it was discovered that design thinking is an active process that allowed the students to make use of their existing knowledge to construct the new ones. The prior knowledge paved way on the development of new knowledge which was very useful in answering the problem. Arnold's Theory of Creative Mindset grounded on the idea that creative experiences enhanced self-belief was made strong after the study found out that design thinkers tend to improve self-esteem after successfully coming up with an output. As design thinkers came up with their respective outputs, their creativity was deeply honed from designing to constructing the product to testing its effectiveness. Moreover, the results also supported the Design Theory focused on the understanding of tangible objects blended with a purpose or a problem to solve which resulted in effective design solution. Design thinking allowed the students to have a full grasp of the problem before arriving at a solution. In fact, this method required the students to explicitly define the problem prior to ideating solutions.

For Practice. The results of the study revealed that design thinking methodology was effective in improving the conceptual understanding and performance task rating in Physics of students. Teachers can adopt design thinking methodology in some of their lessons by incorporating DrSHIRLEY lesson plan format embedded with design thinking process to improve students' comprehension of the topic. With these, the use of design

thinking can increase the Mean Percentage Score (MPS) and General Scholastic Average (GSA) of the students which are monitored quarterly. Since design thinking allowed the learners to solve the problems through hands-on and minds-on activities, learners of different learning styles can be catered. Design thinking is not only limited to Science subject but rather, this methodology is applicable to all subjects with topics that require product or project as an end goal. Math teachers can make use of this methodology in teaching quadratic equations to build small scaled bridges. English and Filipino teachers can use this methodology to come up with their diorama when discussing about Philippine and Asian literatures. Electronics and Robotics teachers can introduce design thinking manual to students who can construct robots which will be useful at home and in the community such as fire and home breaking alarm devices and products to address waste management, and anti-snoring devices. If properly introduced to both teachers and students, the use of design thinking can improve students' rating for written works which comprises 40% of their grades, performance tasks which is also 40% of their grades and the remaining 20% is for their departmental exam. This may attract students to be actively engaged in the lesson because it caters to all students regardless of learning profiles. This can then improve school's academic performance and completion rate and may lessen school's drop out and failure rates. In coming up with a problem for Innovation Expo, Science Investigatory Projects (SIP) and Mathematics Investigatory Projects (MIP), design thinking manual can be used to determine the underlying problems people are facing today and to correctly arrive at a solution to address such problem.

RECOMMENDATIONS

Based on the findings and conclusions, the following recommendations are advanced:

Though known to be the hardest domain in Science, Physics concepts can be taught in ways where students actively and independently learn the concept while undergoing process of design thinking. Thus, teachers can consider the use of design thinking methodology in teaching some topics in Science which requires projects or products as outputs. The use of DrSHIRLEY lesson plan format for design thinking methodology and the use of design thinking manual during problem solving and project making are highly recommended.

Since design thinking methodology is new to both teachers and students, school administrators may spearhead a seminar-workshop about design thinking to inform the teachers about the features of this new methodology. This can be also be done during In-Service Training (InSET) of Teachers and School Learning Action Cells (SLAC) so as not to disrupt classes.

Policy makers and curriculum developers can make use of design thinking methodology in creating new policies and enhancing the current curriculum. If design thinking is carefully followed, these people may communicate to the teachers in the field the problems they have encountered relating to teaching strategies that required attention. The use of this methodology will allow them to test-retest the effectiveness of proposed policies before the actual implementation.

Parents are encouraged to raise their children to become active and independent problem solvers as well as to be responsible in their actions. It is also recommended that

parents may support their children in one way or another to develop their creative confidence and improve their self-esteem.

Further investigation can be done to determine the effect of design thinking strategy in problem conceptualization for Science Investigatory Project (SIP) for elementary and secondary students as well as for thesis writing on tertiary level. Moreover, the effect of design thinking methodology on students' critical and problem-solving skills is highly recommended for future investigation.

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MEASUREMENT OF VISCOSITY OF LIQUIDS USING A VISCOMETER APPARATUS

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ABSTRACT

The teaching of Physics of liquids can be more interesting and understandable using inexpensive experiments and demonstrations. A locally-made Viscometer (measurement of viscosity) was designed, constructed, and tested for accuracy and reliability. It was then used to measure the viscosity of some commonly available liquids such as Corn Syrup, Pure Coconut Oil, Dishwashing Liquid A and Dishwashing Liquid B. Pure Coconut Oil and Dish-washing Liquid B got a percentage difference of 0% on its velocity coefficient. Corn Syrup and Dish-washing Liquid A had a percentage difference of 0.31% and 0.90% respectively.

INTRODUCTION

Another important characteristic of fluids is viscosity, which is the internal friction of fluid. Viscosity plays a vital role in the flow of fluids such as in pipes, the flow of the blood, the lubrication of engine parts, and others. In fact, both liquids and gases have viscosity, but liquids are much more viscous than gases.

THEORY

Viscosity

In an ideal there is no viscosity to hinder the fluid layers as they slide past to one another. Within a pipe of uniform cross section, every layer of an ideal fluid moves with the same velocity, even the layer next to the wall, as **Figure 4.1a** shows. When viscosity is present, the fluid layers do not have the same velocity, as part b of the drawing illustrates. The fluid closest to the

wall does not move at all, while the fluid at the center of the pipe has the greatest velocity. The fluid layer next to the wall surface does not move, because it is held tightly by intermolecular forces. So strong are these forces that if a solid surface moves, the adjacent fluid layer moves along with it and remains at rest relative to the moving surface.

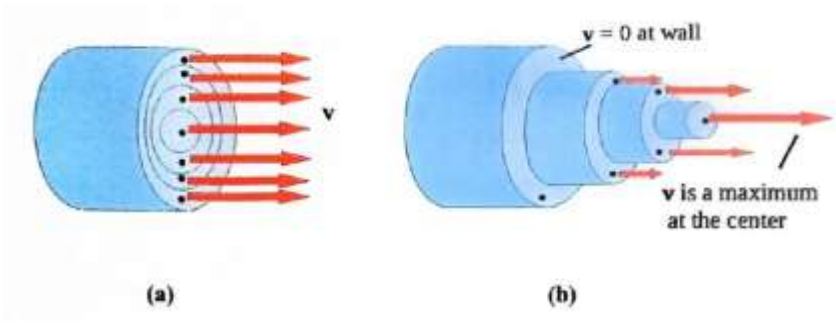

Figure 4.1 *(a) An ideal (nonviscous) fluid flow, all fluid particles across the pipe have the same velocity. (b) In viscous flow, the speed of the fluid is zero at the surface of the pipe and increases to a maximum along the center axis.*

To help introduce viscosity in a quantitative fashion, **Figure 4.2a** shows a viscous fluid between two parallel plates. The top plate is free to move while the bottom is stationary. If the top plate is to move with a velocity **v** relative to the bottom plate, a force **F** is required. For highly viscous fluid, like thick honey, a large force is needed; for a less viscous fluid, like water, a smaller force is necessary. As part ***b*** of the drawing suggests, we may imagine the fluid to be composed of many thin horizontal layers. When the top plate moves, the intermediate fluid layers slide over the other. The velocity of each layer is different, changing uniformly from ***v*** at the top plate to zero at the bottom plate. The resulting flow is called ***laminar flow***, since a thin layer is often referred to as lamina (a lamina is a thin sheet). As each layer moves, it is subjected to viscous forces from its neighbors, and the purpose of the force F to compensate for the effect of these forces, so that any layer can move with a constant velocity.

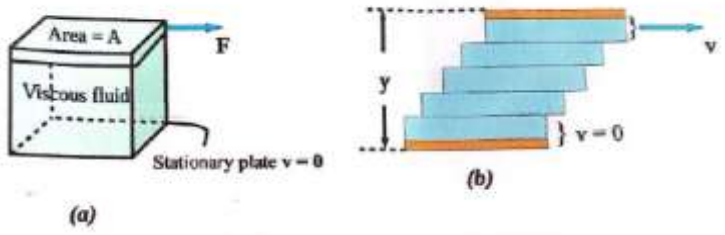

Figure 4.2 *(a) A force F is applied to the top plate, which is in contact with a viscous fluid. (b) Because of the force F, the top plate and the adjacent layer of fluid move with a constant velocity v.*

When we apply a shear stress (ration of F/A) to solid, the effect is to produce a certain displacement of the solid, such as *dd'*. The shear strain is defined as the ratio of this displacement to the transverse dimension *l*, and within the elastic limit the shear stress is proportional to the shear strain. With a fluid, however, the shear strain increases without limit as long as the stress is applied. Experiments show that the stress depends not on the shear strain but on its *rate of change*.

The strain in **Figure 4.4** (at the instant when the volume of fluid has the shape abc'd') is dd'/ad, or dd'/l. Since l is constant, the rate of change of strain equals l/l times the rate of change of dd'. But the rate of dd' is simply the speed of the point d'; that is, the speed v of the moving wall. Hence

$$\text{Rate of change of shear strain} = \frac{v}{l} \qquad (4.3)$$

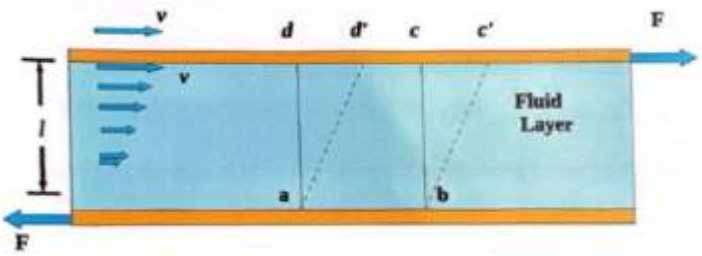

Figure 4.4 *Laminar flow of viscous fluid.*

The rate of change of shear is also referred to simply as the strain rate.

The amount o force required in **Figure 4.2a** depends on several factors. Large areas A, begin in contact with more fluid, require larger forces, so that the force is proportional to the contact ($F \propto A$). For he given area, greater speeds require larger forces, with the result that the force is proportional to the speed ($F \propto v$). The force is also inversely proportional to the perpendicular distance *y* (where *y* is equal to *l*) between the top and bottom plates. The larger the distance y, the smaller the force required to achieve a given speed with a given contact area. These three proportionalities can be expressed together in the following manner: $\boldsymbol{F \propto Avly}$. The coefficient of viscosity if the fluid, or simply its viscosity $\boldsymbol{\eta}$, is defined as the ration of the shear tress, F/A, to the rate of change of shear strain:

$$\eta = \frac{shear\ stress}{rate\ of\ change\ of\ shear\ strain} = \frac{F/A}{v/l}$$

$$F = \eta A \frac{v}{l} \qquad (4.5)$$

Values of viscosity depend on the nature of the fluid. Usually, the viscosities of the liquids decrease as the temperature increased. In general, fluids having smaller values of $\boldsymbol{\eta}$ are more nearly ideal fluids, because they flow more readily with only relatively weak viscous forces impeding their movement; an ideal fluid has $\boldsymbol{\eta}$=0.

From Eq. (4.5) the unit viscosity is that of force times distance, divided by area times velocity. In SI units it is

$$1\text{N.m.m}^{-2}\,(\text{m.s.}^{-1}) = 1\text{N.s.m}^{-2}$$

The corresponding cgs unit, 1 dyn.s.cm^{-2}, is the only viscosity unit in common use and is called 1 poise in honor of the French scientist Poiseuille. Thus,

$$1\text{poise} = 1\ \text{dyn. s. cm}^{-2} = 10^{-1}\ \text{N.s. m}^{-2}$$

Small viscosities are expressed in *centipoises* (1cp= 10^{-2} poise) or *micropoises* (1μp= 10^{-6} poise).

Not all fluids behave accordingly to the direct proportionality of force and velocity predicted by Eq. (4.50. For example, a blood, for which velocity increases more rapidly than force. This behavior results from the fact that blood is not a homogeneous fluid but rather a suspension of solid particles in a liquid. As the strain rate increases, these particles deform and become preferentially oriented to facilitate the flow. The fluids that lubricate human joints show similar behavior. Some points cling to the brush but flow when brushed on. A fluid for Eq. (4.5) does hold is called a Newtonian fluid; it is a useful though approximate model for the behavior of many pure substances. Fluids that are suspensions or dispersions are often non-Newtonian in their viscous behavior.

Poiseuille's Law

When a viscous fluid flows in a stationary tube or pipe, the flow velocity is different at different points of a cross section. The outermost layer of fluid clings to the walls of the tube, and its velocity is zero. The walls exert a backward drag on this layer, which in turns drags backward on the next layer beyond it, and so on. If the velocity is not too great, the flow is *laminar*, with the velocity that is greater at the center and decreases to zero at the walls. The flow is like that of a number of telescoping tubes sliding relative to one another, the central tube advancing the most rapidly and the outer tube remaining at rest.

We can now derive an equation for the variation of velocity with radius for a cylindrical pipe of inner R. So, start by considering the flow of a cylindrical element of fluid coaxial with the pipe, of radius r and length L, as shown in **Figure 4.6a.** The force on the left end is $p_1\pi r^2$, and that on the right end $p_2\pi r2$, as shown. The net force is thus

$$F = (p_1 - p_2)\pi r^2$$

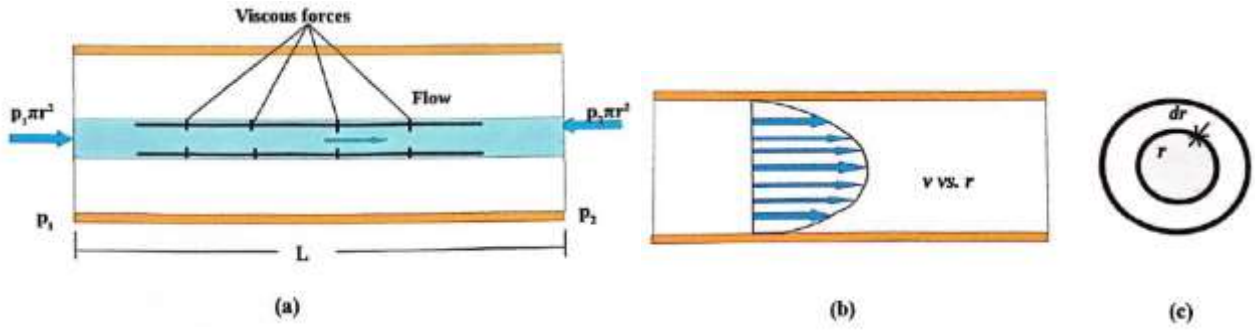

Figure 4.6 *(a) forces on a cylindrical element of a viscous fluid.*

(b) Velocity distribution for viscous flow.

Since the element does not accelerate, this force must just balance this viscous retarding force at the surface of this element. The force is given by Eq. (4.5), but since the velocity does not vary uniformly with distance form the enter, v/l must be replaced in this expression with -dv/dr, where dv is the small change of velocity when we go from distance r to r + dr from the axis. The negative sign must be introduced because v decreases as r increases. The area over which the viscous force acts is A=2πrL. Thus, the viscous force is

$$F = -\eta 2\pi r L \frac{dv}{dr}.$$

Equating this to the net force due to pressure on the ends and rearranging, we find that

$$\frac{dv}{dr} = \frac{(p_1 - p_2)r}{2\eta L}$$

This relation shows that the velocity changes more and more rapidly as going from the center (r = 0) to the pipe wall (r = R). Integrating, can find

$$-\int_v^0 dv = \frac{p_1 - p_2}{2\eta L}\int_r^R r dr$$

and

$$v = \frac{p_1 - p_2}{4\eta L}(R^2 - r^2) \qquad (4.7)$$

The velocity decreases from the maximum value $(p_1 - p_2)\, R^2/4\eta L$ at the center to zero at the wall. Thus, the maximum velocity is proportional to the pressure change per unit length $(p_1 - p_2)/L$, called the pressure gradient. The curve in **Figure 4.6b** is a graph of Eq. (4.7) with the v-axis horizontal and the r-axis is vertical.

Eq. (4.7) can be used to find the total rate of fluid flow through the pipe. Note that the velocity at each point is proportional to the pressure gradient $(p_1 - p_2)/L$, so the total flow rate must also be proportional to this quantity. Now consider a thin-walled fluid element in **Figure 4.6c**. The volume of fluid *dV* crossing the ends of this element in a time *dt* is *v dA dt*, where v is the velocity at the radius r and *dA* is the shaded area, equal to 2πr *dr*. Taking the expression for v from Eq. (4.7), to get

$$dV = \frac{p_1 - p_2}{4\eta L}(R_2 - r_2)2\pi r dr\, dt.$$

The volume flowing across the entire cross section is obtained by integrating over all elements between r=0 and r=R:

$$dV = \frac{\pi(p_1 - p_2)}{2\eta L}\int_0^R (R^2 - r^2) r dr\, dt$$

$$= \frac{\pi}{8}\frac{R^4}{\eta}\frac{p_1 - p_2}{L} dt.$$

The total volume of flow per unit time, *dV/dt*, is given by

$$\frac{dV}{dt} = \frac{\pi}{8}\frac{R^4}{\eta}\frac{p_1 - p_2}{L}$$

This relation was derived first by Poiseuille and is called **Poiseuille's law**. It shows that the volume rate flow is inversely proportional to viscosity, as might be expected. The volume flow rate is also proportional to the pressure gradient along the pipe, and it varies as the fourth power of the radius.

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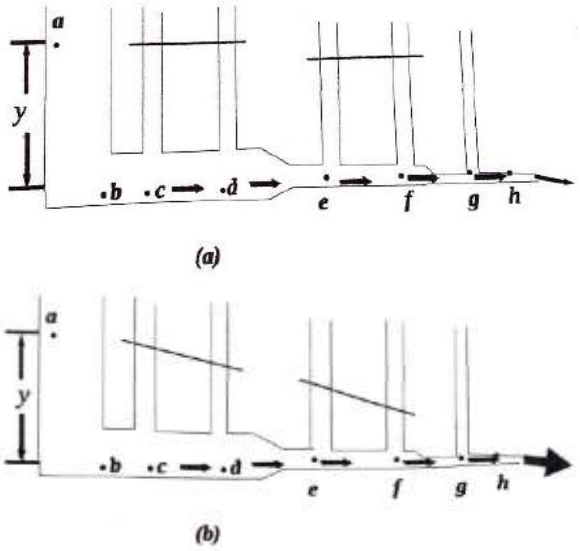


Figure 4.9 *Pressures along a horizontal tube in which is flowing (a) an ideal fluid (b) a viscous fluid.*

In a part ***(a)***, the fluid has no viscosity. The pressure at *b* is very nearly the state pressure *ρgy*, since the velocity is small in the large tank. The pressure at *c* is less than at *b* because the fluid must accelerate between these points. The pressure at *c* and *d* are equal, however, since the velocity and elevation of these points are the same. Further pressure drops occur between *d* and *e*, and between *f* and *g*. The pressure at g is atmospheric, and the gauge pressure at this point is zero.

Figure 4.9b shows the effect of viscosity. Again, the pressure at b is nearly the static pressure *ρgy*. The pressure drops from b to c, due now in part to viscous effects, and there is a further drop from *c* to *d*. The pressure gradient in this part of the tube is represented by the slope of the dotted line. The drop from *d* to *e* results in part from acceleration and is in part from viscosity. The pressure gradient between e and f is greater than between *c* and *d* because of the smaller radius in this point. Finally, the pressure at *g* is somewhat above the atmospheric, since there is now a pressure gradient between this point and the end of the tube.

One more useful relation in viscous fluid flow is the expression for the force F exerted on a sphere of radius *r* moving with speed *v* through a fluid with viscosity $\boldsymbol{\eta}$. This relation is called Stokes's Law and is as follows:

$$\mathbf{F_d} = -6\pi\eta \mathbf{r} \mathbf{V_t} \qquad (4.10)$$

Where $\mathbf{F_d}$ is the drag force of the fluid on a sphere, $\boldsymbol{\eta}$ is the fluid viscosity, **Vt** is the terminal velocity of the sphere relative to the fluid, and **r** is the radius of the sphere. Using this equation, we can now write an expression that describes the rate at which the sphere falls through a quiescent, viscous fluid. To start with, we must draw a free body diagram (FBD) of the sphere. That is, we must sketch the sphere and all of the internal and external forces acting on the sphere as it is dropped into the fluid.

Figure 4.14 illustrates a sketch of the entire system (sphere dropping through a column of liquid). The FBD in this figure has three forces acting on the sphere; $\mathbf{F_b}$, $\mathbf{F_d}$, and **mg**. The first two forces arise from the buoyancy effect of displacing the fluid in question, and from the viscous drag of the fluid on the sphere, respectively. Both forces act upwards-buoyancy tending to 'float' the sphere ($\mathbf{F_b}$) and the drag force ($\mathbf{F_d}$) resisting the acceleration of gravity. The only force acting downwards is the body force resulting from gravitational attraction (**mg**). By assuming forces in the vertical direction, we can write the following equation,

$$F_b + F_d = mg \qquad (4.11)$$

Stokes's law: "The force on a sphere moving through a viscous fluid is proportional to its speed, its radius, and the viscosity."

A sphere falling in a viscous fluid reaches a terminal velocity v_T at which the viscous retarding force plus the buoyant force equals the weight of the sphere. Let **ρ** be the density of the sphere and **ρ'** the density of the liquid. The weight of the sphere is then $(4/3)(\pi r^3 \rho g)$, and the buoyant force is $F_b = m_{df} = (4/3)(\pi r^3 \rho' g)$; when the terminal velocity is reached, the total force is zero, and

$$\frac{4}{3}\pi r^3 \rho_f g + 6\pi \eta r V_t = mg \qquad (4.12)$$

Rearranging and regrouping the terms from the above equation we arrive at the following relationship,

$$\eta = 2r^2 (\rho_s - \rho_f)/9 V_t \qquad (4.13)$$

where η is the viscosity, **r** is the radius of the sphere, ρ_s is the density of the sphere, ρ_f is the density of the fluid, and **Vt** is the terminal velocity of an object moving through the fluid.

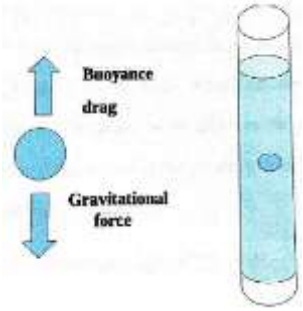


Figure 4.14 *A sketch of the sphere dropping through a column of liquid.*

Effect of Temperature upon Viscosity

The viscosity of a fluid is much affected by the temperature of a fluid. Rise in temperature greatly reduces the viscosity of most liquids. These effects are of evident industrial importance *(White: 1940, p. 167).*

Drag Force

The viscous force that opposes the motion of an object relative to a fluid is often called as the drag force.

The drag force acting on an object moving relative to a fluid depends on whether the flow of the fluid is laminar or turbulent. If laminar, the drag force of increases approximately in proportion to the object's speed relative to the fluid:

$$F_d = D_v,$$

where **D** is the constant. For the situation where a spherical object of radius r falls at speed v through a liquid with viscosity η, the drag force for laminar flow is $F_d = 6\pi \eta r V_t$

The Correction Factor

Equation 4.13 shows the relation between the viscosity of a liquid and the terminal velocity of a sphere falling within it. Having a finite container volume necessitate the modification of equation 4.13 to correct for the effects on the viscosity of the sphere due to its interaction with cylinder walls. For this reason, you must correct for the diameter interaction using the following relationship:

$$W=[1-(2.104d/D)+ 2.09 (d/D)^3 – 0.95 (d/D)^5]$$

where the diameter of the sphere and D is the diameter of the cylinder of the falling sphere viscometer. Therefore, eq. 4.8 becomes

$$\eta c = 2r^2 (\rho_s - \rho_f) W/9 V_t$$

(Shearer and Hudson, Lab. No. 3, Caburog 2013).

CONSTRUCTION GUIDE

Materials:

Rip saw
Adhesive tape (mighty bond)
Transparent hose
Wood
Tape measures (4pcs)
Rubber footing
Paint (optional)

Procedure:

1. Gather all the materials.
2. Construct a wooden stand (as shown in the figure below).
3. Mount the (1"x1"x1.44m) wood on the center of the (1"x 2"x1.93m) wood using nails which serve as a wooden stand.
4. Attach the transparent hose in the wood.
5. Apply adhesive tape (glue) on the wooden stand to hold the hose vertically.
6. Cover the bottom of the hose with a rubber stopper tightly.
7. Glue also the measuring tape (s) along the side of the hose.
8. **Figure 4.1** shows the diagram of the Locally-made Viscosity Apparatus (Viscometer)

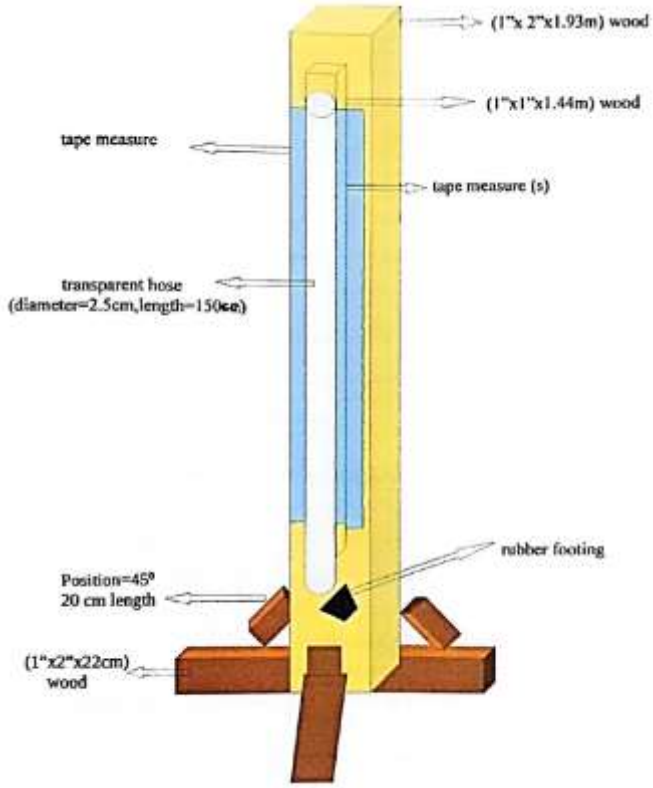


Figure 4.15 *Locally-made Viscosity Apparatus (Viscometer)*

Experiment Guide

Objectives:

1. To determine the viscosity of a certain liquid.
2. To determine the terminal velocity of a falling object.

Materials:

Beaker
Marble (or any spheres) 2pcs
Motor oil (SAE 10)
Weighing scale
Vernier caliper
Stopwatch
Locally-made Viscosity Apparatus
Pure Coconut oil
Corn Syrup
Wings
Surf
Thermometer

Theory:

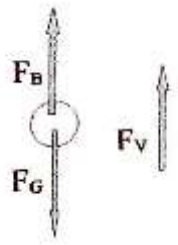
Viscosity is a kind of internal friction that prevents neighboring layers of the fluid sliding freely past one another. Different fluids offer different degrees of resistance to the motion.

Viscosity is defined as η =stress/strain velocity:
Stress = F/A
Strain velocity =v/L

$$\eta = \frac{F/A}{V/L} = \frac{F/L}{AV}$$

where: F= Av η/L = 6$\pi r v \eta$

Measuring the viscosity of a liquid, a sphere of radius r and density ρ is falling in a liquid of viscosity η and density ρL will reach its terminal velocity when its acceleration is equal to zero.



Weight of falling ball:
$F_G = mg = \rho Vg = \rho\,(4/3)\,\pi r^3 g$

Weight of displaced liquid:
$F_B = \rho_L Vg = \rho_L\,(4/3)\,\pi r^3 g$

Stokes Law states that in laminar flow, a sphere of radius r falling /moving in a liquid of viscosity η experiences a force Fv =6$\pi r v \eta$.

So, the total force exerted on the sphere or ball will be:

$$ma = F_G - F_B - F_V$$
$$m\,(0) = \rho\,(4/3)\,\pi r^3 g - \rho_L\,(4/3)\,\pi r^3 g - 6\pi r v \eta$$
$$6\pi r v \eta = (4/3)\,\rho \pi r^3 g - (4/3)\,\rho_L \pi r^3 g$$
$$\eta = (2/9)\,r^2 g\,(\rho_m - \rho_L)\,/V_T$$

To correct the effects on the viscosity of the sphere due to interaction with cylinder walls. Thus, the viscosity becomes

$$\eta_c = 2r^2\,(\rho_s - \rho_f)\,gW/9V_t$$

Procedure:

1. Measure the diameter of the marble or any sphere using vernier caliper (**d**). Then, weight it for its mass (**m_s**).
2. Compute the density of the sphere,
   $\rho s = m_s / v$

   $$Vs = (4/3)\,\pi r^3$$
3. Measure the diameter of the cylinder tube of the falling sphere viscometer. Then, record as (**D**).
4. Get the correction factor (W).

$$W=[1-(2.104d/D)+ 2.09\,(d/D)^3 - 0.95\,(d/D)^5]$$

5. Weigh the beaker. Then pour the liquid (oil, SAE 10) on the beaker. Record the volume (v).
6. Again, measure the mass of the liquid (oil, SAE 10).
7. Get the density of the liquid (oil, SAE 10). $\rho_f = m/v$
8. Pour the liquid (oil, SAE 10) on the hose.
9. Drop the sphere and observe at what distance it will travel with a constant speed.
10. Mark the distance where it reaches its terminal velocity (speed remains constant).
11. Assume a distance (**x**) from the identified point (terminal velocity-where a constant speed of the sphere starts) to get the fall time of the sphere.
12. Drop again the sphere and record the time it falls from the mark distance (**x**) until it reaches the bottom. (**t**)
13. Compute the terminal speed $V_T = x/t$.
14. Compute for the viscosity using the formula:

$$\eta = 2r^2 (\rho_m - \rho_L)\, gW/9V_T$$

15. Do ten (10) trials.
16. Repeat procedures 1 to 12, for other distances (x).
17. Compute its percentage error. (intended to liquids having a known viscosity value (ηc)).

$$percentage\ error = \frac{(accepted\ value - experimental\ value)}{accepted\ value} x\ 100$$

RESULTS AND ANALYSIS

This section discussed the results of the measurements of viscosity made with the locally-made viscometer apparatus. The data were presented in every table. The first part was the test results of the reliability of the viscometer apparatus using the motor oil, SAE 10. The second part was the different experiments of the different available liquids such as Kar Light Corn Syrup, Pure Coconut Oil, Surf Dish-washing Liquid, and Wings Dish-washing Liquid.

Measurements of the densities of the chosen different liquids were presented in **Table 4A**.

***Table 4A**. Different Liquids and Their Densities*

Liquids	Density (g/cm3)
Motor Oil, SAE 10	0.858
(Karo) Light Corn Syrup	1.34
Pure Coconut Oil	0.904
Surf Dish-washing Liquid (A)	1.05
Wings Dish-washing Liquid (B)	1.02

***Table 4B**. Different Symbols used in the Table*

SYMBOL	MEANING
x	Distance traveled by the sphere through the fluid at time t
d	Diameter of the sphere
ρ_s	Density of the sphere
V_T	Terminal velocity of the sphere
η_c	Viscosity

A. Test Results for the Reliability of the Apparatus

Theoretically, the viscosity of the motor oil, SAE 10 is 0.200 Pa.s or 2.00 g.s/cm at 300C. *(Heuvelen, 1986)*

Table 4.1a- 4.1f showed the data for motor oil, SAE 10. Its viscosity was measured using three spheres (particularly, a marble) with a density of 2.58 g/cm3, and 2.80 g/cm3 and a diameter of 1.680 cm, 1.635 cm, respectively. Ten trials were taken for each of the distances 20.0cm, 40.0 cm and 60.0 cm.

The viscosity of motor oil, SAE 10 was calculated using the data from **Tables 4.1a-4.1f.** Sample calculations in getting the corrected viscosity, variance, and standard deviation, were presented below.

A. MOTOR OIL, SAE 10

Table 4.1a *Viscosity of SAE 10 at* ***x = 20.0 cm*** *using a sphere having a diameter of* ***d = 1.680 cm*** *and a density of* ρ_s **= 2.58 g/cm^3**

Trial	Falling time (t) (s)	V_T (cm/s)	η_c (g.s/cm)	%error
1	1.67	12.0	2.1	5.0
2	1.51	13.2	1.9	5.0
3	1.54	13.0	1.9	5.0
4	1.58	12.7	1.9	5.0
5	1.48	13.5	1.8	10.0
6	1.58	12.7	1.9	5.0
7	1.68	11.9	2.1	5.0
8	1.59	12.6	2.0	0.0
9	1.62	12.3	2.0	0.0
10	1.75	11.4	2.2	10.0
		Average	**2.0**	**5.0%**

Variance =0.014 **Standard Deviation =0.118**

Sample Computation :

Trial 1

$t = 1.67$ s
$x = 20.0$ cm
$d = 1.680$ cm
$\rho_s = 2.58$ g/cm^3
$\rho_f = 0.858$ g/cm^3
$g = 980$ cm/s2
$W = 0.09$

$V_T = x/t$
$= 20.0$ cm$/1.67$ s
$= 12.0$ cm/s

$$\% \text{ error} = \frac{2.0\, g.s/cm - 2.1\, g.s/cm}{2.0\, g.s/cm}$$

$= 5.0\%$

Calculation for Viscosity:

$$\eta = 2 r^2 (\rho_s - \rho_f) g W / 9V_T$$

$$\eta_c = \frac{(2(0.5720^2 (2.58-0.858)*980*0.09)}{(9*12.0)}$$

$= 2.1$ g.s/cm

$$W = [1-(2.104 d/D)+2.09(d/D)^3-0.95(d/D)^5]$$

$$= [\ 1-(2.104)(1.680/2.54) + 2.09\ (1.680/2.54)^3 - 0.95\ (1.680/2.54)^5\ ]$$

$W = 0.0929$

Calculation for Variance:

$$\sigma^2 = \Sigma(X-X)^2/N$$

$$\sigma^2 = [\ (2.05-1.97)^2 + (1.86-1.97)^2 + (1.89-1.97)^2 + (1.94-1.97)^2 + (1.82-1.97)^2 + (1.94-1.97)^2 + (2.06-1.97)^2 + (1.95-1.97)^2 + (1.99-1.97)^2 + (2.15-1.97)^2 /10$$

$\sigma^2 = 0.014$

Calculation for Standard Deviation:

$$\sigma = \sqrt{0.014}$$

$\sigma = 0.118$

Table 4.1b *Viscosity of SAE 10 at* ***x = 40.0 cm*** *using a sphere having a diameter of* ***d = 1.680 cm*** *and a density of* ρ_s **= 2.58 g/cm^3**

Trial	Falling time (t) (s)	V_T (cm/s)	η_e (g.s/cm)	%error
1	3.14	12.7	1.9	5.0
2	3.16	12.7	1.9	5.0
3	3.51	11.4	2.2	9.1
4	3.52	11.4	2.2	9.1
5	3.20	12.5	2.0	0.0
6	3.24	12.3	2.0	0.0
7	3.19	12.5	2.0	0.0
8	3.08	13.0	1.9	5.0
9	3.21	12.5	2.0	0.0
10	3.11	12.9	1.9	5.0
		Average	**2.0**	**3.8%**

Variance =0.012 **Standard Deviation =0.110**

Table 4.1c *Viscosity of SAE 10 at* ***x = 60.0 cm*** *using a sphere having a diameter of* ***d = 1.680 cm*** *and a density of* ρ_s **= 2.58 g/cm^3**

Trial	Falling time (t) (s)	V_T (cm/s)	η_e (g.s/cm)	%error
1	4.40	13.6	1.8	10.0
2	4.57	13.1	1.9	5.0
3	4.43	13.5	1.8	10.0
4	4.76	13.6	2.0	0.0
5	4.46	13.5	1.8	10.0
6	4.54	13.2	1.9	5.0
7	4.43	13.5	1.8	10.0
8	4.68	13.8	1.9	5.0
9	4.45	13.5	1.8	10.0
10	4.60	13.0	1.9	5.0
		Average	**1.9**	**7.0%**

Variance = 0.006 **Standard Deviation =0.077**

Table 4.1d *Viscosity of SAE 10 at* ***x = 20.0 cm*** *using a sphere having a diameter of* ***d = 1.635 cm*** *and a density of* ρ_s **= 2.80 g/cm^3**

Trial	Falling time (t) (s)	V_T (cm/s)	η_e (g.s/cm)	%error
1	1.51	13.2	2.1	5.0
2	1.53	13.1	2.1	5.0
3	1.37	14.6	1.9	5.0
4	1.53	13.1	2.1	5.0
5	1.48	13.5	2.1	5.0
6	1.43	14.0	2.0	0.0
7	1.53	13.1	2.1	5.0
8	1.43	14.0	2.0	0.0
9	1.56	12.8	2.2	10.0
10	1.34	14.9	1.9	5.0
		Average	**2.1**	**4.5%**

Variance =0.011 **Standard Deviation =0.105**

Table 4.1e *Viscosity of SAE 10 at* ***x = 40.0 cm*** *using a sphere having a diameter of* ***d = 1.635 cm*** *and a density of* ρ_s **= 2.80 g/cm^3**

Trial	Falling time (t) (s)	V_T (cm/s)	η_e (g.s/cm)	%error
1	2.80	14.3	1.9	5.0
2	2.64	15.2	1.8	10.0
3	2.84	14.1	2.0	0.0
4	2.66	15.0	1.8	10.0
5	2.76	14.5	1.9	5.0
6	2.77	14.4	1.9	5.0
7	2.70	14.8	1.9	5.0
8	2.64	15.2	1.8	10.0
9	2.74	14.6	1.9	5.0
10	3.03	13.2	2.1	5.0
		Average	**1.9**	**6.0%**

Variance =0.008 **Standard Deviation =0.089**

Table 4.1f *Viscosity of SAE 10 at* ***x = 60.0 cm*** *using a sphere having a diameter of* ***d = 1.635 cm*** *and a density of* ρ_s ***= 2.80 g/cm^3***

Trial	Falling time (t) (s)	V_T (cm/s)	η_c (g.s/cm)	%error
1	4.11	14.6	1.9	5.0
2	3.91	15.3	1.8	10.0
3	3.96	15.2	1.8	10.0
4	3.91	15.3	1.8	10.0
5	4.54	13.2	2.1	5.0
6	4.18	14.4	1.9	5.0
7	4.11	14.6	1.9	5.0
8	3.99	15.0	1.8	10.0
9	3.93	15.3	1.8	10.0
10	4.07	14.7	1.9	5.0
		Average	**1.9**	**7.5%**

Variance =0.009 **Standard Deviation =0.095**

Table 4.1g *Viscosity of motor oil, SAE 10 at different distances using two spheres.*

Distance (cm)	d_s = 1.680 cm, ρ_s = 2.58 g/cm^3			d_s = 1.635 cm, ρ_s = 2.80 g/cm^3		
	Viscosity (g.s/cm)	% error	STDev	Viscosity (g.s/cm)	% error	STDev
20	2.0	5.0%	0.118	2.1	4.5%	0.105
40	2.0	3.8%	0.110	1.9	6.0%	0.089
60	1.9	7.0%	0.077	1.9	7.5%	0.095
Average	**2.0**	**5.3%**		**2.0**	**6.0%**	

In performing the viscosity, the researcher was assisted by the two third year BS Physics students.

This experiment was done to test the accuracy and reliability of the locally-constructed viscometer apparatus. To determine if this would work according to its physics principles of viscosity (viscous liquid) and would give better results (less error would be able to take place). The researcher used the motor oil, SAE 10 in testing the viscometer apparatus because it had already a value of viscosity which is

0.200 Pa.s or 2.00 g.s/cm at 30ºC. Here, the experiment results of the viscosity were compared to its theoretical value to determine if it gave approximately equal results on its values.

Ideally, motor oil like SAE 10 is an oil used for lubrication of various internal combustion engines. Viscosity property of motor oil was important in maintaining a lubricating film between moving parts. Thus, the viscosity must be high enough to maintain a lubricating film, but low enough that the oil could flow around the engine parts under all conditions.

Table 4.1g summarized the viscosity of motor oil, SAE 10 for three (3) distances having three different spheres. Hence, it had assumed its constant speed of the sphere where the measurements of the fall time of the sphere started. Using the sphere of a density equal to 2.58 g.s/cm^3 and a diameter equal to1.680cm, the viscosity of SAE 10 had an average value of 2.0 g.s/cm^3. Comparing the result from it expected value SAE 10, it showed a percentage error of 5.3%.

Using the other sphere of a density equal to 2.80 g.s/cm^3 and a diameter equal to 1.635 cm, its viscosity had ana average value of 2.0 g.s/cm^3 and got a percentage error of 6.0%.

Apparently, the results of experiment performed using those different spheres in viscometer apparatus showed a low percentage error. The experimental result got an approximately equal value of viscosity to the expected value. This indicated that it was accurate and reliable.

Error was experienced in this kind of experiment first of all because of the limitation of the said apparatus since it was locally-made. Second, the density of the sphere used. The bigger density the sphere the harder to measure its fall time because its velocity through the liquid was faster. So, its hard to get its accurate time in this experiment. And we know that the time is very important, and it matters most. Lastly, was the ability to distinguish which height corresponds the experiment's terminal velocity.

Thus, the data obtained above proved the accuracy and reliability of the locally-made viscometer apparatus. This implied also that the locally-constructed apparatus could be used in other types of liquids in getting its viscosity value. In fact, other readily available household liquids were used in the experiment to determine also its viscosity like pure coconut oil, light corn syrup, surf dish-washing liquid, and wings active-guard dish-washing liquid.

B. Results of the Experiments

B1. KARO LIGHT CORN SYRUP

Table 4.2a-4.2f show the data for corn syrup. Two spheres with different densities and sizes were used. Ten trials were taken for every distances.

Calculation of its corrected viscosity, variance and standard deviation are the same as that of the Motor Oil, SAE 10.

Table 4.2a *Viscosity of Karo Light Corn Syrup at* ***x = 20.0 cm*** *using a sphere having a diameter of* ***d = 1.680 cm*** *and a density of* ρ_s **= 2.58 g/cm^3**

Trial	Falling time (t) (s)	V_T (cm/s)	η_c (g.s/cm)
1	38.27	0.5	32.1
2	38.58	0.5	32.3
3	38.37	0.5	32.5
4	38.72	0.5	32.4
5	38.44	0.5	32.2
6	38.01	0.5	31.9
7	38.78	0.5	32.5
8	38.83	0.5	32.5
9	38.83	0.5	32.5
10	38.57	0.5	32.3
		Average	**32.3**

Variance =0.038 Standard Deviation =0.195

Table 4.2b *Viscosity of Karo Light Corn Syrup at* ***x = 40.0 cm*** *using a sphere having a diameter of* ***d = 1.680 cm*** *and a density of* ρ_s **= 2.58 g/cm^3**

Trial	Falling time (t) (s)	V_T (cm/s)	η_c (g.s/cm)
1	76.49	0.5	32.1
2	76.53	0.5	32.1
3	76.52	0.5	32.1
4	76.49	0.5	32.1
5	76.55	0.5	32.1
6	76.50	0.5	32.1
7	76.52	0.5	32.1
8	76.55	0.5	32.1
9	76.54	0.5	32.1
10	76.50	0.5	32.1
		Average	**32.1**

Variance =0.000 Standard Deviation =0.000

Table 4.2c *Viscosity of Karo Light Corn Syrup at* ***x = 60.0 cm*** *using a sphere having a diameter of* ***d = 1.680 cm*** *and a density of* $\rho_s = 2.58\ g/cm^3$

Trial	Falling time (t) (s)	V_T (cm/s)	η_c (g.s/cm)
1	116.10	0.5	32.4
2	116.00	0.5	32.4
3	116.05	0.5	32.4
4	116.19	0.5	32.5
5	116.29	0.5	32.5
6	116.63	0.5	32.6
7	116.95	0.5	32.7
8	116.45	0.5	32.5
9	116.74	0.5	32.6
10	116.28	0.5	32.5
		Average	**32.5**

Variance =0.009 Standard Deviation =0.095

Table 4.2d *Viscosity of Karo Light Corn Syrup at* ***x = 20.0 cm*** *using a sphere having a diameter of* ***d = 1.635cm*** *and a density of* $\rho_s = 2.80\ g/cm^3$

Trial	Falling time (t) (s)	V_T (cm/s)	η_c (g.s/cm)
1	30.88	0.7	32.2
2	30.88	0.7	32.2
3	30.86	0.7	32.2
4	30.85	0.7	32.2
5	30.84	0.7	32.1
6	30.85	0.7	32.1
7	30.87	0.7	32.2
8	30.87	0.7	32.2
9	30.85	0.7	32.2
10	30.82	0.7	32.1
		Average	**32.2**

Variance =0.003 Standard Deviation =0.055

Table 4.2e *Viscosity of Karo Light Corn Syrup at* ***x = 40.0 cm*** *using a sphere having a diameter of* ***d = 1.635cm*** *and a density of* $\rho_s = 2.80\ g/cm^3$

Trial	Falling time (t) (s)	V_T (cm/s)	η_e (g.s/cm)
1	61.60	0.6	32.1
2	61.66	0.6	32.1
3	61.60	0.6	32.1
4	61.65	0.6	32.1
5	61.65	0.6	32.1
6	61.62	0.6	32.1
7	61.59	0.6	32.1
8	61.60	0.6	32.1
9	61.64	0.6	32.1
10	61.63	0.6	32.1
		Average	**32.1**

Variance =0.000 Standard Deviation =0.000

Table 4.2f *Viscosity of Karo Light Corn Syrup at* ***x = 60.0 cm*** *using a sphere having a diameter of* ***d = 1.635cm*** *and a density of* $\rho_s = 2.80\ g/cm^3$

Trial	Falling time (t) (s)	V_T (cm/s)	η_e (g.s/cm)
1	94.88	0.6	33.0
2	94.33	0.6	32.8
3	94.32	0.6	33.0
4	94.86	0.6	32.9
5	94.74	0.6	33.0
6	94.89	0.6	32.9
7	94.69	0.6	32.9
8	94.83	0.6	32.9
9.	94.18	0.6	32.7
10	94.77	0.6	32.9
		Average	**32.9**

Variance =0.008 Standard Deviation =0.089

Table 4.2g *Viscosity of Karo Light Corn Syrup at different distances using two spheres.*

Distance (cm)	Sphere diameter (d_s) = 1.680 cm Sphere density (ρ_s) = 2.58 g/cm^3		Sphere diameter (d_s) = 1.635 cm Sphere density (ρ_s) = 2.80 g/cm^3	
	Viscosity (g.s/cm)	STDev	Viscosity (g.s/cm)	STDev
20	32.3	0.195	32.2	0.055
40	32.1	0.000	32.1	0.000
60	32.5	0.095	32.9	0.089
Average	**32.3**		**32.4**	

Table 4.2g showed the viscosity of Karo Light Corn Syrup at different distances using two different spheres. Using the sphere of density 2.58 g.s/cm^3, its viscosity value obtained was 32.3 g/cm while using the sphere of density 2.80 g.s/cm^3 , was 32.4 g/cm.

Notice the two results in every distance of each sphere, there was a slight difference between the viscosity values since its standard deviation was small. This occurred due to some errors in the measurements of a fall time for each sphere.

B2. PURE COCONUT OIL

The data for Pure Coconut Oil were shown in **tables 4.3a-4.3f**. Its viscosity was determined for three (3) distances 20.0 cm, 40.0cm, and 60.0 cm taking ten trials for each distance of each of the two spheres.

Table 4.3a: *Viscosity of Pure Coconut Oil at* ***x = 20.0 cm*** *using a sphere having a diameter of* ***d = 1.680 cm*** *and a density of* $\rho_s = 2.58\ g/cm^3$

Trial	Falling time (t) (s)	V_T (cm/s)	η_c (g.s/cm)
1	1.10	18.2	1.2
2	1.11	18.0	1.3
3	1.13	17.7	1.3
4	1.08	18.5	1.2
5	1.11	18.0	1.3
6	1.10	18.2	1.2
7	1.12	17.9	1.3
8	1.12	17.9	1.3
9	1.08	18.5	1.2
10	1.12	17.9	1.3
		Average	**1.3**

Variance =0.004 **Standard Deviation =0.063**

Table 4.3b *Viscosity of Pure Coconut Oil at* ***x = 40.0 cm*** *using a sphere having a diameter of* ***d = 1.680 cm*** *and a density of* $\rho_s = 2.58\ g/cm^3$

Trial	Falling time (t) (s)	V_T (cm/s)	η_c (g.s/cm)
1	2.22	18.0	1.3
2	2.25	17.8	1.3
3	2.22	18.0	1.3
4	2.18	18.4	1.2
5	2.22	18.0	1.3
6	2.17	18.4	1.2
7	2.23	17.9	1.3
8	2.22	18.0	1.3
9	2.21	18.1	1.3
10	2.17	18.4	1.2
		Average	**1.3**

Variance =0.003 **Standard Deviation =0.055**

Table 4.3c *Viscosity of Pure Coconut Oil at* ***x = 60.0 cm*** *using a sphere having a diameter of* ***d = 1.680 cm*** *and a density of* $\rho_s = 2.58\ g/cm^3$

Trial	Falling time (t) (s)	V_T (cm/s)	η_c (g.s/cm)
1	3.28	18.3	1.2
2	3.27	18.3	1.2
3	3.30	18.2	1.2
4	3.33	18.0	1.3
5	3.36	17.9	1.3
6	3.34	18.0	1.3
7	3.31	18.1	1.2
8	3.34	18.0	1.3
9	3.33	18.0	1.3
10	3.30	18.2	1.2
		Average	**1.3**

Variance =0.005 Standard Deviation =0.071

Table 4.3d *Viscosity of Pure Coconut Oil at* ***x = 20.0 cm*** *using a sphere having a diameter of* ***d = 1.635cm*** *and a density of* $\rho_s = 2.80\ g/cm^3$

Trial	Falling time (t) (s)	V_T (cm/s)	η_c (g.s/cm)
1	0.95	21.1	1.3
2	0.94	21.3	1.3
3	0.90	22.2	1.2
4	0.91	22.0	1.2
5	0.94	21.3	1.3
6	0.93	21.5	1.3
7	0.90	22.2	1.2
8	0.91	22.0	1.2
9	0.98	20.4	1.3
10	0.90	22.2	1.2
		Average	**1.3**

Variance =0.005 Standard Deviation =0.071

Table 4.3e *Viscosity of Pure Coconut Oil at* ***x = 40.0 cm*** *using a sphere having a diameter of* ***d = 1.635cm*** *and a density of* $\rho_s = 2.80\ g/cm^3$

Trial	Falling time (t) (s)	V_T (cm/s)	η_c (g.s/cm)
1	1.85	21.6	1.3
2	1.87	21.4	1.3
3	1.85	21.6	1.3
4	1.85	21.6	1.3
5	1.84	21.7	1.2
6	1.84	21.7	1.2
7	1.89	21.2	1.3
8	1.88	21.3	1.3
9	1.84	21.7	1.2
10	1.85	21.6	1.3
		Average	**1.3**

Variance =0.003 Standard Deviation =0.055

Table 4.3f *Viscosity of Pure Coconut Oil at* ***x = 60.0 cm*** *using a sphere having a diameter of* ***d = 1.635cm*** *and a density of* $\rho_s = 2.80\ g/cm^3$

Trial	Falling time (t) (s)	V_T (cm/s)	η_c (g.s/cm)
1	2.76	21.7	1.2
2	2.75	21.8	1.2
3	2.78	21.6	1.3
4	2.74	21.9	1.2
5	2.75	21.8	1.2
6	2.79	21.6	1.3
7	2.78	21.5	1.3
8	2.79	21.6	1.3
9	2.80	21.4	1.3
10	2.82	21.3	1.3
		Average	**1.3**

Variance =0.004 Standard Deviation =0.063

Table 4.3g *Viscosity of Pure Coconut Oil at different distances using two spheres.*

Distance (cm)	Sphere diameter (d_s) = 1.680 cm Sphere density (ρ_s) = 2.58 g/cm^3		Sphere diameter (d_s) = 1.635 cm Sphere density (ρ_s) = 2.80 g/cm^3	
	Viscosity (g.s/cm)	STDev	Viscosity (g.s/cm)	STDev
20	1.3	0.063	1.3	0.071
40	1.3	0.055	1.3	0.055
60	1.3	0.071	1.3	0.063
Average	**1.3**		**1.3**	

The above table summarized the data from **tables 4.3a-4.3e**. It presented the viscosity of pure coconut oil for every distance of each sphere. It revealed that using the two different spheres densities, the average results were the same, having a viscosity of 1.3 g/cm.

Table 4.3f shown that there was a slight difference between the values for every distance of each sphere with respect to the trials taken. The variation of the results was due to some error in the measurement of the fall time of each sphere.

B3. SURF DISH-WASHING LIQUID

Tables 4.4a-4.4f presented the data for Surf Dish-Washing Liquid. There were three (3) distances chosen and two spheres of different densities were used in determining its viscosity for each distance. Ten trials were also taken for each sphere.

Table 4.4a *Viscosity of Surf Dish-washing Liquid at* ***x = 20.0 cm*** *using a sphere having a diameter of* ***d = 1.680 cm*** *and a density of* $\rho_s = 2.58\ g/cm^3$

Trial	Falling time (t) (s)	V_T (cm/s)	η_k (g.s/cm)
1	11.27	1.8	11.2
2	11.10	1.8	11.3
3	11.10	1.8	11.4
4	10.90	1.8	11.6
5	10.36	1.9	10.5
6	10.50	1.9	11.3
7	10.81	1.9	10.8
8	10.50	1.9	11.5
9	10.22	2.0	11.4
10	10.50	1.9	11.4
		Average	**11.2**

Variance =0.104 Standard Deviation =0.322

Table 4.4b *Viscosity of Surf Dish-washing Liquid at* ***x = 40.0 cm*** *using a sphere having a diameter of* ***d = 1.680 cm*** *and a density of* $\rho_s = 2.58\ g/cm^3$

Trial	Falling time (t) (s)	V_T (cm/s)	η_k (g.s/cm)
1	21.20	1.9	11.4
2	21.60	1.9	11.3
3	21.53	1.9	11.3
4	21.33	1.9	11.2
5	21.76	1.8	11.3
6	20.96	1.9	11.3
7	21.06	1.9	11.1
8	21.12	1.9	11.3
9	21.76	1.8	10.6
10	21.22	1.9	10.5
		Average	**11.1**

Variance =0.091 Standard Deviation =0.302

Table 4.4c *Viscosity of Surf Dish-washing Liquid at* ***x = 60.0 cm*** *using a sphere having a diameter of* ***d = 1.680 cm*** *and a density of* $\rho_s = 2.58\ g/cm^3$

Trial	Falling time (t) (s)	V_T (cm/s)	η_c (g.s/cm)
1	32.13	1.9	11.4
2	32.69	1.8	11.5
3	32.13	1.9	11.5
4	32.13	1.9	11.1
5	32.85	1.8	10.8
6	32.20	1.9	11.2
7	31.43	1.9	11.2
8	31.39	1.9	10.8
9	31.78	1.9	10.8
10	31.46	1.9	10.8
		Average	**11.1**

Variance =0.079 Standard Deviation =0.281

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Table 4.4d *Viscosity of Surf Dish-washing Liquid at* ***x = 20.0 cm*** *using a sphere having a diameter of* ***d = 1.635 cm*** *and a density of* $\rho_s = 2.80\ g/cm^3$

Trial	Falling time (t) (s)	V_T (cm/s)	η_c (g.s/cm)
1	8.95	2.24	11.7
2	9.05	2.21	11.5
3	9.15	2.19	11.5
4	8.52	2.35	10.3
5	8.44	2.37	10.7
6	9.02	2.22	10.9
7	8.65	2.31	11.2
8	9.20	2.17	10.9
9	9.15	2.19	10.6
10	9.12	2.19	10.9
		Average	**11.0**

Variance =0.18 Standard Deviation =0.424

Table 4.4e *Viscosity of Surf Dish-washing Liquid at* ***x = 40.0cm*** *using a sphere having a diameter of* ***d = 1.635 cm*** *and a density of* ρ_s **= 2.80 g/cm^3**

Trial	Falling time (t) (s)	V_T (cm/s)	η_c (g.s/cm)
1	18.21	2.2	10.9
2	18.06	2.2	11.2
3	18.03	2.2	11.1
4	17.96	2.2	11.1
5	18.11	2.2	11.2
6	18.01	2.2	10.8
7	17.80	2.3	10.9
8	18.06	2.2	10.9
9	16.93	2.4	11.2
10	16.87	2.4	11.0
		Average	**11.0**

Variance =0.021 Standard Deviation =0.145

Table 4.4f *Viscosity of Surf Dish-washing Liquid at* ***x = 60.0 cm*** *using a sphere having a diameter of* ***d = 1.635 cm*** *and a density of* ρ_s **= 2.80 g/cm^3**

Trial	Falling time (t) (s)	V_T (cm/s)	η_c (g.s/cm)
1	27.45	2.2	11.1
2	27.56	2.2	11.3
3	27.63	2.2	11.1
4	26.25	2.2	11.1
5	26.04	2.3	11.3
6	26.91	2.2	11.1
7	26.85	2.2	10.8
8	26.05	2.3	10.8
9	25.94	2.3	11.0
10	25.92	2.3	10.8
		Average	**11.0**

Variance =0.034 Standard Deviation =0.184

Table 4.4g *Viscosity of Surf Dish-washing Liquid at different distances using two spheres.*

Distance (cm)	Sphere diameter (d_s) = 1.680 cm Sphere density (ρ_s) = 2.58 g/cm^3		Sphere diameter (d_s) = 1.635 cm Sphere density (ρ_s) = 2.80 g/cm^3	
	Viscosity (g.s/cm)	STDev	Viscosity (g.s/cm)	STDev
20	11.2	0.322	11.0	0.424
40	11.1	0.302	11.0	0.145
60	11.1	0.281	11.0	0.184
Average	**11.1**		**11.0**	

The table above presented the results on the viscosity of Surf Dish-Washing Liquid at different distances using two different spheres. Comparing the two viscosity values, its viscosity using the sphere density of 2.58 g.s/cm^3 was bigger compared to that sphere density of 2.80 g.s/cm^3. Here, there was a difference between the results of the two spheres. This could have been resulted dues to some errors in the measurement of the fall time of the sphere. The sphere of a smaller density was not difficult to determine its fall time since it had a lower velocity than the sphere of a greater density.

B4. WINGS ACTIVEGUARD DISH-WASHING LIQUID

Table 4.5a-4.5f show the data for Wings Activeguard Dish-Washing Liquid. Two spheres with different densities and sizes were used. Ten trials were taken for every distances.

The same calculations were done in getting corrected viscosity, variance and standard deviation.

Table 4.5a *Viscosity of Wings Activeguard Dish-washing Liquid at* ***x = 20.0 cm*** *using a sphere having a diameter of* ***d = 1.680 cm*** *and a density of* $\rho_s = 2.58\ g/cm^3$

Trial	Falling time (t) (s)	V_T (cm/s)	η_c (g.s/cm)
1	20.92	1.0	22.1
2	20.93	1.0	22.1
3	20.97	1.0	22.1
4	21.25	0.9	22.4
5	21.07	0.9	22.2
6	20.99	1.0	22.1
7	21.07	1.0	22.2
8	20.86	1.0-	22.0
9	21.09	0.94	22.2
10	20.66	1.0	21.8
		Average	**22.1**

Variance =0.022 Standard Deviation =0.148

Table 4.5b *Viscosity of Wings Activeguard Dish-washing Liquid at* ***x = 40.0cm*** *using a sphere having a diameter of* ***d = 1.680 cm*** *and a density of* $\rho_s = 2.58\ g/cm^3$

Trial	Falling time (t) (s)	V_T (cm/s)	η_c (g.s/cm)
1	43.1	0.9	22.7
2	42.72	0.9	22.5
3	42.73	0.9	22.5
4	41.57	1.0	21.9
5	41.53	1.0	21.9
6	41.59	1.0	21.9
7	42.65	0.9	22.5
8	42.05	1.0	22.2
9	41.60	1.0	21.9
10	41.99	1.0	22.1
		Average	**22.2**

Variance =0.089 Standard Deviation =0.298

Table 4.5c *Viscosity of Wings Activeguard Dish-washing Liquid at* ***x = 60.0 cm*** *using a sphere having a diameter of* ***d = 1.680 cm*** *and a density of* ρ_s ***= 2.58 g/cm3***

Trial	Falling time (t) (s)	V_T (cm/s)	η_c (g.s/cm)
1	62.61	1.0	22.0
2	62.66	1.0	22.0
3	62.54	1.0	22.0
4	62.99	1.0	22.1
5	62.33	1.0	21.9
6	62.26	1.0	21.9
7	62.42	1.0	21.9
8	61.99	1.0	21.8
9	61.97	1.0	21.8
10	62.66	1.0	22.0
		Average	**21.9**

Variance =0.01 Standard Deviation =0.1

Table 4.5d *Viscosity of Wings Activeguard Dish-washing Liquid at* ***x = 20.0 cm*** *using a sphere having a diameter of* ***d = 1.635cm*** *and a density of* ρ_s ***= 2.80 g/cm^3***

Trial	Falling time (t) (s)	V_T (cm/s)	η_c (g.s/cm)
1	17.78	1.1	22.6
2	17.62	1.1	22.4
3	17.75	1.1	22.6
4	18.04	1.1	22.9
5	17.75	1.1	22.6
6	17.68	1.1	22.5
7	16.75	1.2	21.3
8	17.01	1.2	21.6
9	17.10	1.2	21.7
10	16.96	1.2	21.6
		Average	**22.2**

Variance =0.288 Standard Deviation =0.537

Table 4.5e *Viscosity of Wings Activeguard Dish-washing Liquid at* ***x = 40.0 cm*** *using a sphere having a diameter of* ***d = 1.635 cm*** *and a density of* ρ_s ***= 2.80 g/cm^3***

Trial	Falling time (t) (s)	V_T (cm/s)	η_e (g.s/cm)
1	34.88	1.1	22.2
2	35.88	1.1	22.8
3	34.86	1.1	22.1
4	34.88	1.1	22.2
5	34.96	1.1	22.2
6	35.49	1.1	22.5
7	35.01	1.1	22.2
8	35.53	1.1	22.6
9	34.96	1.1	22.2
10	34.88	1.1	22.2
		Average	**22.3**

Variance =0.062 Standard Deviation =0.249

Table 4.5f *Viscosity of Wings Activeguard Dish-washing Liquid at* ***x = 60.0 cm*** *using a sphere having a diameter of* ***d = 1.635 cm*** *and a density of* ρ_s ***= 2.80 g/cm^3***

Trial	Falling time (t) (s)	V_T (cm/s)	η_e (g.s/cm)
1	51.99	1.2	22.0
2	51.73	1.2	21.9
3	51.97	1.2	22.0
4	51.75	1.2	21.9
5	51.71	1.2	21.9
6	51.69	1.2	21.9
7	51.68	1.2	21.9
8	51.90	1.2	21.9
9	51.68	1.2	21.9
10	51.66	1.2	21.9
		Average	**21.9**

Variance =0.08 Standard Deviation =0.283

Table 4.5g *Viscosity of Wings Activeguard Dish-washing Liquid at different distances using two spheres.*

Distance (cm)	Sphere diameter (d_s) = 1.680 cm Sphere density (ρ_s) = 2.58 g/cm^3		Sphere diameter (d_s) = 1.635 cm Sphere density (ρ_s) = 2.80 g/cm^3	
	Viscosity (g.s/cm)	STDev	Viscosity (g.s/cm)	STDev
20	22.1	0.148	22.2	0.537
40	22.2	0.298	22.3	0.249
60	21.9	0.1	21.9	0.283
Average	**22.1**		**22.1**	

Table 4.5g showed the viscosity of Wings Activeguard Dish-Washing Liquid at different distances using two different spheres. Using the sphere having a density of 2.58 g/cm^3, the viscosity was 22.1 g/cm and using the sphere of a density 2.80 g/cm^3, its viscosity also was 22.1 g/cm.

As shown in the table above, there was a difference between the two viscosity values with respect to the spheres used yet, got only a less percent difference. This happened because of the discrepancy in the measurement of a fall time of the spheres. The velocity of the sphere having a smaller density was low compared to the velocity of the sphere with a bigger density. Thus, it's so hard to measure the fall time on the latter and this result to errors.

SUMMARY OF RESULTS FOR DIFFERENT LIQUIDS

The four (4) chosen different liquids used in the experimentation were not modified. They were not mixed with another liquid. Its viscosity coefficients were determined without doing any changes in it. **Table 4.6** showed a summary of viscosity coefficients of the four (4) chosen liquids which were available at home using two different spheres.

Table 4.6 *Different Liquids and Their Viscosities*

Liquids	Sphere diameter (d_s) = **1.680 cm** Sphere density (ρ_s) = **2.58 g.s/cm³**	Sphere diameter (d_s) = **1.635 cm** Sphere density (ρ_s) = **2.80 g.s/cm³**	% diff.
	Viscosity (g.s/cm)	**Viscosity (g.s/cm)**	
Karo Corn Syrup	32.3	32.4	0.31
Pure Coconut Oil	1.3	1.3	0.0
Surf Dishwashing Liquid	11.1	11.0	0.90
Wings Dishwashing Liquid	22.1	22.1	0.0

Table 4.6 presented the different liquids and their viscosities. These different readily available liquids at home have no known viscosity value being identified. Thus, the researchers triggered to measure or determine its viscosity coefficients since Viscometer apparatus had been tested its reliability already.

Based on **Table 4.6**, using two spheres, Pure Coconut Oil and Wings Activeguard Dish-washing liquid got a percentage difference of 0% on its viscosity coefficient. Karo Corn Syrup and Surf Dish-washing liquid had a percentage difference of 0.31% an 0.90% respectively.

The higher the viscosity of a liquid the more it resisted motion of a body through it. This result could be very low in terminal velocity. This was true comparing the two (2) dish-washing liquids (sur dis-washing and wings dish-washing liquids). Wings had a higher viscosity value and low terminal velocity (see **Table 4.41-Table 4.4f**) compared to surf dish-washing liquid (see **Table 4.5a-Table 4.5f**).

Generally, liquids of different viscosities acted differently and therefore had very different application and uses. It was observed that the higher the viscosity value of a liquid, the slower it flows. Any liquids with higher viscosities made smaller splashes when poured at the same velocity just like the Karo Corn syrup experienced.

Noticed also that the viscosity coefficient of the four (4) liquids differed with respect to the spheres used. However, obtained only a less percentage difference. These differences occurred due to the limitations of the set-up. Also, getting the fall time of the sphere through the liquid was done manually. Thus, the spheres fall time in every trial differed. This resulted to error since its viscosity coefficient would vary in every trial.

The viscosity of a liquid decreased as temperature increased as observed by the researcher. Thus, the viscosity of most liquids was affected by temperature.

RECOMMENDATIONS

The viscosity experiment was found to have an error based on the data presented since the experimental results was compared to its theoretical value. This was due to some factors like temperature that may affect the viscosity of a liquid, the reading of the falling time of the spheres, and others.

So, in order to minimize those errors, the researcher recommended that more refined timing in reading the falling time is necessary to get more accurate results. It's better to have three or more persons who would do the reading of the falling time of the sphere to verify the consistency of the time at a constant temperature. The experimentation must be performed in a room to have a constant temperature.

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INEXPENSIVE DESALINATION APPARATUS FOR SMALL ISLAND COMMUNITIES

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ABSTRACT

The researcher constructed an inexpensive desalination apparatus commonly named as passive solar still. It only used the heat coming from the sun to desalinate the seawater. It was found out that this is positively effective in producing drinkable water using seawater water. Using Total Dissolved Salt experiment (TDS) and Electrical Conductivity method (EC) it was proven that the water is distilled and the existence of salt concentration can only be identified as a trace. The apparatus is affordable for the small island communities due to its resources that is being used that can be found only in their locality and everything comes in a low cost. Based on the survey that was conducted in Apo Island, the primary target community of the study it was determined that a passive solar still with a dimension of 2ft by 4ft still can affirmatively support the weekly drinkable water needs of a household with 2 family members in it.

STATEMENT OF THE PROBLEM

The purpose of the study is production of drinkable water in Apo Island using the seawater by performing the procedures of desalination through passive solar still. Specifically, the study aimed to:

1. Construct an apparatus in desalination; namely,
   a. Passive Solar Still Desalination Apparatus
   b. Conductance Meter Apparatus

2. Collect 6 liters of seawater sample in Apo Island and Lazi, Siquijor then measure the salinity of the sample using two methods:
   a. Electrical Conductivity (EC) and,
   b. Total Dissolved Salts (TDS)

3. Conduct a census survey among the residents of Apo Island with respect to the family's amount of weekly water consumption. The data that will be gathered includes volume of the water that they use in drinking.

4. Test the amount of water concentration in the distillate water using Electrical Conductivity Method (EC) and Total Dissolved Salt (TDS).

5. Make desalination experiment guide of passive solar still distillation.

REVIEW OF LITERATURE

Mubasher Ahmed (2016), Freshwater, being vital for mankind survival, has become a very serious concern for the public especially living in countries with limited water, energy and economic resources. Freshwater generation is an energy-intensive task particularly when fossilbased fuels are required as energy source. However, environmental concerns and high energy costs have called for the alternative and renewable sources of energy like wind, hydro, geothermal and solar etc. Since solar is the most sustainable, readily available, abundant, lowcost and maintenance free energy source, it can be the best solution to the water scarcity especially the regions of plentiful sunshine. However, the dominant use of solar energy in passive systems for water treatment requires more research and development. In this work, a literature review is conducted on the application of low cost, passive, solar driven water treatment systems for freshwater production from different contaminated water resources. The review includes water quality parameters for intended reuse, traditional water sources, description and application of alternative water sources, existing water recycling technologies, illustrative account and critical analysis of the passive solar driven water treatment systems. In last section, the three passive solar technologies; solar pasteurization, solar water disinfection and solar water distillation are compared and the best out of three is sorted out based on cost, capacity, production and quality.

Abella (2015), conducted a study about seawater salinity of the twelve coastal Towns and Cities of Southern Negros. The researcher's objective is to construct an easy to operate and inexpensive apparatus in determining salinity, and to measure the salinity of seawater samples by using two methods; Electrical Conductivity (EC) and Total Dissolved Salts (TDS). It was found out that the two methods resulted to almost the same salt concentration. The result shows that Poblacion I, Basay has the highest conductance and salt concentration while Talaban, Himamaylan has the lowest conductance and salt concentration. Concentration against conductance curve and conductance line were created through the use of distilled water and rock salt. The conductivity of the solution was measured, plotted and used to determine salt concentration of Method 2 (Electrical Conductivity). In comparing the results, Method 1 (Total Dissolved Salts) and Method 2 (Electrical Conductivity) obtained a percent difference of less than 10%. An indication that the two methods can be of used in determining salinity and can be substituted to each other. The researcher recommended that more studies about seawater salinity should be done in other places in order to have a better comparison of results since salinity may vary from time to time using locally constructed apparatus to minimize the expenses.

Angana (2016), most of the salt in the sea comes from minerals that are part of the land. When river flow over rocks, minerals get dissolved by the water. Salinity is a measure of the concentration of total dissolved salts in water, mainly sodium chloride. The researcher used two methods in measuring the seawaters' salinity, Total Dissolved Salts (TDS) and Electrical Conductivity (EC). The seawater samples were taken in twelve coastal Municipalities of Southern Cebu from Sibunga to Badian. The concentration obtained in the concentrationconductance curve using the

conductance of the second method which is Electrical Conductivity (EC) method, is slightly similar to the concentration obtained in the first method which used Total Dissolved Salts (TDS). The researcher recommended that we must continue to conduct more studies in measuring seawater salinity so that we don't have to depend anymore on the authorities assigned in geophysical studies.

Resomadero (2015), conducted a study about an experimental determination of some physical properties of seawater samples in seven southern coastal towns of Negros Oriental. The measurement of seawater's physical properties from the seven southern coastal towns of Negros Oriental is useful to people since seawater can be a supplemental drinking water when desalted. The researcher constructed apparatuses namely, Double-walled calorimeter apparatus, conductance meter apparatus, and volume expansion apparatus that were made up out recyclable materials and experiment guides were designed for every property. It was found out that seawater's index of refraction ranges from 1.34 to 1.36. The result of seawater's density ranges from 1.00 g/cm^3 to 1.00g/cm^3. Boiling point of the seawater samples ranges from 74.19 dynes/cm to 76.80 dynes/cm. The seawater's specific heat capacity ranges from 0.93 cal/gCº to 0.96 cal/gCº which is lower than the specific heat capacity of distilled water (1cal/ gCº). In the coefficient of volume expansion, it ranges from 354.53 (1 x 10^{-6}/Cº) to 376.47 (1 x 10^{-6}/Cº). Distilled water has a lower coefficient of volume expansion compared to seawater samples, its conductance is 0.05S.

Gutierrez (2017), the study aims to determine some physical properties of water samples taken from inland bodies of water in Central and Southern Negros Oriental that had been considered as top tourist destination sites by the Provincial Tourism Office. The study aimed also to design and construct inexpensive apparatuses such as Volume Expansion Apparatus and Conductance Meter Apparatus, and test their accuracies and reliability using distilled water. The water samples collected were particularly, in Bayawan City, Mabinay, Siaton, Sibulan and Valencia City. These inland bodies include Niludhan Falls in Bayawan City, Mabinay Spring in Mabinay, Lake Balanan in Siaton, Twin Lakes in Valencia City, Tejeros Resort in Valencia City, Casaroro Falls in Valencia City and Forest Camp Resort in Valencia City. The researcher through experiments determines the values of the following physical properties namely; density, boiling point, index of refraction, coefficient of volume expansion and electrical conductivity at room temperature. After performing all of the experiments, with same procedures done in every water sample for each property, values and data were obtained. The water sample's index of refraction ranges from 1.34 to 1.32. The result of water samples' density ranges from 1.00 g/cm^3 to 1.01g/cm^3. Boiling point's results of the water samples ranges from 94.56 to 96.55 ℃ lower than that of distilled water which is 92.51 ºC. In coefficient of volume expansion, the ℃ result ranges from 277.668 (1 x 10^{-6}) to 342.646 (1 x 10^{-6} ℃). The result for water ℃ samples' conductance ranges from 1.085 (1 x 10-03 S/m) to 4.49 (1 x 10^{-03} S/m). Distilled water's conductance was 5.28 (1 x 10^{-06} S/m).

Gajelomo (2018), Rivers derive their water from precipitation, in the form of rain either directly from surface runoff, or indirectly from springs and marshes. Rivers are both the means and the routes by which the products of weathering on the continents are carried to the oceans. It provides water for industries, agriculture, aquaculture,

commercial and domestic purpose. It has many physical properties. The researcher aims to construct an apparatus out of recyclable materials and design experiment guides for each property. The constructed apparatuses were Double-walled calorimeter apparatus, Conductance meter apparatus, Volume Expansion Apparatus, and the Optico-Capillary Tensiometer Apparatus. The researcher focused only on the seven physical properties such as; density, boiling point, electrical conductivity, coefficient of volume expansion, index of refraction, surface tension, specific heat and total dissolved solid was also included. The water sample's index of refraction ranges from 1.31 to 1.37. The result of the water sample's density ranges from 0.995 g/cm^3 to 1.003 g/cm^3. Boiling point of the water sample ranges from 96.40 ^{o}C to 92.2 ^{o}C. The surface tension of water samples ranges from 67.2 dynes/cm to 75.48 dynes/cm. The water sample's specific heat capacity ranges from 0.91 cal/gC^o to 1.11 cal/gC ^{o}. In coefficient of volume expansion, it ranges from 277.79 (1.0 x 10^{-6}/C ^{o}) to 315.60 (1.0 x 10^{-6}/C^o). The result for water sample's conductance ranges from 4.41x10^{-4} S to 0.027.

Tan, Mario Y. (1976), he determined the present average daily domestic water consumption per person in the area. Among the major types of water consumers in Cebu City (based on their source of water supply), he dealt only with the first and second type of water consumers. From Metropolitan Cebu Water District (MCWD) Office, data of the first consumers were obtained, those with metered connections. These data were given on a monthly basis. Since a month's data might not be representative, the consumption taken were those for the preceding months of February, March and April 1976 -months of improved service when there were only few complaints of a low pressure of no flow. A random selection of 300 connections in different districts served was made for eventual sampling. It was found out that these sample consumers used the water supply for purely domestic purposes, like cooking, drinking, bathing, washing and many more. For the second type consumers – those having their own wells run with electric pumps, the data were obtained from households with storage tanks. When interviewed, these owners were able to give an idea of how much water they consumed per day, based on the volume of their tanks. These data were, of course, not as precise as those obtained from the records of meter readings on the file at the MCWD. There, was, however, no way of getting more precise information. The results showed that for MCWD consumers, its interval has 106 lpdph $\leq$ u $\leq$ 118 lpdph. For the electric pump users, the interval obtained was 107 lpdph $\leq$ u $\leq$ 116 lpdph. The usual test of significance applied to the means, 112 and 111 lpdph revealed no significant difference them at the 5% level. It was observed that on the assumption that the consumption of the water by the people is directly related to income, it would be worthwhile to compare the consumption distribution of the people belonging to the economic class which included the MCWD consumers and electric pump users. Another, a bimodal distribution possessed 2 modes, a primary and a secondary one. Both distributions appeared to be bimodal. For the MCWD case the primary mode is at the class mark 84.5 lpdph and the secondary at 174.5 lpdph. For the electric pump users, the primary occurs at 104.5 lpdph and the secondary at 204.5 lpdph. The existence of these modes suggested a further stratification within the economic class to which the MCWD consumers and electric pump users belong. This implied a more precise value for the average daily domestic

consumption could be obtained with stratified random sampling.

Futi, Arama Peter, et al… (2011), investigated groundwater harvesting as a method of collecting surface runoff from a catchment's area and storing it in surface reservoirs. The water harvested is usually contaminated and turbid. Methods used to purify water include filtration, sedimentation, boiling and chlorination. This project was carried out in Nyatike district, Western Kenya where water is scarce and water-borne diseases such as cholera, typhoid and dysentery are prevalent. The main objectives of the research were to disseminate water harvesting technology using hand-dug water pans and to evaluate the effect of Moringa oleifera seed extract as water purifier. Sites were identified for construction of demonstration pans. Moringa seeds were milled after which methanol was used to extract water soluble components. Studies on water purification indicated that Alum lowered the water pH from 7.4 to 4.4 while samples treated with Moringa extract did not affect water pH. Alum was the better water purifier whereby application of 0.25g/L decreased water turbidity from 310.7 to 1.1 NTU while M. oleifera decreased turbidity to 45.6 NTU. M. oleifera extract showed antibacterial activity. S. typhi was the most sensitive while V. cholera was the least sensitive.

Danilo C. Israel (December, 2009) he reviewed the local service delivery of potable water nationally and analyzed the same in the case study areas of Dumaguete City and Agusan del Sur. Data and information for the national review were generated from the relevant literature while those for the case analysis were had through a survey done in late 2008 and early 2009. The national review found that although pertinent laws, institutions, strategies and programs on potable water service delivery were already in place, institutional problems remained. It further asserted that while the country may be heading towards meeting its national and MDG objectives related to the provision of potable water, more needs to be done with the limited time at hand. Among the important conclusions of the case study was that Dumaguete City has met or is about to meet national and MDG objectives related to potable water delivery while Agusan del Sur and at least some of its municipalities still have to work harder to meet them. The study further found that the price, quality and accessibility of potable water were major factors influencing households in their choice of water source. Furthermore, it asserted that there were key issues and challenges facing local water service delivery most of which were institutional nature. Based on the results, findings and conclusions of the national review and case analysis, the study suggested some recommendations intended for the further development of local service delivery of potable water nationally, in the case study sites and in other local areas.

Ontoy (2016), millions of people in the rural areas around the world would depend on rainwater for drinking and other domestic purposes and the number of reported cases of serious health problems related to rainwater supplies are very few. The researcher aimed to construct a low-cost apparatus that would purify rainwater, a rainwater purifier that would (a) remove certain impurities, (b) remove discoloration, bad odor, and unpleasant taste so that it could be used for drinking, food preparation, personal hygience, and sanitation; test the reliability of the constructed apparatus and the acceptability of the distillate rainwater (final result) as a substitute potable drinking water to any DOH accredited water testing

laboratory; and make purification guide. The area of the study is limited only to Bagacay, Dumaguete City and used nipa/native roofing's as a catchment surface. The results according to Dumaguete City Water District Laboratory, showed that both Microbiological Analysis and Physico-Chemical Analysis (for sulfate and pH) of the sample passed the 2007 Philippine National Standards for Drinking Water.

Hikmet S. Aybart (2015), made a review on desalination by solar still, and the recent studies on the solar still systems. The review includes basic principle of solar distillation, and also the quality of distilled water. A classification of the solar still systems was made in order to explain the types of solar still systems. General mathematical modeling methodology of solar stills and some mathematical modeling studies are given. The efficiency and performance of the solar still system is also given and discussed. He concluded that solar still is the simplest device to get potable/fresh distilled water from impure water using solar energy as fuel. The basin type single-solar still can be classified as a conventional solar still system. There are many different designs of solar still system in the open literature. Researchers have modified the conventional solar still system to get a better performance, such as multi-basin, multi-slop solar still systems, and coupled with solar collector to increase the water temperature. Especially, solar stills look like the best choice to obtain fresh drinkable water in remote areas usage.

Labiste, Florencio & Maxino, Gerardo (2014), investigates the feasibility of rain harvesting to augment the water resources of a small rural community. The water consumption and rainfall pattern of Oslob, Cebu were determined. The rain collection efficiencies of galvanized iron (GI) and nipa roofing's were measured. The size of the needed water tank was then calculated. Finally, the study assessed the potential of rain harvesting to help meet the water needs of the community. Oslob is one of the 48 municipalities of the Province of Cebu. It is located 117 km southeast of Cebu City. It is mountainous town with the plane extending a few kilometers from the shore westward. It has no river which can supply water for the town but fortunately it has a spring located in Barangay Tumalog, 10 km away from the town proper. It serves as source of water for most of the barangays. Other barangays of Oslob have few scattered deep wells which supply their water demand. The town has two seasons, the dry and wet. Oslob receives the lowest amount of annual rainfall, 777.73 mm(depth), while Medellin, Lahug, and Mantalungon have mean annual rainfall of 1600 mm, 1620 mm, 1983 mm, respectively. Oslob gets only half of the rainfall in these places. The water needs of the people in Oslob are limited only to drinking, washing, watering the plants, cleaning, taking a bath, cooking and some other minor activities. Their water consumption varies from month to month and usually reaches its peak during the months of November, December and January. In year 1991 registered the lowest amount of rainfall while 1996 registered the highest. The mean annual rainfall of Oslob is 777.73. The mean average water consumption is 83.35 liters per day per head (lpdph) and the standard deviation is 31.11 lpdph. Rainfall in Oslob, Cebu is much less than those in other parts of the province. Thus, depending on a particular house fold, rainwater can supply from 2% to 20% of water needs, which is significant, considering the rising cost of water. Rain harvesting however, may by worthwhile pursuing in some localities. Amper, this paper looks into how the residents of Gilutungan Island in

Central Visayas have coped with water scarcity, specifically through water use and conservation strategies. This study focuses mainly on qualitative data highlighting perceptions and narratives of community residents on water use and conservation. Barangay Gilutungan is an island-coastal community in the municipality of Cordova, Cebu were water is scarce. Access to the mainland requires going across bodies of water by boat. The study's research participants included water users in the community, as well as local government officials. Respondent's were mostly fishers who primarily relied on fishing and other marine-related livelihoods. Gilutungan is one such island that is both local and foreign tourists visit because of its marine sanctuary. An island-resort has been constructed on the island to cater the needs of the tourists, including water. Water on the island for both tourists and local residents alike comes from the mainland, brought in by motorized boats. The socio-economic condition on Gilutungan is largely characterized by and increasing population relying on subsistence fishing supplemented with income from guso farming. Thus, income remains at subsistence level for most households. One of the daily needs to be met by households on the island is water for drinking, cooking, bathing, and other domestic uses. In 1950's there was a ground water but years after it becomes saline due to too much demand that is not suitable anymore for drinking. Although there are five other dugs wells on the island, water from these wells is salty and is only used for flushing the toilet and cleaning, not for drinking or cooking. These wells dry up also during low tide. Since the well was closed, rain become the only source of fresh water on the island. Rainwater was such an important water resource that each household installed big water jars (martabana) or tanks for collecting rainwater. A regular sized martabana can collect more than 100 gallons of rainwater, while regular-sized drum or barrel can collect about 50 gallons. Other houses with no gutters on their roof have to buy rainwater from their neighbors for P5 per five-gallon container. During the dry season thy have to buy fresh water from March to May, residents have to buy fresh water from their distributors who go to mainland to fetch water from private wells or from faucets installed y MCWD. A number of elderly residents say that they still drink rain water. They just put amount of chlorine in the container to purify the water and they can drink it already. With the availability of fresh water from the mainland Cordova from water distributors, a number of residents have shifted from rainwater to tap water, and lately to purified water/mineral water. While rainwater can be bought at P5 per container, freshwater bought in from Cordova costs P10 per container, and purified water is priced at P50 to P60. Considering the income levels of most fisherfolks on the island water costs takes more or less 25 percent of the monthly income of those engage in guso farming, for fisher folks they set aside 50 percent of their income. Based on the monthly bills from MCWD, the cooperative managing the water consumption of the island reaches an average total of 5,000 cubic meters (1,320,860 gallons) per month and increases during the dry season to around 6,000 cubic meters (1,585,032 gallons) with a computed average of P396,258 a month. As part of the conservation strategies rainwater tanks are incorporated in their buildings. Houses with GI roofing have installed martabana, barrels or tanks right below the gutter and down spouts of their roofs. To save daily water they utilize other water sources such as rainwater and seawater and conserving water through minimizing water utilization and reusing and recycling. Increasing population is one of the most pressing factors affecting water supply

especially on small islands as evidenced by demographic data as well as accounts of local residents. High fertility as well as in-migration have contributed to the increase in population. The impact of a growing population is seen in the saltwater intrusion in the old water source of Gilutungan due to over-extraction.

THEORETICAL CONSIDERATIONS

Passive Solar Driven Systems for Water Treatment

The passive solar driven water treatment solutions depict the simplest, cheapest, easily manufactured, high effectiveness and attractive techniques compared to other water decontamination processes. These technologies have the potential for potable water production. They remove the impurities without degrading the environment, in a sustainable way, and thus save huge costs involved in the use of other water purification techniques (Burch & Karen 1998). The passive solar driven water treatment of contaminated water, at the very least expense and infrastructure brings up the topic at the three techniques; solar cooking / solar disinfection, solar pasteurization and solar water distillation. The solar disinfection process purifies water by the action of ultraviolet radiations of specific wavelength. While in solar pasteurization, the water is decontaminated by the temperature / heat achieved from solar radiations. Whereas, solar distillation involves the process in which the water is evaporated by solar radiations and condensate is collected within the same enclosed system (Burch & Karen 1998) (Chittaranjan & Ravi 2011) (Meierhoffer & Wegelin 2002) (Caslake et al. 2004). Solar driven water distillation provides a promising alternative water purification process that can partially support humanity's needs for fresh water with free energy, simple technology and a sustainable environment. However, researchers have tried to investigate several means to improve the productivity of solar still and enhancing the thermal efficiency. Several have tried to condense the water vapors externally such as in additional condensing surfaces and the wasted latent heat of condensation was also recovered (Fath 1998). No doubt, solar water distillation technique is the sole, most effective, low cost and sustainable solution to meet the freshwater needs of the public residing in remote and underdeveloped areas of the world.

Basic Principle of Solar Distillation

The basic principle of solar distillation depicts the water purification process of our nature- the hydrological cycle. In this method, the contaminated water in a transparent, enclosed and airtight unit is heated by the solar radiations. When the heated water starts evaporating, the water vapors rise to the inclined transparent cover. As the water vapors reach up to the transparent surface, the droplets start sliding along the slope due to condensation. Hence, these droplets of fresh and pure water are collected in a channel at the end of slope (inclined surface.) (KALITA, DEWAN et al. 2016) The distillation, a fairly slow process, evaporates only water and leaves the impurities behind in the basin. The occurrence of relatively high temperature inside the basin results in microbial death and thus high-quality fresh water production. And, regular cleaning is required for the removal of sludge left behind in the still after evaporation of water (Badran and Abu-Khader 2007) "Solar radiation is transmitted

inside the enclosure of the distiller unit after reflection and absorption by the glass cover. The transmitted radiation is partially absorbed by the water mass and partially reflected by the water mass. The transmitted radiation further reaches the blackened surface where it is mostly absorbed. The thermal energy absorbed by the basin liner (i.e. the blackened surface) is then convicted to the water mass in the basin and the rest of the energy is lost in atmosphere by conduction through the insulated bottom and sides of the distiller unit. Due to convection of energy by the basin liner, the water mass in the basin gets heated and the temperature of the water mass is higher than the glass cover temperature, there occurs internal heat transfer from the water surface to the glass cover. The heat is transferred by radiation, convection and evaporation. The evaporated water is condensed on inner surface of glass cover after releasing the latent enthalpy to the condensing surface. Due to cover's small inclination, condensate flows by gravity into the collection troughs at the lower edge of the glass cover. The cover is at sufficient slope such that surface tension of the condensate water causes to flow only into the collection trough and not to drop back into the basin. Finally, the condensed water is trickled into the container. The collected water is taken out of the system for an appropriate use. Externally the thermal energy received by the glass cover is lost to ambient by convection and radiation." ((Balan, Chandrasekaran et al. 2011) Primarily, there are three factors that affect the efficiency of a solar still; the design of still, the amount and intensity of solar radiations and the sunshine duration (Abdallah, Abu-Khader et al. 2009). The design factors include; surface area, the depth of water in basin, material and color of the basin, wind velocity, water temperature, absorbing dish area, inlet-water temperature, air tightness and insulation patterns of the still, inclination angle of the glass, water surface area, depth of water in the still and temperature differences in the water and glass (Velmurugan and Srithar 2011). The intensity of solar rays, wind velocity and ambient temperature are uncontrollable parameters while rest of the parameters can be controlled to improve the performance of solar stills. A basin coated black comparatively absorbs most of the transmitted solar energy and thereby enhances the productivity of solar still. However, the loss of some amount of energy in the basin and inclined glass cover by conduction or convection and radiation might make the still less efficient. Also, the parameters such as inclination angle of the cover, glass thickness, latitude, climatic conditions and radiation diffusion are amongst the key driving forces influencing the still's productivity (Cooper 1969). The inclination angle of glass and the latitude must be equal to maximize the incoming and received radiation packets for the entire year. And during the summer season, a lower inclination increases the incoming flow of radiation towards the still because the sun's declination angle remains at its highest during summer and a still having 19° inclination maximizes the incoming radiation from during the peak summer days (Muthu Manokar, Kalidasa Murugavel et al. 2014) (Al-Hinai 2003). Un-saturated air is vital for the occurrence of evaporation in the still because the energy required to transform the water into vapors, the latent heat of vaporization depends on the temperature. And for the condensation process i.e. the transformation of water vapors into liquid (distilled water); a temperature difference between the still's inside and outside air is crucial. Therefore, the still placed in a windy surrounding or providing the outer glass cover with cooling increases the condensation process and thus still's productivity. The

presence of salts in water affects the evaporation rate as well; the evaporation rate decreases with an increase in salinity and vice versa. Principally, the intensity and distribution of solar radiations throughout the day-time has the most central role in prediction of a solar still's yield. The average daily production of a still is calculate as: Q = E*G*L, whereas, Q=Daily output of water (l/d); E = Overall efficiency / effectivity of the still (%), G = Daily global horizontal solar irradiation (MJ/m2); A = Aperture area of the solar still (m2); L= Latent heat of vaporization (J/kg).

The above-mentioned equation is used to estimate the productivity of a solar still for both, the prior and post experimental calculations. However, normally, depending the design and material, the efficiency of a still ranges between 30 to 60 percent. ((Al-Hinai 2003) (Muthu Manokar, Kalidasa Murugavel et al. 2014) (Ray and Jain 2011)

METHODOLOGY

This provides the map of the area of the study, the design of the constructed apparatus, materials to gather, experiments done in measuring the salinity of seawater and the desalination guide. In this case, seawater samples were tested from the perspective of electrical conductivity and total dissolved salt as the approaches used in measuring salinity and solar still is the method being used as a desalination technique. The researcher proposed to measure the salinity of seawater samples coming from Apo Island and Lazi, Siquijor and put it in the passive solar still apparatus for desalination and as a way of computing the apparatus' total production in each day.

Area of Study

Methods of Research

A. Gathering Samples

The study focused only at Apo Island which is located off the southeastern tip of Negros Island, 7 kilometers from the town of Zamboanguita, and 25 kilometers south of the Negros Oriental capital; Dumaguete. Extending approximately 1.5 km (0.9 mi) from north to south and 1 km (0.6 mi) from east to west, the island has a land area of approximately 74 hectares and rises to a height of 120 meters (390 feet) above sea level at its highest point. In getting the sample, the distance is 6 meters away from the shoreline using a rope and one meter from the surface of the seawater to its seafloor.

B. Methods in Measuring Salinity

The seawater samples are subjected to the following methods; (a) Total Dissolved Salts through Boiling (b) Electrical Conductivity.

Construction of Conductivity Apparatus

The researcher builds the housing of the conductance meter using plywood. A battery holder is attached inside on it that could hold three D size batteries. A positive wire was connected to the positive probe of the multimeter using an alligator clip. One electrode was connected to the negative wire while the other to the negative probe.

Testing the Conductance Meter Apparatus

To test the reliability of the apparatus, standard deviation should be calculated using a formula:

$$\sigma = \sqrt{x}$$

which is

$$x = \frac{\Sigma|Xseawater - Xaverage|}{dx}$$

where x= variance, N = no. of trials.

Distilled water was used as a subject during the experiment to test the functionality of the apparatus.

Set-up for Salinity Measurement

A. Total Dissolved Salts

Materials:

Seawater sample, digital weighing scale, kettle, electric stove, graduated cylinder, dry cloth

Procedure:

1. Prepare all the materials.
2. Determine the initial mass of the kettle. Using a cylinder, measure 250 ml of seawater sample and put it in the kettle.
3. Boil the measured seawater sample until all the liquid will evaporate and solid residues are left. Seal the kettle tightly to prevent loss of dissolved salts.
4. Weigh the kettle again to obtain the mass of the dissolved salts,

$$DS = M_{ko} - M_{ki}.$$

Refer to the sample table below**.**

Table#: _____ Location: _____ Amount of Seawater: _____ Mass of Kettle: _____

Trials	Mass of Kettle with Salt (g)	Dissolved Salt (g)	Salt Concentration(g/L)
1			
…			
10			
		Average	

B. Electrical Conductivity

Using the conductance meter apparatus, we can measure the salinity of seawater samples.

Materials:

Conductance Meter Apparatus, glass container or plastic cup container, seawater samples

Procedure:

1. The materials were prepared.
2. An amount of seawater was poured into the glass container.
3. The electrodes were dipped into the seawater samples (250ml) in the glass.
4. The current and voltage were noted using a digital multimeter.
5. The resistance was computed using the relationship

$$resistance = voltage/current$$

6. Using the computed resistance, the conductance was computed using the formula:

$$conductance = 1/resistance$$
or
$$C = 1/R.$$

Refer to the sample table below.

Table #: _____ Location: _____ Amount of Seawater Sample: _____

Trials	Voltage (V)	Current (A)	Resistance (R)	Conductance (S/m)
1				
…				
10				
			Average	

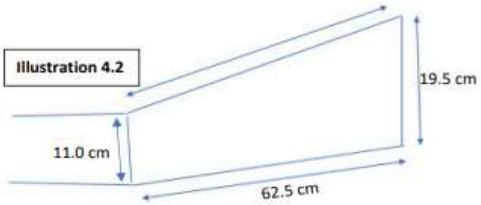
Construction and Set-up of Passive Solar Still Apparatus

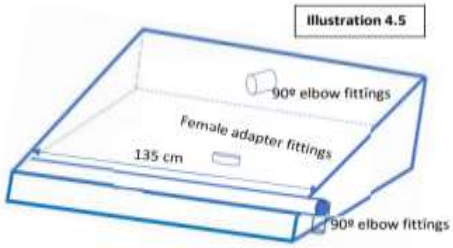
The solar still is constructed throught the use of locally inexpensive available materials. Because the researcher believes that for us to avert freshwater crisis from the escalating demands around the globe we need to come up with a solution which can be done easily and economically in the community.

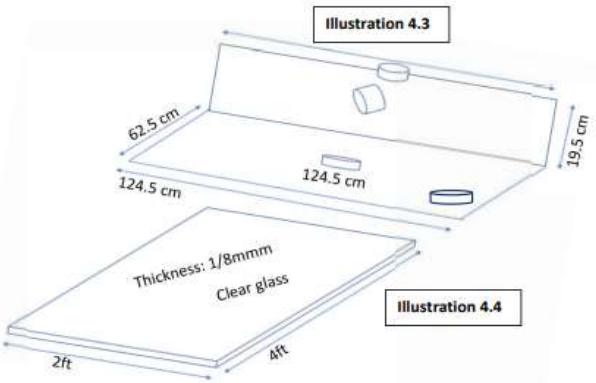
Materials:

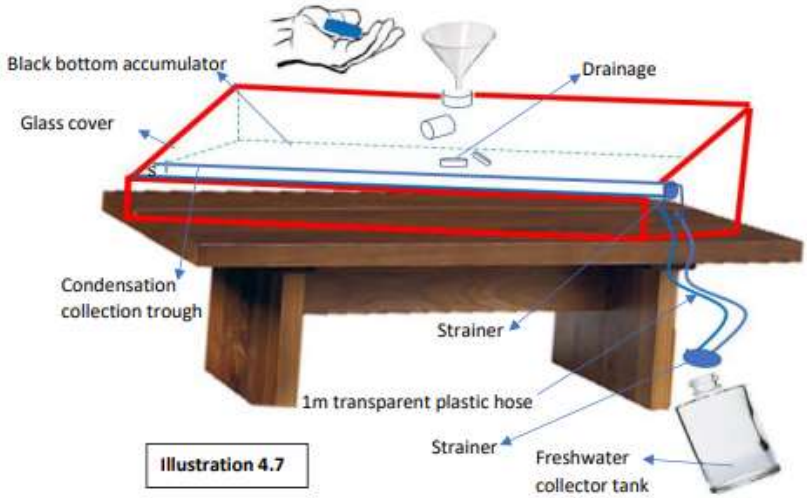
plyboard (1 whole), paint (1L-black & 1L-white), DAP 100% Silicone Sealant(black), wood glue, fitting female adapter, epoxy, 1/8mm clear glass (2ft x 4ft), 3/4 Polyvinyl Chloride plastic plumbing pipe, PVC Cement Solvent, 3/4 transparent plastic hose, 90˚ elbow fittings, glass bottle water collector or clean empty Nature's Spring gallon.

Refer to the illustrations below 4.1-4.7.









Desalination Guide

Materials:

Alcohol thermometer, freshwater collector tank, duct tape, strainer, funnel, feed water, teflon/epoxy, measuring gallon, black bottom accumulator, glass cover, 1m transparent plastic hose, condensation collection trough, strainer and drainage.

Procedure:

1. The materials are prepared.
2. The solar still itself, the surfaces are cleaned with a chlorine solution. To complete the decontamination process, the still is left outside under the direct exposure to the sun for two hours to let the volatile contaminants evaporate. Conduct an experiment twice for the first ever used of the still and throw away the product just to disinfect the apparatus.
3. While the other equipment that will be used such as the trough and distillate water collector is subjected also for disinfection.
4. During the desalination, the still is placed in an open area of where there's no obstructions from the irradiance that the glass cover can capture during the treatment.
5. Liters of feed-water are added into the still. Approximately 30 minutes to 1 hour (during fair weather and clear skies that heat coming the sun is strong/hot enough) the boiling of the feed-water inside the still starts and as well as the evaporation later on that leads into condensation of which the water will run down from the slope of the still going into the through and flows into the freshwater collector tank.
6. The still is left behind for hours (during the experiment the still sitting under the heat of the sun for 8 hours) letting solar energy to decontaminate the water by evaporation and condensation within the closed system. Impurities were removed such as heavy metals, salts, arsenic, nitrates, pathogens and other contaminants, even carcinogenic pollutants present in water.
7. Four hours after, the amount of distilled water is being checked and also with respect to the identified value of the surroundings corresponding temperature and other meteorological aspects that could affect the desalination such as the weather condition and relative humidity.
8. After eight hours, the solar still will be checked again and it is ready for harvest. The freshwater collector will be removed from the PVC that is connected to the trough and transfer the distilled water into a clean and decontaminated container.
9. Relate cloud cover with the production on each day.

   Sample table below.

Date	Cloud Cover	Production

10. In case of the remaining feed-water inside the through (waste product) you can open the drainage and place a container below to collect the waste product.
11. Empty the desalinator and clean the remaining residues inside before using it again on the next day.
12. Before leaving behind the desalinator, conduct a simple check up on each side of the still just to make sure it is airtight and as a prevention from unnecessary external heat exchange.

13. The distilled water will be put into EC (Electrical Conductivity) method and TDS (Total Dissolved Salts) if the need arises and there's a chance to know the salt concentration present in the distilled water, if ever is.

RESULTS AND ANALYSIS

The results of the total production of the solar still desalinator within the range of four months, the results of using the two methods, Total Dissolved Salts (TDS) and Electrical Conductivity (EC) in determining the salinity of the seawater samples taken from the sample sites namely, Apo Island and Lazi, Siquijor and lastly, the results of the distilled water of which Electrical Method (EC) is applied to test its conductivity. The data obtained is tabulated for each day/trial. For the amount of production of the solar still, every week there are 5 experimental days (Mon-Fri). The total number of days of collecting the data is 80. For Total Dissolved Salts, the concentration content is obtained by subtracting the original mass of the kettle from the mass of the kettle with the salt residue remained inside and to be divided by the amount of seawater. For Electrical Conductivity (EC), the voltage and the current are measured using the multimeter. Resistance and conductance are computed using the formula: for Resistance, R=V/I and for Conductance l=1/R, where V and I are the measured voltage (V) and current (I).

Total Production of the Passive Solar Still

For the data collected for the total production of the passive solar still, the researcher performed the gathering of the data every five (5) days in a row every week (Mon-Fri). She started last November 28, 2018 and ended last March 29, 2019. During those experimental months two types of glass were used; namely, 3/16mm bronze and 1/8mm clear glass. The researcher was using the 3/16mm bronze for 54 days from November 28, 2018 until February 10, 2019. On the other hand, she was using 1/8mm clear glass during the subsequent days for 34 from February 11, 2019 to March 29, 2019.

Based on the data result, a 2ft x 4ft passive solar still using a bronze glass with a thickness of 3/16mm can have a total production of 29,622 mL of distilled water for ten weeks having an average production of 79.83 mL/wk. Each week (5 days) the range of production from 1,150 mL to 4,757 mL. (*Refer to **table 5.1-1***.) On the other hand, the passive solar still that uses 1/8mm thick of clear glass would be able to have a total production of 3,371.11mL/week. In every week the range of production lies between 1,676 mL and 4,207mL. (*Refer to **table 5.1-2**.)*

Table 5.1-1 *Average Production of Solar Still for 3/16mm Bronze Type of Glass*

Week (5 days)	Total Production Per Week (mL/wk)	Average Production Per Day (mL/day)
1	2185.00	728.33
2	3667.50	916.875
3	4587.50	917.00
4	3070.00	767.50
5	2052.50	513.125
6	4127.50	1031.88
7	1552.50	517.50
8	1150.00	575.00
9	2474.50	494.50
10	4757.00	792.83
Total Production	29,622.00 mL	725.45

Table 5.1-2 *Average Production of Solar Still for 1/8mm Clear Type of Glass*

Week (5 days)	Total Production Per Week (mL/wk)	Average Production Per Day (mL/day)
1	14258.33	2851.67
2	8380.00	1676.00
3	21035.00	4207.00
4	20140.00	4028.00
5	19312.50	3862.50
6	161013.67	4025.42
7	20226.67	3371.11
Total Production	11,9454.20mL	2402.17

Computation for the Total Dissolved Salts

The salt concentration was calculated using the data obtained from the trial. Example, using the trial, the obtained resultant used the formula, $SC= M_{ks}-M_kA_{sw}$ where, M_{ks} - is the mass of the kettle with the remaining salt residue inside M_k - is the original mass of the kettle used in the experiment A_{sw} – is the amount of seawater sample used in every trial SC – is the salt concentration of every sample. In this method, dissolved salts were obtained by subtracting the mass of the kettle from the mass of the kettle with salt residue. The amount of seawater and the mass of the kettle was made constant throughout the whole experiment. Salt concentration was obtained by dividing dissolved salt with the amount of seawater. The unit of Salt Concentration was expressed in grams per liter.

Sample Computation (from the first trial of Apo Island):

Dissolved Salt = Mass of kettle with salt (g) – Mass of Kettle (g)
= 161.3 g – 151.6 g
= 9.7 g

Salt Concentration = Dissolved Salt / Amount of Seawater
= 9.7 g / 0.25 L

In getting the average salt concentration, compute the summation of the salt concentration taken from all trials that you performed then, divide it by the total number of trials that you have.

Determining the Conductance in EC Method

The resistance and the conductance of the seawater sample can be computed using a formula and by substituting the obtained voltage and current in the trial. Resistance is computed as R=V/I, R – is the resistance of the seawater sample V – is the voltage and, I – is the current. L=1/R for the Conductance where, L – is the conductance obtained from every seawater sample R – is the resistance of the computed voltage over current.

Sample Computation (from the first trial of Apo Island):

Resistance = Voltage / Current
= 4.20V / 0.67A
= 6.39 ohms

Conductance = 1/Resistance
= 1/6.39
=0.16

The graph above summarizes the obtain data which includes the computed conductance (S/m) and the concetnration (g/L) which are used in creating the concentration-conductance curve.

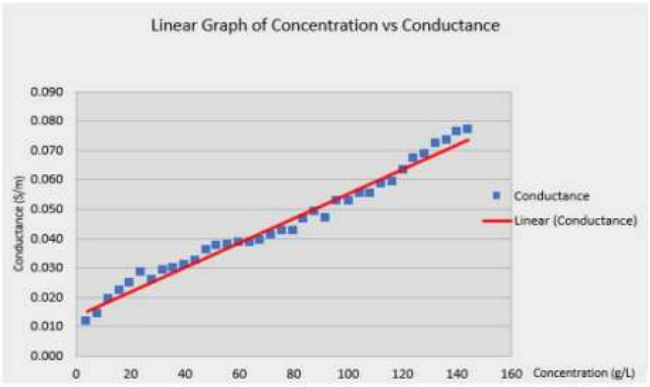


Figure 5.1 *The linear graph of Concentration vs Conductance.*

Salt Concentration Derive from The Line

The corresponding salt concentrations derived from the line are the following, for the 3/16mm bronze type of glass it ranges from 0.01 g/L to 0.40 g/L while in 1/8 mm clear type of glass, the lowest value is 0.01g/L and the highest value is 0.05g/L.

Drinkable Water Consumption

The drinkable water consumption of a family in every household. The researcher conducted a survey using a census method. She aims to get the record of all the families that live in Apo Island. Apo Island is composed of 7 puroks namely, Purok 1, Purok 2, Purok 3, Purok 4, Purok 5, Purok 6, Purok 7 (Cogon). The survey used the 2018 record of the island which states that there are 199 households all in all in the island. However, during the survey the researcher was only able to cover a total of 182 households for some of the families weren't in their households during the conduct of the survey. Based on the data that the researcher gathered the amount of drinkable water needs

of every household varies depending on the number of persons living in that house and on the amount of water that a member can consume per day.

CONCLUSION AND RECOMMENDATIONS

The researcher was able to construct an inexpensive desalination apparatus commonly known as passive solar still which is eco-friendly, low cost, resources are available in the locality, easy to construct and efficient in producing a distilled water. During the Electrical Conductivity experiment in the distilled water the results for the amount of concentration that is derived from a line are the following, for the 3/16 mm bronze type of glass it rages from 0.06 g/L – 0.40 g/L. On the other hand, for the 1/8 mm clear type of glass the results lie in between 0.01 g/L – 0.07 g/L. The clear type of glass with 1/8 mm thickness is the desirable kind of glass that can be used in a passive solar still. Based on the results also, clear type of glass produces an output that contains a very very small amount only of salt concentration that even if you will try to put it in Total Dissolved Salt (TDS) experiment it will be so hard to notice the remaining salt residue in the kettle, it is unmeasurable that you can only consider it as a trace. In addition, the total production of the 2ft by 4ft passive solar still with a clear glass with thickness of 1/8mm is 119,454.2 mL for 35 days. In connection with the needs of a family per household, this size of a still is positive to support the drinkable water needs of a household with a maximum of 2 family members. Therefore, the study proves that the passive solar still could be helpful to alleviate the water crisis in small island communities especially in their drinking water supply. It would be useful to those communities that don't have a direct access of drinkable water in their vicinity and the abundance of seawater is more available than freshwater.

Through significant findings and conclusion, the researcher would like to recommend the following.

1. This research, specifically the apparatus itself could be a subject for modification. It is the addition of some principles that could make it more productive such as it will become a bit of robotics but the essence of having it as a locally constructed and low cost apparatus should remain as an objective of the study.
2. The study must be continued such that its efficiency will increase as much as possible as it could. There are a lot of ways that can be implemented in the apparatus and put it in experiment for further observations and study of the results.
3. The apparatus should be available to the communities and not for sale. This research should remain its goal to help the community in their drinkable water needs and not to boost economic profits.
4. The researcher should have the willingness in her heart to share this study to the community, to help the society diminish water shortage. That includes demonstration and free tutorials to the people who are in need.
5. Lastly, the researcher should always consider that this study should be valuable, applicable and harmless to the environment.

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SMARTSCOPE-INTEGRATED ONE-CLOSE-END (OCE) RESONANCE TUBE FOR SPEED OF SOUND MEASUREMENT

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ABSTRACT

This study focuses on designing and constructing a one-closed-end (OCE) resonance tube integrated with the SmartScope smartphone application for measuring the speed of sound in air at two different room temperatures using the resonance method. The apparatus includes a transparent plastic tube with a metric scale, a speaker connected to a smartphone with a sound frequency generator for producing pure-tone sound, a movable piston indicating the effective length of the tube, and a mini-microphone connected to a smartphone with the SmartScope application. By precisely adjusting the movable piston, resonance conditions are established, with the maximum sound signal clearly indicated in the SmartScope app. Experimental error values are found to be significantly small when compared to the calculated speed of sound at the two different temperatures. The apparatus proves effective and can efficiently demonstrate the physics of acoustics, particularly longitudinal standing waves and speed of sound experiments.

INTRODUCTION

Amidst the various mechanical waves present in nature, sound waves emerge as particularly vital to our daily lives, propagating as longitudinal waves through a medium, typically air. The movement of sound from molecule to molecule within a medium characterizes its nature as a mechanical wave. Numerous studies and experiments have been undertaken to measure the speed of sound. One method involves using a tuning fork and a closed cylindrical tube partially filled with water, known as a resonance tube. Altering the water level in the tube causes resonance when the length matches a specific fraction of the sound wave's wavelength, resulting in amplified sound. Utilizing the known frequency of the tuning fork and the measured length of the air column at resonance enables the calculation of the speed of sound.

Traditionally, tuning forks, frequency sound generators, and oscilloscopes were expensive tools limited to a few well-funded schools. However, in a captivating integration of technology, smartphones now serve as accessible tools for delving into the physics of sound. Sound frequency generator apps and sound oscilloscope apps are readily available, allowing enthusiasts and students to explore acoustics directly from their smartphones. In this study, the researcher has ingeniously designed and constructed a one-closed-end resonance tube integrated with the free smartphone app Smartscope. This application turns a smartphone into a mobile oscilloscope and is available for free download, playing a crucial role in this investigation.

THE PROBLEM

The Problem and Significance of the Study

The primary objective of this study is to assess the accuracy of a self-constructed resonance tube integrated with the Smartscope mobile application in measuring the speed of sound in air. The integration of the Smartscope mobile application with a self-constructed resonance tube establishes an accessible and cost-effective learning tool. This study bears several potential benefits for students, physics teachers, and physics enthusiasts alike. Students, particularly those in schools with limited resources, stand to gain by conducting experiments on sound waves without the need for expensive equipment. Furthermore, this study empowers students to partake in hands-on experiments, nurturing a more profound understanding of the principles of acoustics and the measurement of the speed of sound. For teachers, incorporating the results of the study into their teaching materials introduces an innovative and practical approach to teaching acoustics. Additionally, physics enthusiasts and individuals keen on conducting experiments at home can utilize this study as a guide to explore and measure the speed of sound, fostering a culture of lifelong learning.

RELATED STUDIES

In exploring the accuracy of a self-constructed resonance tube integrated with the Smartscope mobile application for measuring the speed of sound in air, it is essential to delve into the fundamental concepts of acoustic waves and their propagation. Resonant vibration results in the production of a sound characterized by a constant frequency. Understanding this phenomenon requires a thorough review of related studies. With this, the researcher carefully examined many studies in the field to gather essential knowledge and insights for investigation. By examining the literature and related studies, this study aims to build upon existing understanding and contribute to the broader discourse on the accuracy of innovative methodologies in measuring the speed of sound.

In the book of **Marsh William White**, three experiments dealing with vibration can be found, one of them is speed of sound in air and in metal. The Speed of Sound in Air and in Metal Experiment aims to determine the speed of sound in air by resonance method. A tuning fork of known frequency is sounded at the mouth of a vertical column of air in a glass tube partly filled with water. The length of the air column is adjusted by regulating the water level until the air column produces resonance.

Bañas (2005) developed experiments and demonstrations on vibration and sound in an inexpensive way. She made the learning fun to the students by letting them use

available string set-ups and musical instruments which are familiar to the students. The researcher studied and developed these implements into a specific experimental set-up and assessed and defined which of the vibration and sound principles these implements demonstrate.

Alwielland Q. Bello (2011) conducted an experiment using a resonance tube setup in the physics classroom at Bukidnon State University, Malaybalay City, Bukidnon. The setup included an economy resonance tube, a laptop computer, a desktop speaker, and a digital thermometer. Bello aimed to determine the speed of sound at room temperature by conducting frequency-vs-harmonic number (f-vs-n) experiments. These experiments involved both open-pipe and stopped-pipe procedures across multiple trials. Due to fluctuations in room temperature throughout the day and varying weather conditions, Bello performed frequency-vs-harmonic number (f-vs-n) measurements at different room temperatures and time intervals.

It is concluded that the constructed resonance tube setup is suited for experiments and other related activities in the Physics classroom. The concepts of resonance, normal modes and speed of sound can be demonstrated without the need of spending much on the commercially available models.

Aina Maree Siason (2017) created and built two sound devices: the Kundt's tube, which assesses the speed of sound in air using standing waves, and Ruben's tube, designed for measuring sound in gases. These devices are suitable for use in both public and private schools, offering valuable tools to enhance students' comprehension of acoustics and physics.

Wijitwongwan, P., & Wuttiprom, S. (2019) introduced a cost-effective, small-scale experimental setup for determining the speed of sound in the air through resonance. Utilizing basic materials like a bubble tea straw, a plastic water bottle, and a mobile application (n-Track Tuner for iOS or Guitar Tuner for Android), sound waves were sent through the straw filled with air. The waves reflected back and interfered, creating a resonance condition that could be established by adjusting the water level. The experiment specified a frequency of 1,500 Hz at different temperatures. Calculated sound speeds closely matched standard values, with minimal percent error (0.1 % or lower). This efficient and affordable experiment offers a practical tool for educational physics, providing students with a hands-on approach that is easy to use and portable, and allowing them to prepare the equipment themselves.

Niu, Z. J., & Luo, D. (2022) introduces a homemade experiment that showcases acoustic resonance in an air column. Using basic materials like a plastic tube, a mobile phone, a loudspeaker, and a tape measure, the experiment allows for the convenient calculation of the speed of sound in air through the resonance phenomenon. The experimental results demonstrate good agreement with reference values, highlighting the effectiveness of this homemade approach. The type of experiment holds particular significance as it provides valuable guidance for students conducting relevant research in non-laboratory settings.

Coban, A., & Coban, N. (2020) in their study, employed a double open-ended resonance tube, a computer, and a speaker for generating sound with different frequencies, along with an Arduino UNO, KY038 Sound Sensor, Green LED, and a 220 Ω resistance to measure the speed of sound in air at room

temperature. Utilizing the sound sensor, they determined two consecutive harmonic frequency values and calculated the fundamental frequency. Using the tube's features and the fundamental frequency, they calculated the speed of sound propagation in air at room temperature as 350.90 m/s, compared to the theoretical value of 346 m/s. Their study, demonstrating a very low-cost method and coding studies with a 1.42 % error margin, is significant for encompassing all STEM gains and can be easily applied in classrooms.

Bin, M. (2013) conducted an experiment to measure the speed of sound using solely a computer. In this experiment, a fixed frequency (1000 Hz) was input into the computer's speaker, and an external microphone monitored the wave train near the speaker. Subsequently, the microphone was moved approximately one meter away, resulting in a shift in the waveform. By comparing this shifted waveform to the original recording, the precise count of wavelengths shifted was determined. The flight time, calculated as the product of these wavelengths and the period, facilitated the calculation of the velocity of sound by dividing the distance the microphone was moved by the flight time. This innovative approach demonstrates a practical and computer-based method for measuring the speed of sound, providing a simple yet effective means for experimentation and analysis.

Yavuz, A., & Temiz, B. K. (2015), in their paper, propose a modification to the traditional experiment for measuring the speed of sound by investigating destructive interference in a pipe using a headset, iPhone, and iPad. The iPhone functions as an emitter with a signal generator application, while the iPad serves as the receiver with a spectrogram application. Two experiments are conducted: one with the emitter inside the tube and the receiver outside, and vice versa. The authors concluded that it is feasible to measure the speed of sound using common items accurately and easily like a cup or a can of coke, employing the method outlined in their paper. This innovative approach offers a practical and accessible means of conducting experiments to determine the speed of sound.

Jaafar, R., & Daud, A. N. M. (2019) employed Audacity Open Source Software (OSS) in their study to conduct harmonic series experiments on a three-in-one resonance tube. The tube was configured as both-closed-end (BCE), one-closed-end (OCE), and both-open-end (BOE), and Audacity was utilized for measuring their resonance frequencies. The experiments aimed to determine the speed of sound in air (v) across five different lengths of BCE, OCE, and BOE tubes (15, 20, 25, 30, and 35 cm). The experimental values of v were calculated from the slope of f_n versus n graphs for all types of resonance tubes. The results revealed that the experimental values of v exhibited less than a 5.00% error when compared to the reference values. This suggests that Audacity can serve as a viable alternative to an oscilloscope, providing accurate peak values of frequency spectrum within audible ranges.

METHODOLOGY

Construction and Set-up

Figure 1 illustrates the constructed resonance tube integrated with the Smartscope oscilloscope mobile application.

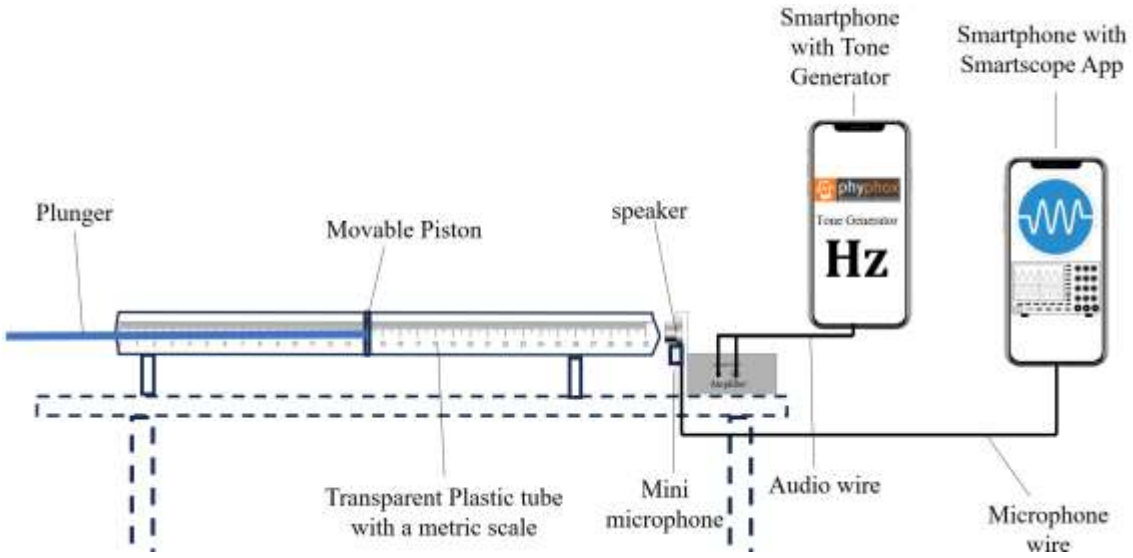

Figure 1. *Illustration of the set-up for the resonance tube.*

Clear Plastic tube with metric scale – A transparent plastic tube with a metric scale of 1.3m is utilized in this setup. The tube, sourced from a broken LED light tube, is attached by a tailor's measuring tape, with the zero-point aligned at the opening of the tube. The tube is configured as one-closed-end.

Speaker – The speaker is linked to the tone generator application via a smartphone, with its primary function being to produce a pure tone sound. The position of the speaker is precisely 1 cm away from the tube, aligning it with the opening of the tube at the same level. The smartphone is connected to the input of the amplifier and the speaker to the speaker output of the amplifier. The amplifier is plugged into an AC voltage supply.

Mini microphone - The microphone is mounted in the microphone hole below the speaker. It serves the purpose of identifying the position of the plunger where resonance occurs, captured by detecting the loudest sound. The maximum sound signal is clearly indicated in the Smartscope app.

Piston with Plunger - The piston is movable and fits snugly inside the tube. The scale on the resonance tube concurrently denotes the precise position of the piston.

RESULTS AND ANALYSIS

***Table 1**. Measured speed of sound at room temperature of 29 °C.*

Room Temperature: 29 °C											
v(T): 349.75 m/s											
	L_1 (m)			Average L_1 (m)	L_2 (m)			Average L_2 (m)	Wavelength (m)	Measured Speed of sound (m/s)	% error
Frequency (Hz)	Trial 1	Trial 2	Trial 3		Trial 1	Trial 2	Trial 3				
300	0.254	0.255	0.255	0.255	0.845	0.845	0.845	0.845	1.181	354.42	1.52
350	0.19	0.19	0.19	0.190	0.694	0.694	0.694	0.694	1.008	352.80	1.06
400	0.216	0.209	0.209	0.211	0.654	0.654	0.654	0.654	0.885	354.13	1.44
450	0.17	0.17	0.169	0.170	0.558	0.559	0.559	0.559	0.778	350.10	0.29
500	0.15	0.15	0.149	0.150	0.501	0.5	0.502	0.501	0.703	351.33	0.64
550	0.145	0.146	0.145	0.145	0.465	0.465	0.466	0.465	0.640	352.00	0.83
600	0.114	0.114	0.114	0.114	0.404	0.411	0.411	0.409	0.589	353.60	1.29
650	0.12	0.12	0.12	0.120	0.384	0.385	0.384	0.384	0.529	343.63	1.57
700	0.362	0.363	0.363	0.363	0.613	0.613	0.612	0.613	0.500	350.00	0.26
750	0.04	0.04	0.04	0.040	0.274	0.273	0.274	0.274	0.467	350.50	0.40
800	0.092	0.092	0.092	0.092	0.312	0.312	0.312	0.312	0.440	352.00	0.83
850	0.293	0.293	0.293	0.293	0.5	0.5	0.5	0.500	0.414	351.90	0.80
900	0.066	0.066	0.066	0.066	0.262	0.262	0.262	0.262	0.392	352.80	1.06
950	0.258	0.258	0.258	0.258	0.443	0.443	0.443	0.443	0.370	351.50	0.69
1000	0.247	0.248	0.248	0.248	0.424	0.424	0.424	0.424	0.353	352.67	1.02
1050	0.391	0.391	0.391	0.391	0.559	0.558	0.559	0.559	0.335	352.10	0.86
1100	0.222	0.222	0.222	0.222	0.381	0.381	0.382	0.381	0.319	350.53	0.41
1150	0.21	0.21	0.21	0.210	0.36	0.36	0.36	0.360	0.300	345.00	1.18
1200	0.194	0.194	0.194	0.194	0.341	0.341	0.341	0.341	0.294	352.80	1.06
1250	0.192	0.192	0.192	0.192	0.33	0.331	0.332	0.332	0.280	350.00	0.26
Average										**351.19**	**0.87**

Table 1 presents data on the measured velocity of sound for 20 frequencies at a room temperature of 29 °C, using the constructed apparatus. The experiment was conducted by two groups of Bachelor of Science in Education majors, specializing in General Science, at Foundation University in Dumaguete City during the school year 2023-2024 as part of the Waves and Optics course. The frequency range extended from 300 Hz (lowest) to 1250 Hz (highest), with the first group handling the first ten frequencies and the second group managing the remaining frequencies.

The measured values of sound velocity are compared to the computed value (349.75 m/s) at 29 °C using percentage error. Across the 20 frequencies, the lowest percentage error was recorded at 0.26 % for frequencies 700 Hz and 1250 Hz, while the highest percentage error occurred at 650 Hz, reaching 1.57 %. The table also reveals that the average measured speed of sound in air at a room temperature of 29 °C is 351.19 m/s, with an average percentage error of 0.87 %. Notably, most percentage error values are below 2.00 %, indicating a closer proximity to 0.00 % rather than 5.00 %. Consequently, the data robustly justifies the accuracy of the constructed apparatus.

***Table 2**. Measured speed of sound at room temperature of 22 ^{o}C.*

Room Temperature: 22 ^{o}C											
v(T): 344.85 m/s											
	L_1 (m)			Average L_1 (m)	L_2 (m)			Average L_2 (m)	Wavelength (m)	Measured Speed of sound (m/s)	% error
Frequency (Hz)	Trial 1	Trial 2	Trial 3		Trial 1	Trial 2	Trial 3				
300	0.26	0.26	0.26	0.260	0.84	0.84	0.84	0.840	1.160	348.00	0.91
350	0.19	0.19	0.19	0.190	0.667	0.667	0.713	0.682	0.985	344.63	0.06
400	0.208	0.208	0.208	0.208	0.641	0.641	0.64	0.641	0.865	346.13	0.37
450	0.15	0.15	0.15	0.150	0.538	0.538	0.538	0.538	0.776	349.20	1.26
500	0.142	0.142	0.142	0.142	0.486	0.486	0.486	0.486	0.688	344.00	0.25
550	0.148	0.148	0.148	0.148	0.465	0.465	0.465	0.465	0.634	348.70	1.12
600	0.112	0.112	0.112	0.112	0.403	0.403	0.401	0.402	0.581	348.40	1.03
650	0.119	0.119	0.119	0.119	0.387	0.387	0.387	0.387	0.536	348.40	1.03
700	0.111	0.111	0.111	0.111	0.36	0.36	0.36	0.360	0.498	348.60	1.09
750	0.108	0.108	0.108	0.108	0.338	0.338	0.338	0.338	0.460	345.00	0.04
800	0.096	0.096	0.097	0.096	0.313	0.313	0.313	0.313	0.433	346.67	0.53
850	0.087	0.087	0.087	0.087	0.29	0.29	0.29	0.290	0.406	345.10	0.07
900	0.077	0.077	0.077	0.077	0.268	0.268	0.269	0.268	0.383	344.40	0.13
950	0.078	0.078	0.078	0.078	0.258	0.258	0.258	0.258	0.360	342.00	0.83
1000	0.246	0.246	0.246	0.246	0.419	0.419	0.419	0.419	0.346	346.00	0.33
1050	0.221	0.221	0.221	0.221	0.385	0.386	0.385	0.385	0.329	345.10	0.07
1100	0.218	0.218	0.218	0.218	0.375	0.375	0.375	0.375	0.314	345.40	0.16
1150	0.208	0.208	0.208	0.208	0.358	0.358	0.358	0.358	0.300	345.00	0.04
1200	0.193	0.193	0.193	0.193	0.337	0.337	0.337	0.337	0.288	345.60	0.22
1250	0.191	0.19	0.19	0.190	0.329	0.329	0.329	0.329	0.277	346.67	0.53
Average										**346.15**	**0.5**

Table 2 presents data on the measured velocity of sound for 20 frequencies at a room temperature of 22 °C. The experiment was conducted by two groups of Bachelor of Science in Information Technology students enrolled in the subject General Physics 2 at Foundation University, Dumaguete City, during the school year 2023-2024. The frequencies used in this part are the same as those performed at 29 °C, with the first group handling the initial ten frequencies, and the second group managing the remaining frequencies.

Like the experiment conducted at a room temperature of 29 °C, the measured values of the speed of sound in air are compared to the computed value (344.85 m/s) at 22 °C. Among the 20 frequencies, the lowest percentage error was recorded at 0.04% for frequency 750 Hz, while the highest percentage error occurred at 450 Hz, reaching 1.26 %. Additionally, it reveals that the average measured speed of sound at 22 °C is 346.15 m/s, with an average percentage error of 0.5 %. These results are in close agreement with the data shown in Table 1, indicating that the constructed apparatus is accurate enough and can be used to demonstrate and experiment on longitudinal standing waves and measure the speed of sound in air.

CONCLUSION

Considering the obtained results, the experiment demonstrates minimal error values, with many percentage errors closely approaching zero. This indicates that the constructed apparatus exhibits a high level of accuracy and reliability. Consequently, it can be confidently utilized for both demonstrating and conducting experiments on standing longitudinal waves, as well as accurately measuring the speed of sound.

RECOMMENDATION

The researchers have drawn the following recommendations to guide future researchers.

1. Since the experiment is limited to only two positions of the piston where resonance occurs, the researcher recommends exploring additional positions to validate the presence of standing waves in a one closed-end tube.
2. The clear plastic tube must be securely fastened to ensure it remains stationary and does not change its distance from the speaker when the piston changes position.
3. The longer the wavelength of a sound wave, the lower its frequency. Since the clear tube used in the experiment has a length of only 1.3 m, it becomes challenging to determine the piston's position where resonance occurs for frequencies lower than 200 Hz. Therefore, it is recommended to use a longer tube to accommodate lower frequencies.
4. Explore free mobile and PC applications that can enhance the teaching and learning of waves and sound.

Experiment Guide

The following is the designed experiment guide.

One-Closed-End Resonance Tube:
Measuring the Speed of Sound

I. Theory

A sound wave is a longitudinal wave characterized by oscillation in the direction of its propagation. In the case of a traveling wave with speed v, frequency f, and wavelength λ, the relationship between these variables can be expressed as follows.

$$v = \lambda f \qquad \text{eq. 1}$$

In this laboratory experiment, we will utilize a fundamental property of a traveling wave, known as resonance, to determine the wavelength and, consequently, the speed of a sound wave. Sound waves are generated using a speaker connected to a smartphone with a tone generator. The tone generator transmits an oscillating current signal to the speaker, inducing vibrations in the speaker's diaphragm. As the diaphragm moves outward, the air near the speaker is compressed, resulting in a small volume at relatively high pressure, which then propagates away from the speaker. Conversely, as the diaphragm moves inward, a low-pressure area is created, propagating away from the speaker.

In this experiment, we will constrain the sound waves to move in one direction by employing a one-closed-end resonance tube apparatus. Inside the tube is a movable piston that effectively closes off one end. When a sound wave is generated by the speaker positioned at one end of the tube, it travels

along the tube's volume until it encounters the piston. At this point, the wave is reflected towards the speaker-end of the tube. The piston's movement can alter the tube's length, causing the incident and reflected waves within the tube to interfere in a manner that maximizes the amplitude of the sound waves.

A miniature microphone, positioned below the speaker, serves the purpose of identifying the plunger's position where resonance occurs, detected by capturing the loudest sound. This resonance position is clearly indicated in the Smartscope app. When resonance occurs, the standing waves created within the tube are said to be in resonance. As illustrated in Figure 2, additional resonant modes can be identified by gradually adjusting the tube's length through piston movement.

Figure 2 below illustrates the essential connections between the tube's length and the wavelength of the wave, specifically focusing on the initial four resonances of the tube. Distances denoted as L_1, L_2, and L_3 signify the measurements from the tube's opening to the piston's position during the three resonances. The precise positions of multiple resonances corresponding to each pure tone frequency will be determined through experimental means.

If the resonance tube is closed at one end, the relationship between the tube length L, and the wavelength λ of the sound wave, is given by the equation.

$$L = \frac{n\lambda}{4}, \quad n = 1,3,5,7,9,11, \ldots \quad \text{eq. 2}$$

The relationship given in equation 2 is not valid for a real resonance tube because the point at which the upper antinode occurs is just outside the end of the tube. The exact location depends upon the diameter of the tube. The end effect is the same for each of the resonances and will cancel if differences between locations of the individual resonances are considered. Considering the differences between adjacent resonances gives the following equations.

$$L_2\text{-}L_1 = L_3\text{-}L_2 = L_4\text{-}L_3 = \frac{\lambda}{2} \qquad \text{eq. 3}$$

Equation 3 determines the wavelength, and the frequency of the generated tone is known. Equation 1 then allows the determination of the speed of the sound. The speed of the sound in air has a slight linear dependence on the air temperature for a limited range of temperature. The speed of sound V_T at a temperature T will be determined from

$$V_T = (331.5 + 0.607T)\ \text{m/s} \qquad \text{eq. 4}$$

where T is the temperature in ^oC.

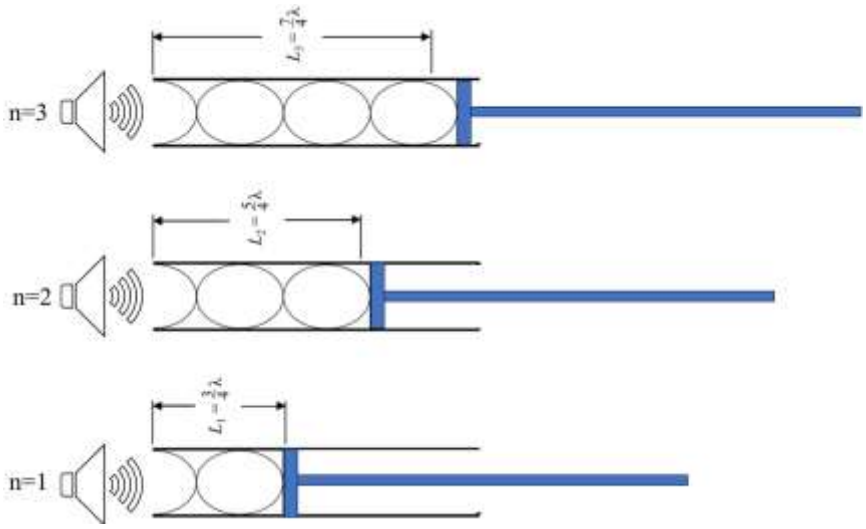

Figure 2. *Effective tube's length and the wavelength of the wave.*

II. Objective

1. Determine the effective length of a closed tube at which resonance occurs for 20 pure tone frequencies.
2. Determine the wavelength of the standing wave produced from the effective length of the resonance tube for each pure tone frequency.
3. Determine the speed of sound in air from the measured wavelength and known frequency and compare with the accepted value.

III. Materials

1. Resonance tube assembly (comprising a speaker, mini-microphone, and a movable piston)
2. Thermometer
3. Audio and microphone chord.
4. Two smartphones—one equipped with the SmartScope App and the other with a sound frequency generator app.

III. Procedure

1. Measure the room temperature and record it on the Data Sheet. Determine the speed of sound as a function of temperature using equation 4.
2. Place the resonance tube horizontally on the table, positioning the speaker approximately 1 cm from one end of the tube, as illustrated in Figure 1. Connect the speaker to the amplifier's speaker output.
3. Connect the smartphone with the sound frequency generator application to the amplifier's input using an audio cord.
4. Connect another smartphone with the SmartScope application to the mini microphone.
5. Install the microphone in the designated hole below the speaker and activate the SmartScope mobile application.
6. Adjust the Sound Frequency Generator to 300 Hz. Gradually increase the speaker volume until you hear a sound.

7. Slowly adjust the position of the piston to identify the point that results in maximum amplitude, as indicated by SmartScope. Mark this position as L_1, representing the distance from the opening of the tube to the piston's position. Repeat this procedure for three trials and calculate the average value for L_1.
8. Slowly move the piston for the second position that will result again in maximum amplitude, marking it as L_2. Conduct three trials and determine the average L_2.
9. Calculate the wavelength of the sound wave using the equation.

$$\lambda = 2(average\ L_2 - average\ L_1)$$

10. Determine the measured value of speed of the sound using the equation.

$$v_{measured} = \lambda f$$

where f is the set frequency.

11. Compare the standard and measured values of the speed of sound using the percentage error equation.
12. For subsequent trials, repeat steps 6-11 for the next 19 higher frequencies (increase by 50 Hz)

IV- Data and Results

$$error = \frac{|standardvalue - observedvalue|}{standardvalue} x100$$

Computed speed of sound -v(T) =(331.5 +0.607T) m/s
Measured speed of Sound = λf

Data Sheet

Room Temperature: _____^oC											
v(T): _____m/s											
	L_1 (m)			Average L_1 (m)	L_2 (m)			Average L_2 (m)	Wavelength (m)	Measured Speed of sound (m/s)	% error
Frequency (Hz)	Trial 1	Trial 2	Trial 3		Trial 1	Trial 2	Trial 3				
Average											

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TEMPERATURE AND RAINFALL PATTERNS OF DATAGON, PAMPLONA, NEGROS ORIENTAL AS COMPARED TO THOSE IN PAGASA-SIBULAN STATION AND BAGACAY, DUMAGUETE CITY, NEGROS ORIENTAL

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ABSTRACT

This study aimed to determine the temperature and rainfall patterns of Datagon, Pamplona, Negros Oriental. Also, it aimed to make climate study inexpensive to communities specially to those who have interests to conduct their own studies through the use of meteorological equipment that can be constructed out of locally available materials.

Temperature and rainfall data were gathered for a period of thirty-one (31) months between May 1, 2016 and November 30, 2018 and compared to that from PAGASA-Sibulan. As a separate exercise, data were also collected separately from Bagacay, a place very near to PAGASA Sibulan (3 km) thus expected to be closely correlated.

The results of the study show that the rainfall data for Datagon diverge from PAGASA Sibulan even though the temperature data correlates sufficiently.

Instructions for constructing meteorological equipment as used in this study, such as temperature housing and rain gauge, out of locally available materials are included in this article.

STATEMENT OF THE PROBLEM

The purpose of this study is to determine the temperature and rainfall pattern of the site in Datagon, Pamplona, Negros Oriental and compare the data to the stations of Bagacay, Dumaguete City and PAGASA-Sibulan. Specifically, the study aimed to:

a. design and use an inexpensive measuring instrument-rain gauge and thermometer housing.
b. determine the temperature and rainfall patterns of the (3) sites: Datagon, Pamplona, Negros Oriental; Bagacay, Dumaguete City, Negros Oriental; and PAGASA-Sibulan, Negros Oriental Station.
c. graph the temperature and rainfall data of the three sites.

d. analyze and compare the temperature and rainfall patterns of Datagon, Pamplona to the data gathered by PAGASA - Sibulan Station and Bagacay, Dumaguete City and determine the following:
   i. monthly minimum, maximum, mean and extreme temperature
   ii. monthly minimum, maximum, mean and extreme rainfall
   iii. temperature and rainfall variability
   iv. total amount of rainfall
   v. consecutive dry days and wet days

e. process rainfall data using a rainfall software produced by the Maxino College Climate Studies Center.

f. Publish gathered data including the results of the study.

RELATED LITERATURE

The people who are listed in the table below are all the climate researchers from Maxino College who have conducted temperature and rainfall patterns from his/her respective home location/s and comparing the data to the stations of Bagacay, Dumaguete City and PAGASA- Sibulan Station.

Table 2.1 *Shows the location of the study by the corresponding climate researcher and the length of time the data was gathered.*

LOCATION	NAME OF RESEARCHER	YEAR OF STUDY
Maloh, Siaton	Ryan Tubog	July 2010 - December 2010
Bago, Tayasan	Alden N. Tiongco	November 2011 - December 2012
San Miguel, Tanjay City	Jonel S. Noblesala	April 2013 - January 2014
Tandayag, Amlan		
Tambulan, Tayasan	Rasel Asentista Dayuday	June 2013 - December 2014
Kalumboyan, Bayawan City	Pelerd C. Langga	July 10, 2014 - January 2015
Mag-abo, Zamboanguita	Arnel G. Tubog	July 22, 2013- December 31, 2014
Mantuyop, Siaton		August 19, 2013 – December 31, 2014
Pindahan, Tayasan	Jossa Teves	May 2015 - December 2016
Catulayan, San Juan, Siquijor	Christine Sumagang Alom	March 26, 2015- January 31, 2016
Pancil, Cambanjao, Bais City	Raymond John Palomar	May 2016 - December 2017
Pandanon, Mabinay	Rodney Nale Fabillar	January 1, 2017 - December 31. 2017
Ulayan, Maloh, Siaton	Deon T. Gabica	January 4, 2015 - December 31, 2017
Datagon, Pamplona	Analuz P. Frejoles	May 1, 2016 - November 30, 2018

Summarized Conclusion:

Locations that can be represented by PAGASA-Sibulan and Bagacay Dumaguete City in terms of temperature pattern but cannot be represented in rainfall are as follows:

- Pindahan, Tayasan
- Pandanon, Mabinay
- Tambulan, Tayasan
- Pancil, Cambanjao, Bais City
- Kalumboyan, Bayawan City
- Mag-abo, Zamboanguita
- Mantuyop, Siaton
- Ulayan, Maloh, Siaton
- Catulayan, San Juan, Siquijor
- Datagon, Pamplona

Bago, Tayasan can only be represented by Bagacay, Dumaguete City in terms of temperature; its rainfall profile cannot be represented by the other two stations. And, only San Miguel, Tanjay City and Tandayag, Amlan can be represented by PAGASA-Sibulan and Bagacay, Dumaguete City in both temperature and rainfall profiles.

Figure 2.1 *shows the map of Negros Oriental with the dotted locations of climate study by Maxinian researchers.*

METHODOLOGY

Research Locale

Datagon, Pamplona is located 29.8 miles (48 km) away from Dumaguete City. It is situated at approximately 9.4513, 123.0879. Elevation at these coordinates is estimated at 67.6 meters or 221.8 feet above mean sea level.

Dumaguete City is located at 9º 18' 28'' N latitude and 123º 18' 28" E longitude. It has flat maximum slope of 5% at the boundary with Valencia to the west at about 80 meters above the sea level. About 93% of the land has slope of less than 3%. The city has a land area of 34.26 km. Of the province's 20 Municipalities and 5 Cities, Dumaguete City is the smallest in terms of land area.

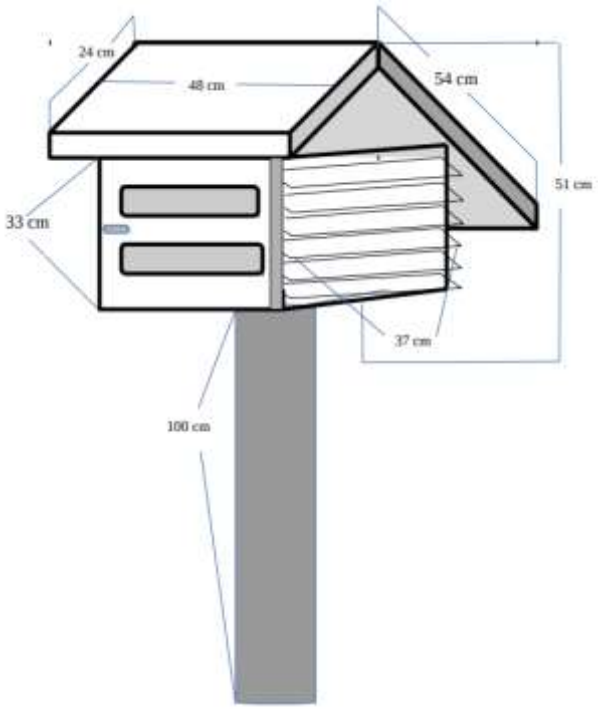
Construction of Equipment

Pieces of apparatus were constructed using the following guides

a. For Temperature Measurement (Thermometer Housing)

A) Materials:

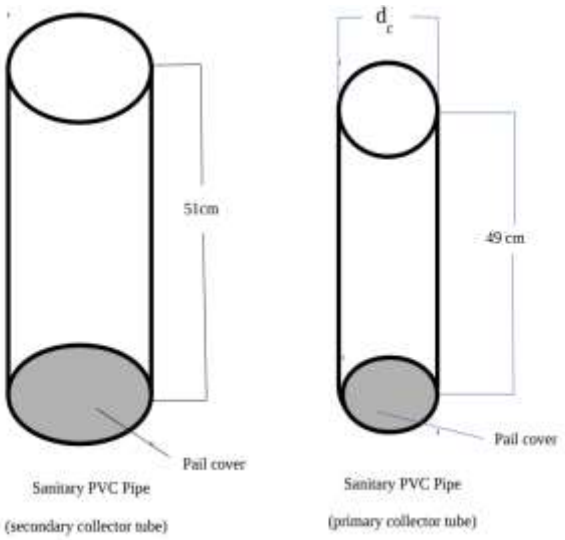
1. Thermometer
2. Marine Plywood (54cm × 48cm) and (24cm × 48cm)
3. Common nails
4. White Paint
5. Marine Plyboard (1/2 inch × 4 ft. × 8 ft.)
6 Hammer
7 Screw Driver
8. Hinge (2pcs.)
9. One (1) cm long post.



B) Procedure:

1. Gather the materials needed.
2. Cut the marine plyboard into strips (1/2 inch × 2 inches × 37cm).
3. Cut the plyboard strips into two equal lengths (33cm long), and cut another two equal lengths (51cm long). Then use it as a post.
4. Put a plyboard strip (37cm) parallel to each other in an equal interval perpendicular to the post.
5. On the top, put a plywood (54cm × 48cm) and (24cm × 48cm) on the opposite side as a roof. Nail it using hammer.
6. Measure the distance in between the two longer posts (51cm long)

7. Using a marine plyboard, take a part equal to the distance between the two longer post (34cm long).
8. Divide it into two equal parts by cutting it horizontally.
9. Put hinges on the door.
10. Make a rectangular hole.
11. Attach them in the post according to their positions.
12. Have the finished thermometer housing held by the 100cm long post. Consider sturdiness upon attaching it to the post.



b. For Rainfall Measurement (Rain Gauge Apparatus)

A) Materials:

1. One (1) empty plastic gallon container.
2. Empty plastic bottle of soy sauce or vinegar 385 ml.
3. Two (2) inches in diameter sanitary PVC pipe (49 cm long) primary.
4. Three (3) inches in diameter sanitary PVC pipe (51cm long) secondary collector.
5. All Purpose Marine Epoxy.
6. Hacksaw
7. Empty Plastic container 500 ml
8. Kitchen Knife.
9. Plastic Pail cover

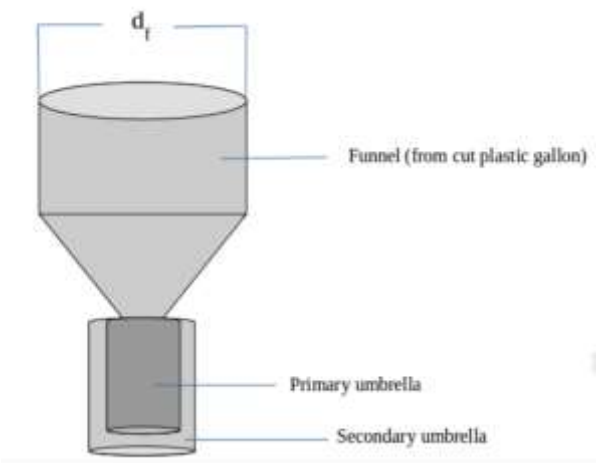
B) Procedures:

Rain Collector:

1. Cut the 3 inches in diameter sanitary PVC pipe (51centimeters long) using hacksaw.
2. Cut the two inches in diameter PVC pipe (49 centimeters long) using hacksaw.
3. Cut the plastic pail cover into 3 inches in diameter equal to the diameter of the secondary collector then use it to close one end. Put marine epoxy to prevent leakage.
4. Cut the plastic pail cover into 2 inches in diameter equal to the diameter of the primary collector then use it to close one end. Put a marine epoxy to prevent from leak.

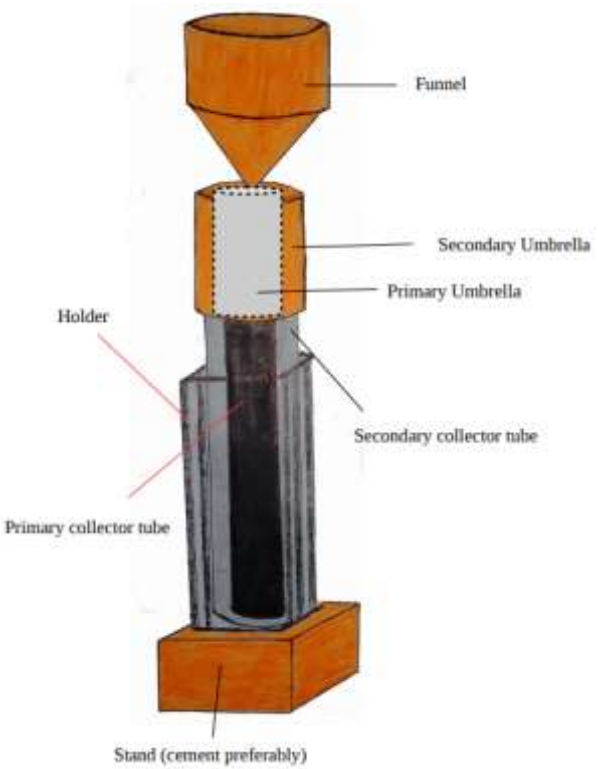
Funnel:

5. Cut the bottom part of the empty 1-gallon container and then use it as funnel.
6. Cut the upper part of the 500 ml plastic container and then make a hole equal to the mouth of the gallon then use it as secondary umbrella. Twist to tighten.
7. For the 385 ml cut the upper part and make a hole at the bottom part of the plastic equal to the mouth of the gallon then use it as primary umbrella. Twist to tighten.



Rain-Gauge Apparatus:

8. Put the two (2) inches (primary collector) inside the three (3) inches (secondary collector) tube respectively.
9. Put a funnel on the top of the two collector tube.



Time and Method of Collecting Data

Observations are taken at specific time every day; 8:00 am, 11:00 am, 2:00 pm, 5:00 pm. In measuring rainfall during a rainy day, the use of umbrella is not allowed to avoid errors in the measurement (errors often come from the droplets of water from the umbrella dropped to the raingauge). And even if there is already lightning up in the sky, the data is still taken.

The measurement of rainwater is collected from the primary collector tube and it is emptied after the measurement is taken. The overflowed rainwater from the primary collector, specially during heavy rains, will automatically be stored in the secondary collector tube. Thus, the overflowed water will be transferred to the primary collector tube to be measured. The total amount of rainfall is the sum of measurements taken from the primary tube and the overflowed from the secondary tube. When there is no rainfall, zero (0) is recorded, asterisk (*) is for missed observation, and trace (T) for unmeasurable rainfall. Since the funnel is easily destroyed, it is duly replaced. For temperature measurement, ºC is the unit used. When holding the thermometer, it is not allowed to touch the bulb. The thermometer housing is monitored from time to time to replace rotten woods if there are any.

Method of Comparison

The temperature and rainfall data results of Datagon, Pamplona are compared to PAGASA- Sibulan Station and Bagacay, Dumaguete City, Negros Oriental with the same span of time the study is conducted. The *trends and magnitude* for both temperature and rainfall that is presented through graphs are highly concerned in the comparison of data

including the *maximum and minimum temperatures* and *the highest recorded rainfall in each site*. Also, the number of consecutive wet and dry days are included using the same software for both stations.

RESULTS AND ANALYSIS

a. Temperature Patterns

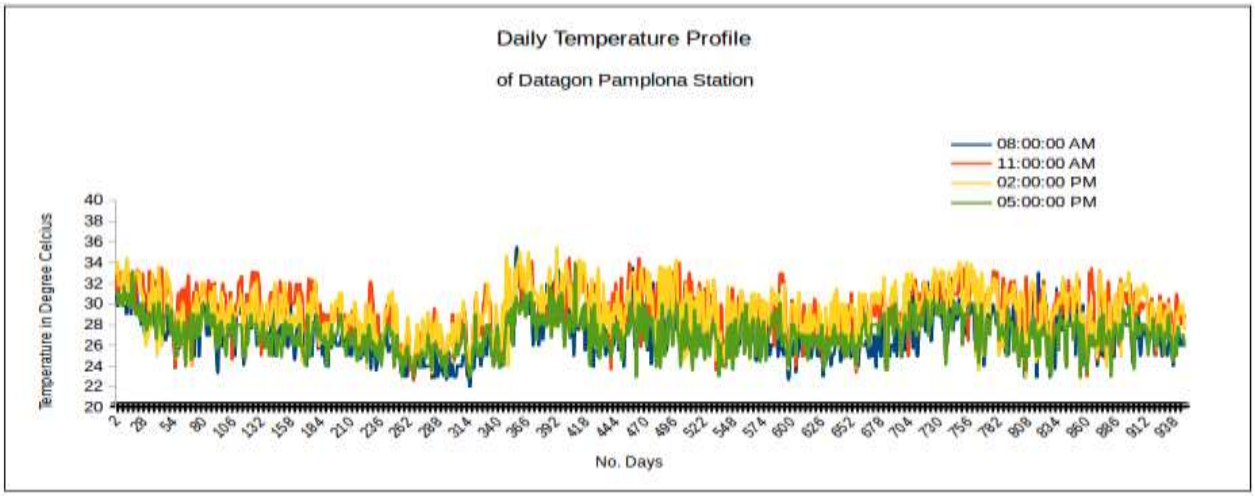


Figure 4.1a *Daily Temperature Profile of Datagon, Pamplona Station.*

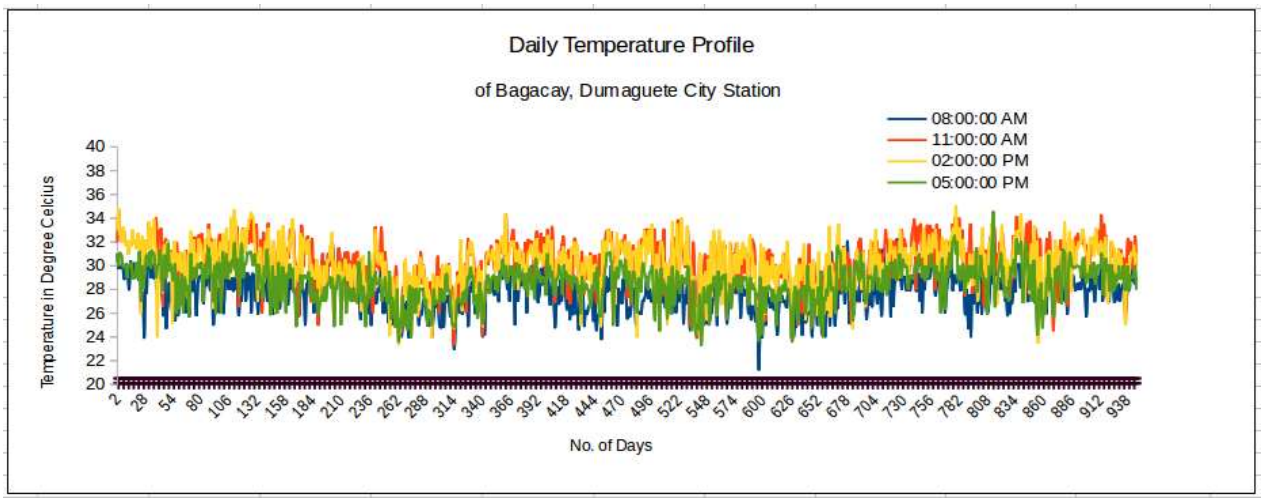


Figure 4.2a *Daily Temperature Profile of Bagacay, Dumaguete City Station.*

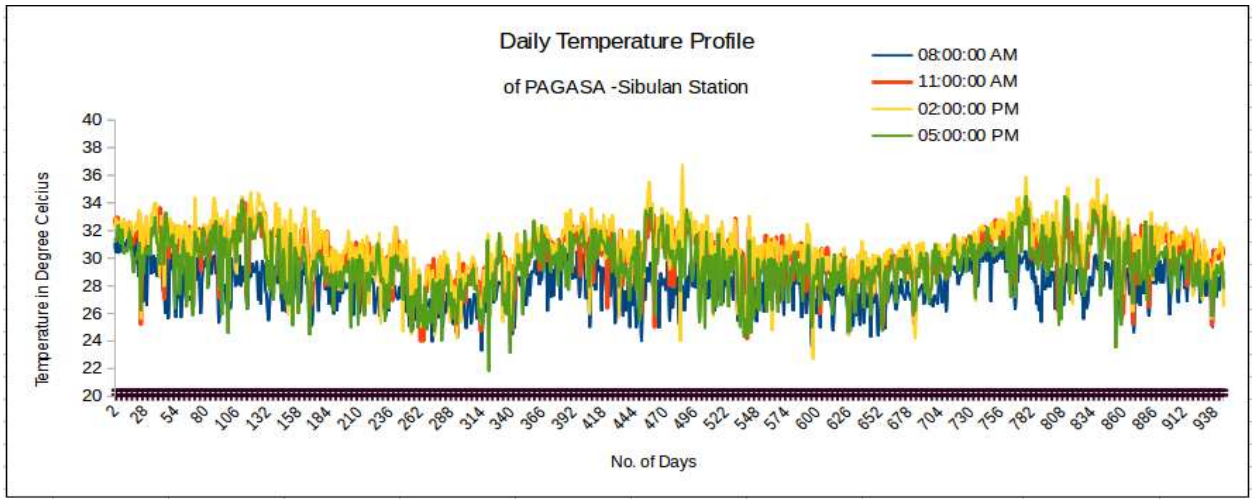


Figure 4.3a *Daily Temperature Profile of PAGASA-Sibulan Station.*

Figure 4.1a is the temperature pattern of Datagon, Pamplona, Negros Oriental. Based on the graph, most of the hottest temperature values are found at 11:00 AM and 2:00 PM in which the temperature values are just close to each other. The lowest and coldest temperature values on the other hand are found at 8:00 AM and 5:00 AM. From the graph, the highest recorded temperature is 35.5 °C which occurred at 02:00 PM last May 25, 2017 (day 390). The lowest recorded temperature is 22 °C which occurred at 8:00 AM last March 9, 2017 (day 313).

Figure 4.2a shows the daily temperature profile of Bagacay, Dumaguete City. Based on the graph, most of the low temperature values are found at 8:00 AM and 5:00 PM. Highest temperature values are at 11:00 AM and 2:00 PM. The highest recorded temperature is 35°C which occurred at 2:00 PM last June 16, 2018 (day 777) and the lowest recorded temperature is 21.5°C last December 16, 2017 (day 595) at 8:00 AM.

Figure 4.3a shows the daily temperature profile of PAGASA-Sibulan Station. As shown in the graph, most of the low temperature values are found at 8:00 AM and 5:00 PM. At 11:00 AM and 2:00 PM is where the highest temperature values are mostly found. The highest recorded temperature is 36.4°C which occurred at 2:00 PM last August 27, 2017 (day 484) and the lowest recorded temperature is 22°C occurred at 5:00 PM last March 15, 2017 (day 319).

The three stations have similar temperature trend. They only differ on the magnitude of temperature.

b. Temperature Variability

The sudden rise and fall of temperature brings danger to any living things. Heat waves, particularly, is one of the most concerned problem that climate change brings for it can cause various diseases. And so, getting the temperature variability in a climate study is important to determine if a certain place is experiencing the latter phenomenas. Temperature variability mainly uses the maximum temperature in each calculation- the overall mean of the maximum temperatures is

calculated. This MEAN value is used for MEAN-1STDEV, MEAN-2STDEV, MEAN-3STDEV, MEAN+1STDEV, MEAN+2STDEV, and MEAN+3STDEV.

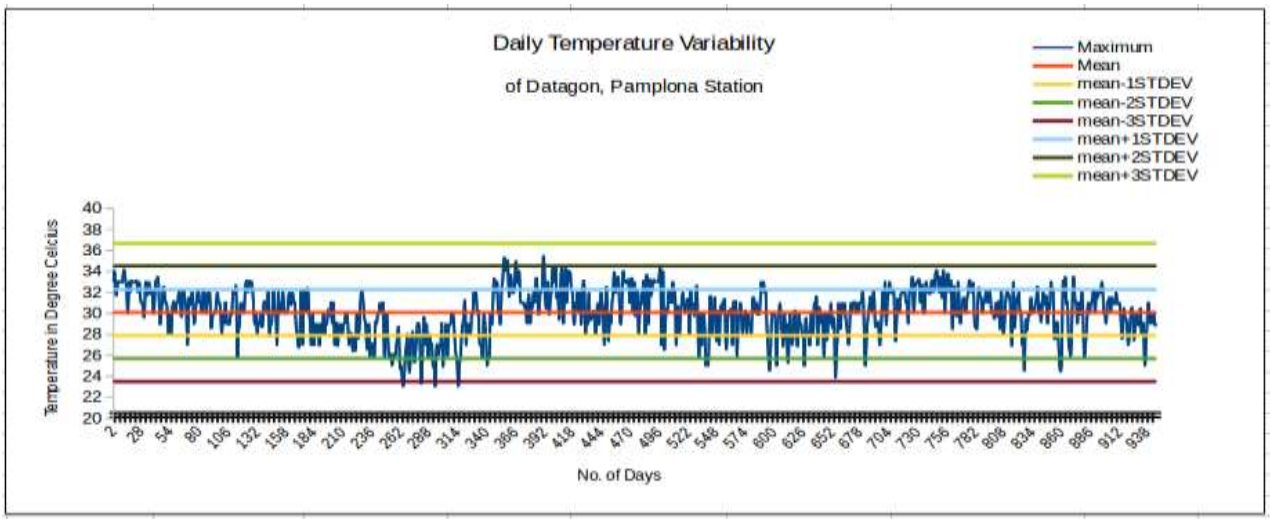


Figure 4.1b *Temperature Variability of Datagon, Pamplona Station.*

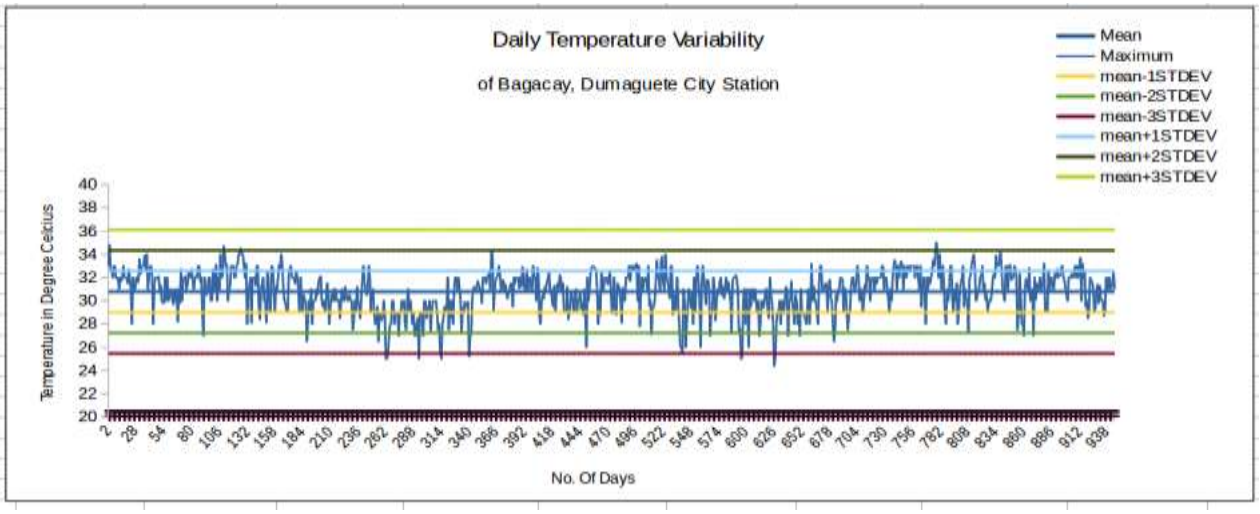


Figure 4.3b *Temperature Variability of Bagacay, Dumaguete City Station.*

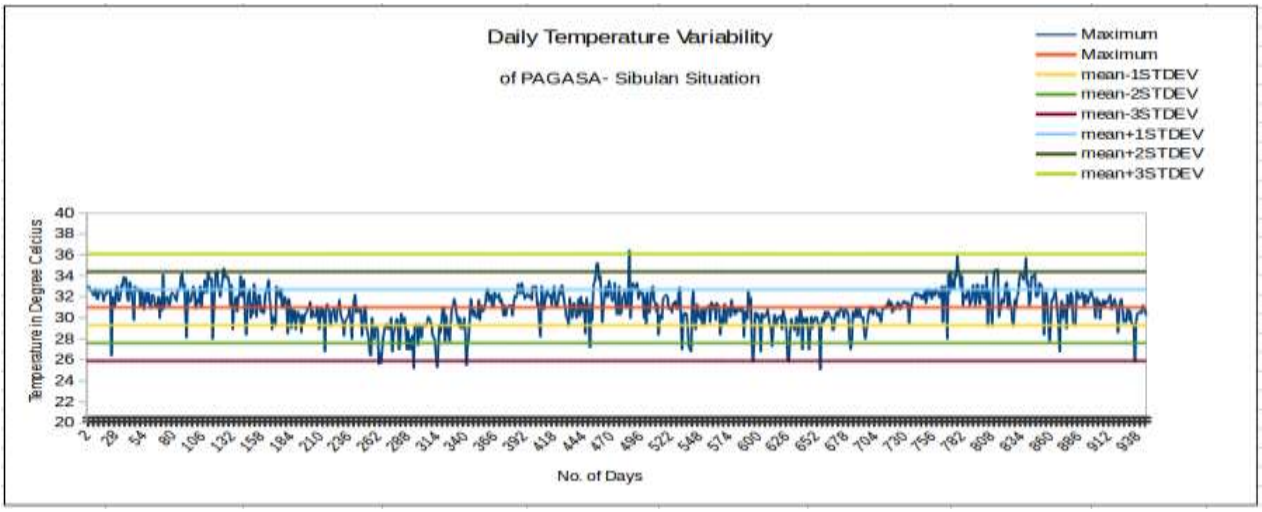


Figure 4.3b *Temperature Variability of PAGASA-Sibulan Station.*

The sudden rise and fall of temperature brings danger to any living things. Heat waves, particularly, is one of the most concerned problem that climate change brings for it can cause various diseases. And so, getting the temperature variability in a climate study is important to determine if a certain place is experiencing the latter phenomenas. Temperature variability mainly uses the maximum temperature in each calculation- the overall mean of the maximum temperatures is calculated. This MEAN value is used for MEAN-1STDEV, MEAN-2STDEV, MEAN-3STDEV, MEAN+1STDEV, MEAN+2STDEV, and MEAN+3STDEV.

Figure 4.1b shows the daily temperature variability of Datagon, Pamplona, Negros Oriental. It can be seen that many temperature values go beyond MEAN-1STDEV and MEAN+1STDEV. A few can also be found beyond MEAN-2TDEV, MEAN+2TDEV, and MEAN-3TDEV. There are no temperature values beyond MEAN+3TDEV.

Figure 4.2b is the daily temperature variability of Bagacay, Dumaguete City. Many temperature values can be seen beyond MEAN-1STDEV, and MEAN +1STDEV. Some are found beyond MEAN-3STDEV, MEAN+2STDEV but are only fewer when compared to those temperature values beyond MEAN-2STDEV. There are no values beyond MEAN+3STDEV.

In **Figure 4.3b** (Daily temperature variability of PAGASA-Sibulan Station), many temperature values can be seen that go beyond MEAN-1STDEV, MEAN+1STDEV. In MEAN+2STDEV and MEAN+3STDEV you can also see values beyond these points but are only fewer compared to those beyond MEAN-2STDEV and MEAN-3STDEV.

c. Minimum Temperature

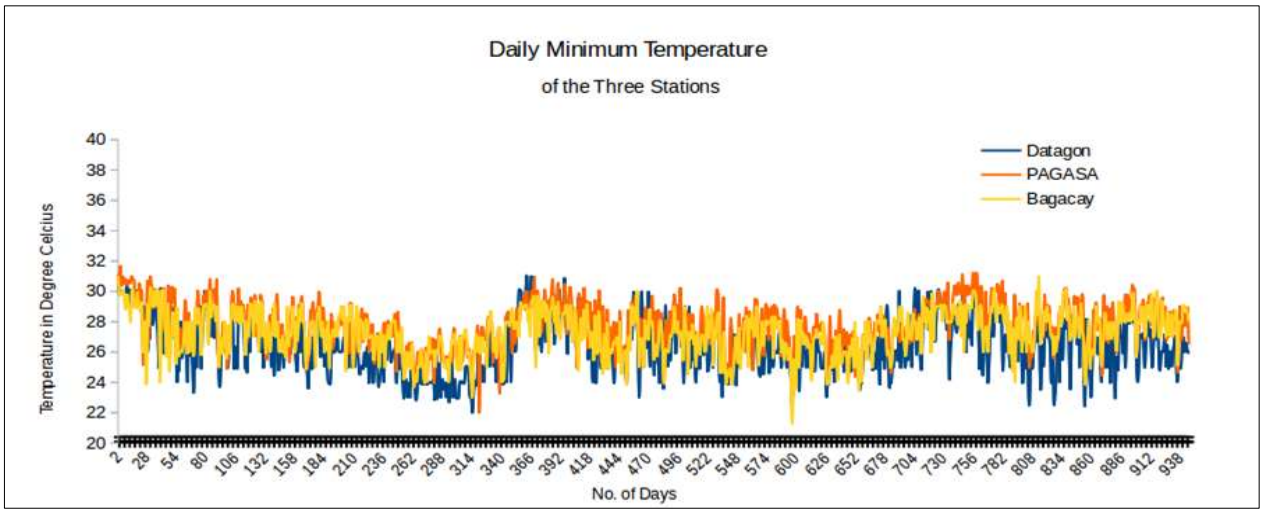


Figure 4.1c *Daily Minimum Temperature of Datagon, Bagacay, and PAGASA-Sibulan Station.*

The lowest minimum temperature throughout the study in Datagon, Pamplona is 22°C which occurred at 8:00 AM last March 9, 2017 (day 313). The highest minimum temperature is 31°C recorded on May 1, 2016 (day 1), April 26, 2017 (day 361), and April 30, 2017 (day 365).

The lowest minimum temperature throughout the study in Bagacay, Dumaguete City is 21.5°C last December 16, 2017 (day 595) at 8:00 AM. The highest minimum temperature profile is 31°C recorded on May 1, 2016 (day 1) and July 21, 2018 (day 812).

PAGASA- Sibulan Station's lowest minimum temperature throughout the study is 22°C occurred at 5:00 PM last March 15, 2017 (day 319). The highest recorded minimum temperature is 31.7°C occurred at 8:00 AM on May 3, 2016.

The three stations have similar minimum temperature pattern specially in the rise and fall of the graphs. It can be seen that PAGASA- Sibulan Station and Bagacay, Dumaguete City stations show closer trend similarities. Among the three, Datagon, Pamplona has the lowest trend.

d. Maximum Temperature

The highest temperature throughout the study in Datagon, Pamplona station is 35.5°C (day 390) last May 25, 2017 at 2:00 PM. Its lowest maximum temperature value is 23°C occurred on February 16, 2017 (day 292) and March 09, 2017 (day 313).

The highest recorded temperature in Bagacay, Dumaguete City station is 35 °C (day 777) last June 16, 2018 at 2:00 PM and the lowest recorded maximum value is 24.4°C

occurred on January 15, 2018 (day 625) at 2:00 PM.

In PAGASA-Sibulan station, the highest recorded temperature is 36.4 °C occurred last August 27, 2017 (day 484) at 2:00 PM and the lowest maximum value is 21.5 °C last February 13, 2018 (day 654) at 11:00 AM.

The three stations have similar maximum temperature pattern specially in the rise and fall of the graph. But only PAGASA-Sibulan and Bagacay, Dumaguete City stations show closer similarities. Datagon, Pamplona station shows the lowest maximum temperature trend except only on the third crest, as seen on the graph, where it is highest compared to PAGASA-Sibulan and Bagacay, Dumaguete City stations.

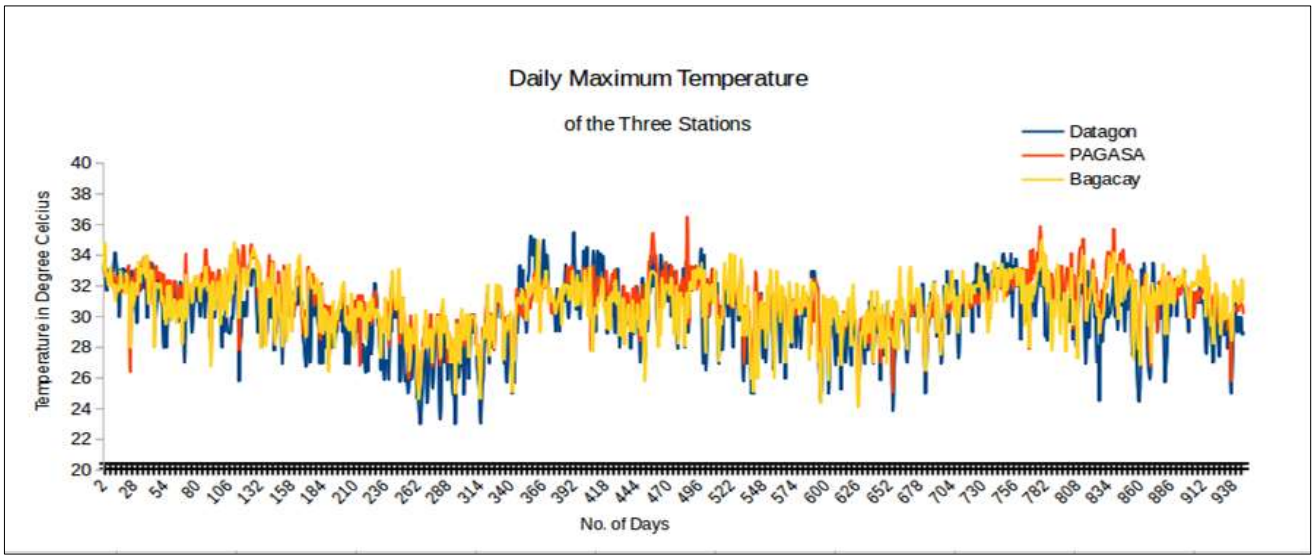


Figure 4.1d *Daily Maximum Temperature of Datagon, Bagacay, and PAGASA-Sibulan Station.*

e. Daily Mean Temperature

The highest daily mean temperature in Datagon, Pamplona station is 32.9°C urred on April 20, 2017 (day 355). The lowest daily mean temperature is 22.8°C last March 9, 2017 (day 313).

The highest recorded daily mean temperature in Bagacay, Dumaguete City station is 32.8 last July 21, 2018 (day 812) and the lowest recorded mean temperature is24.2 that occurred on December 15, 2017 (day 594), December 16, 2017 (day 595).

The highest daily mean temperature in PAGASA Sibulan station is 33.4 °C occurred on June 15, 2018 (day 776). The lowest daily mean temperature is 24.6°C last February 16, 2017 (day 292).

It can be seen on the graph that Datagon, Pamplona station has the lowest mean temperature pattern while PAGASA Sibulan station has the highest mean temperature pattern.

f. Daily Rainfall Profile of Datagon, Bagacay, and PAGASA-Sibulan Stations

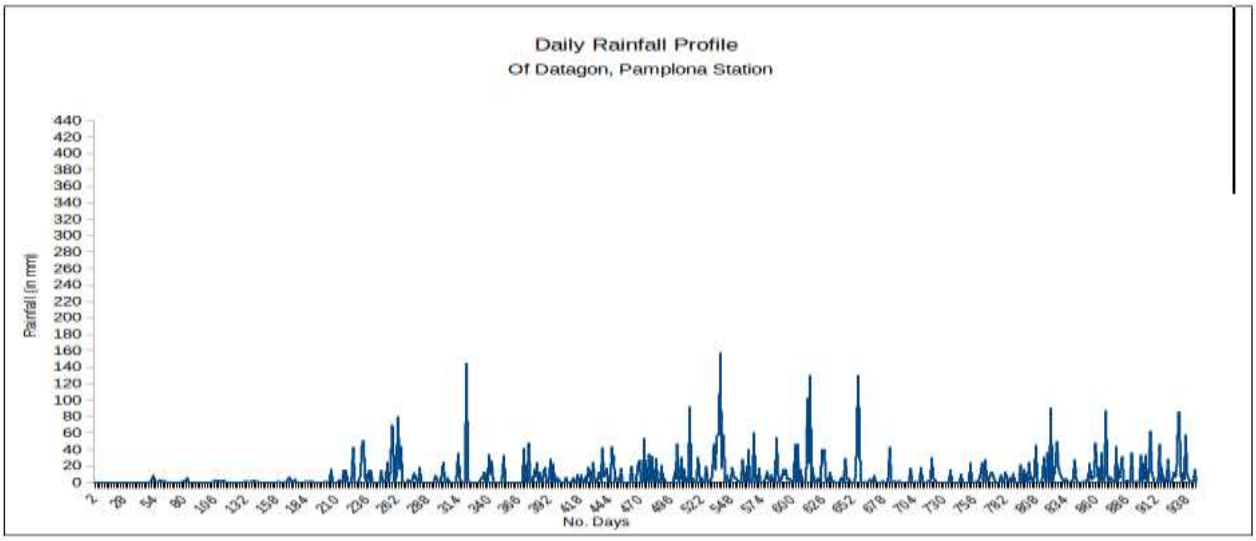


Figure 4.1f *Daily Rainfall Profile of Datagon Station.*

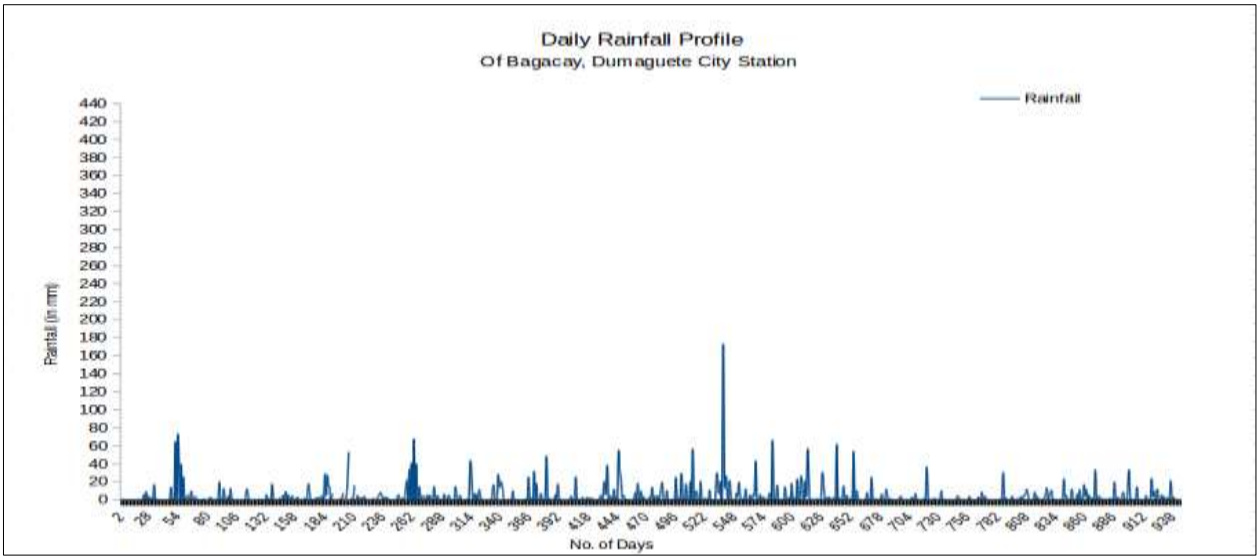


Figure 4.2f *Daily Rainfall Profile of Bagacay Station.*

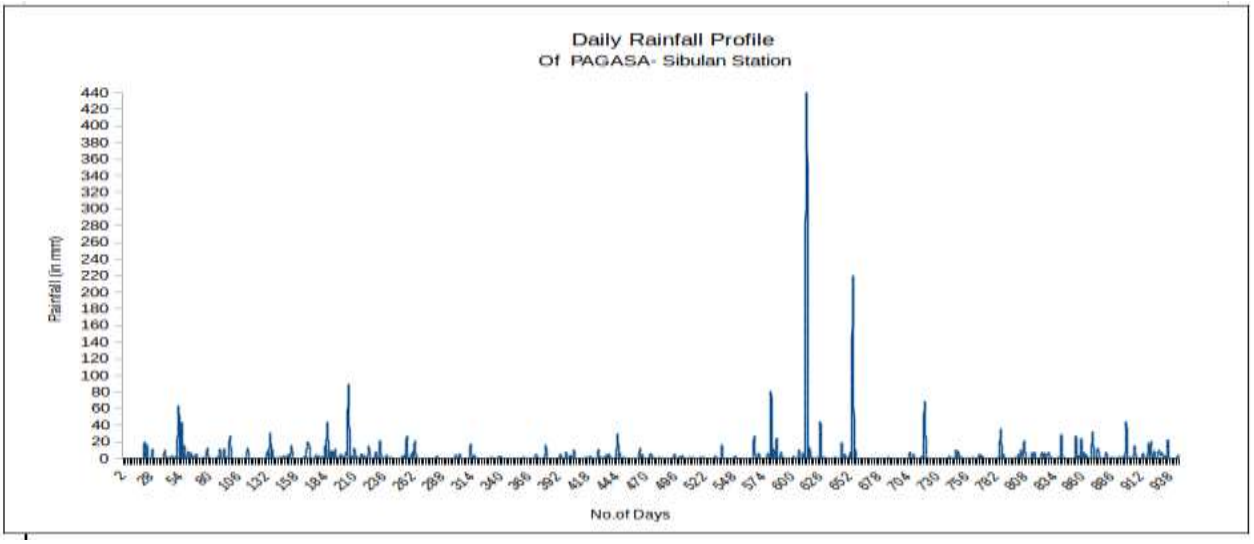


Figure 4.3f *Daily Rainfall Profile of PAGASA Station.*

Figure 4.1f shows the daily rainfall profile of Datagon, Pamplona station. At the first month of the study, May 2016, the site got a zero record of rainfall. The site experienced many dry days most especially in the months of March, April, and May in the whole year of study. Most of the rainfall occurences were experienced in June 2016, and from October 2016 to December 2016; January 2017, May 2017, and from July 2017 to December 2017; January 2018 to February 2018, and from June 2018 to November 2018 (last month of the study).

Figure 4.2f shows the daily rainfall profile of PAGASA-Sibulan station. In this site, February, March, April, and May, were mostly the months of dry days. The most experienced rainfall occurences were in June 2016 to July 2016, and from September 2016 to December 2016; January 2017, June 2017 to July 2017, October 2017 and December 2017; from June 2018 to November 2018.

Figure 4.3f shows the daily rainfall profile of Bagacay, Dumaguete City station. The site experienced many dry days in the months of March, April, and May. Rainfall occurences were mostly experienced in June 2016 to July 2016 and from September 2016 to December 2016; January 2017 and from July 2017 to December 2017; January 2018 and from June 2018 to November 2018.

Among the three stations, only Datagon, Pamplona station has the different rainfall trend. It has the highest number of rainfall occurences compared to the other two stations. PAGASA- Sibulan and Bagacay, Dumaguete City stations have similar trend only in terms of rainfall occurences, not in magnitude.

g. Rainfall Variability

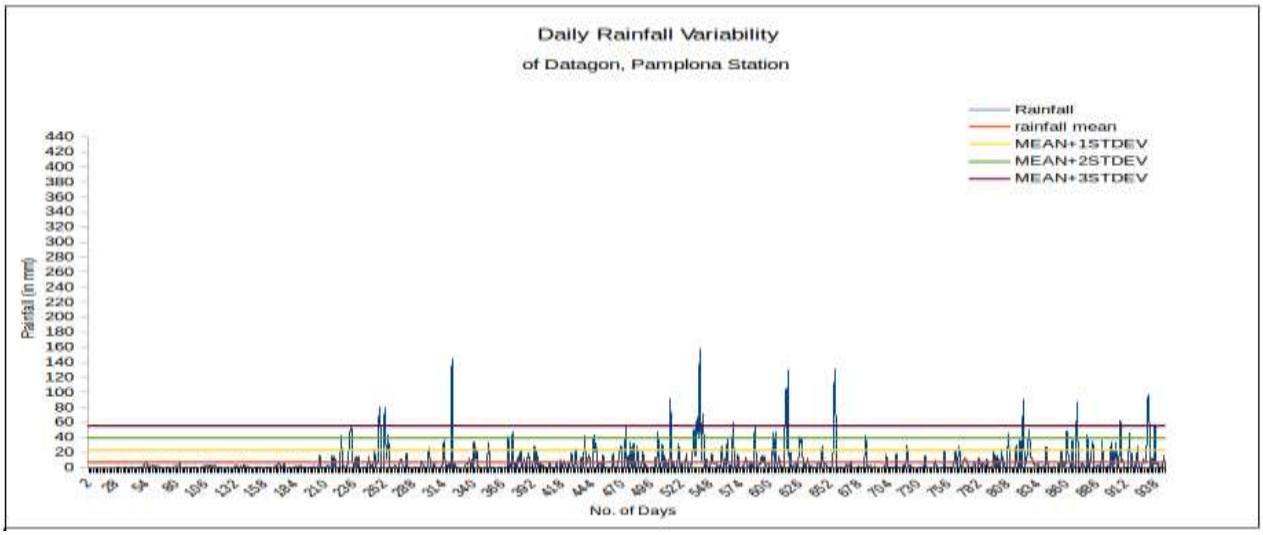


Figure 4.1g *Daily Rainfall Variability Profile of Datagon Station.*

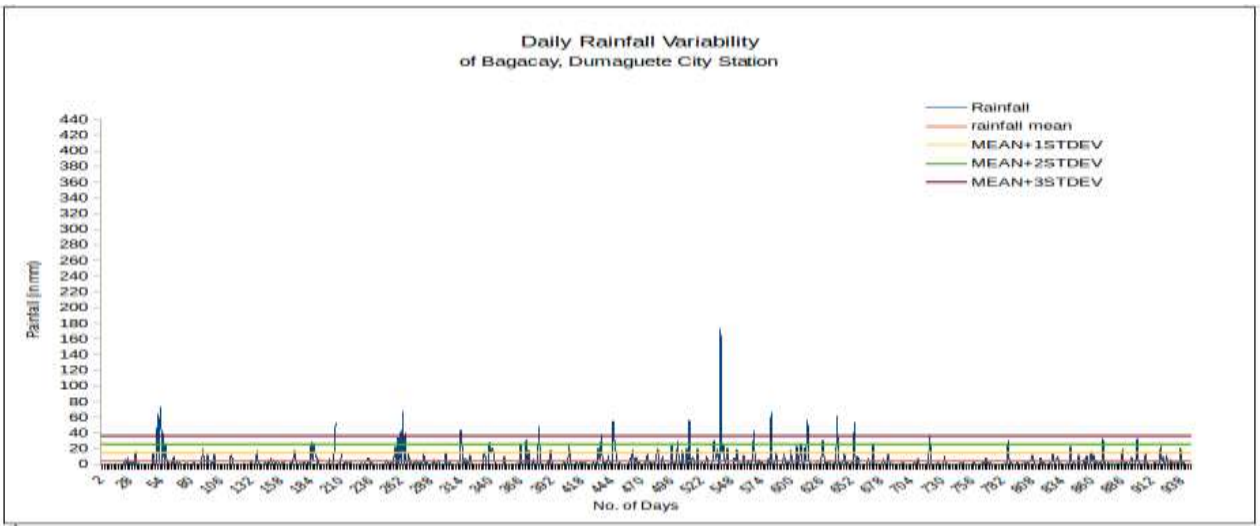


Figure 4.2g *Daily Rainfall Variability Profile of Bagacay Station.*

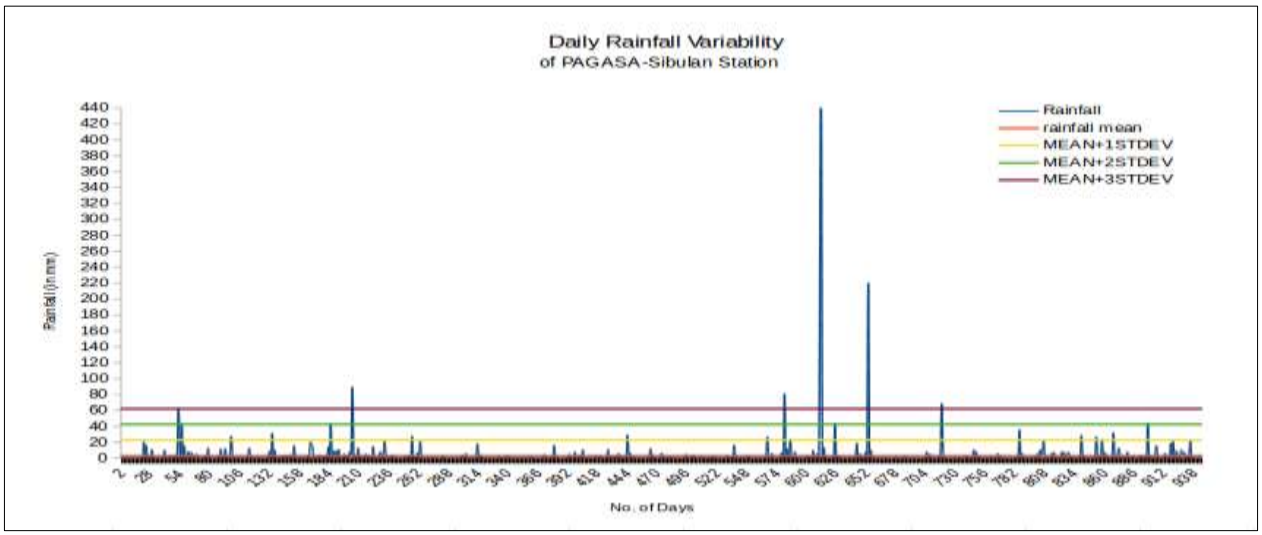


Figure 4.3g *Daily Rainfall Variability Profile of PAGASA Station.*

Figure 4.1g to **Figure 4.3g** show the daily rainfall variability of the three stations. To all stations, the heaviest rainfall values are those crossing the mean plus third standard deviation (MEAN+3STDEV).

In Datagon, Pamplona station, the highest amount of rainfall was recorded on October 19, 2017 (day 537) measuring 157.47 mm. The same date had the heaviest rainfall occured in Bagacay, Dumaguete City station measuring 172 mm. PAGASA- Sibulan station has the highest recorded rainfall among the other two stations measuring 438 mm that was recorded on January 2, 2018 (day 611).

There are only a few extreme rainfall values that were seen crossing beyond + 3STDEV for both stations. But the only thing is that, PAGASA- Sibulan station had the very sudden rise of rainfall amount on January 2, 2018 (day 611). On the other hand, it can be seen on the graph of Datagon that the occurences of rainfall are just so close to each other that means the place was frequently visited by rainfall. Bagacay's trend has a slight similarity with that of PAGASA's, specifically on the occurences. Furthermore, it can generally be seen that only Datagon's station has the most different rainfall pattern.

h. Rainfall Extremes

Table 4.1h presents the rainfall extremes of the three stations. Rainfall is more variable than the temperature and is the main basis for telling the climate pattern of a place. Mean + 3STDEV is used to get the the rainfall extreme since it is where rainfall reach its maximum.

PAGASA-Sibulan station has the highest number of zeros and traces of 604 and a rainfall extreme percentage of 64.64%. Followed by Bagacay, Dumaguete City station with 541 zeros and traces and a rainfall extreme percentage of 59.4%. Lastly, Datagon, Pamplona station with 525 number

of zeros and traces and a rainfall extreme percentage of 57.8%.

Datagon, Pamplona station has the highest frequency of rainfall values that go beyond mean + 3STDEV having 21 occurrences (22%), followed by Bagacay, Dumaguete City station with 20 occurrences (2.1%), and PAGASA-Sibulan station having only 6 occurences (0.64%).

Table 4.1 *Rainfall Extremes of the Three Stations.*

Rainfall Extremes			
Station	Rainfall	Frequency	Percentage (%)
Datagon, Pamplona Station	Zeros and Traces	525	55.6
	Above +3STD	21	2.2
Total			57.8
PAGASA-Sibulan Station	Zeros and Traces	604	64
	Above +3STD	6	0.64
Total			64.64
Bagacay, Dumaguete Station	Zeros and Traces	541	57.3
	Above +3STD	20	2.1
Total			59.4

i. Monthly Rainfall Occurrences

Table 4.1i shows the number of rainfall occurrences per month of the three stations. Based on the table, October 2017 and November 2018 were the months of highest number of rainfall occurrences having it experienced 22 times in Datagon, Pamplona and PAGASA-Sibulan stations, respectively. The least occurrence of rainfall was experienced in May 2015 in Datagon, Pamplona station with 0 times of rainfall.

Among the three stations, Datagon, Pamplona station has the highest total number of rainfall occurrences of 419 times followed by Bagacay, Dumaguete City station and PAGASA- Sibulan station of 403 and 340 occurrences, respectively.

Table 4.1i *No. of Daily Rainfall Occurrences Per Month (May 2016 -November 2018).*

No. of Daily Rainfall Occurrences Per Month			
Month – Year	**Datagon, Pamplona Station**	**PAGASA-Sibulan Station**	**Bagacay, Dumaguete Station**
May-2016	0	4	6
June	13	17	13
July	8	14	12
August	9	9	9
September	6	19	13
October	11	18	16
November	10	18	16
December	13	15	14
January-2017	18	13	19
February	8	5	11
March	10	5	11
April	7	6	9
May	19	6	9
June	9	13	9
July	18	11	20
August	15	7	18
September	15	7	14
October	22	10	17
November	17	6	13
December	19	11	18
January-2018	19	6	15
February	15	6	10
March	6	2	8
April	9	4	6
May	9	10	7
June	17	13	10
July	17	21	16
August	19	12	14
September	21	20	21
October	19	10	11
November	21	22	18
TOTAL	**419**	**340**	**403**

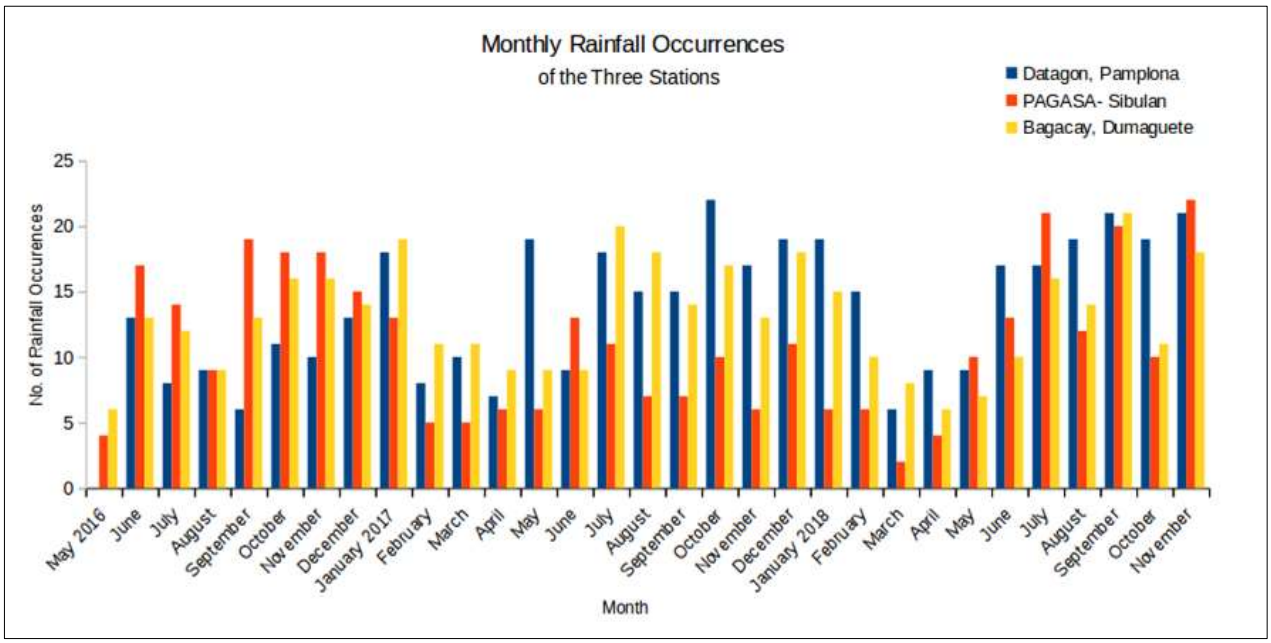


Figure 4.2i *shows the bar graph of the monthly rainfall occurrences of the three stations.*

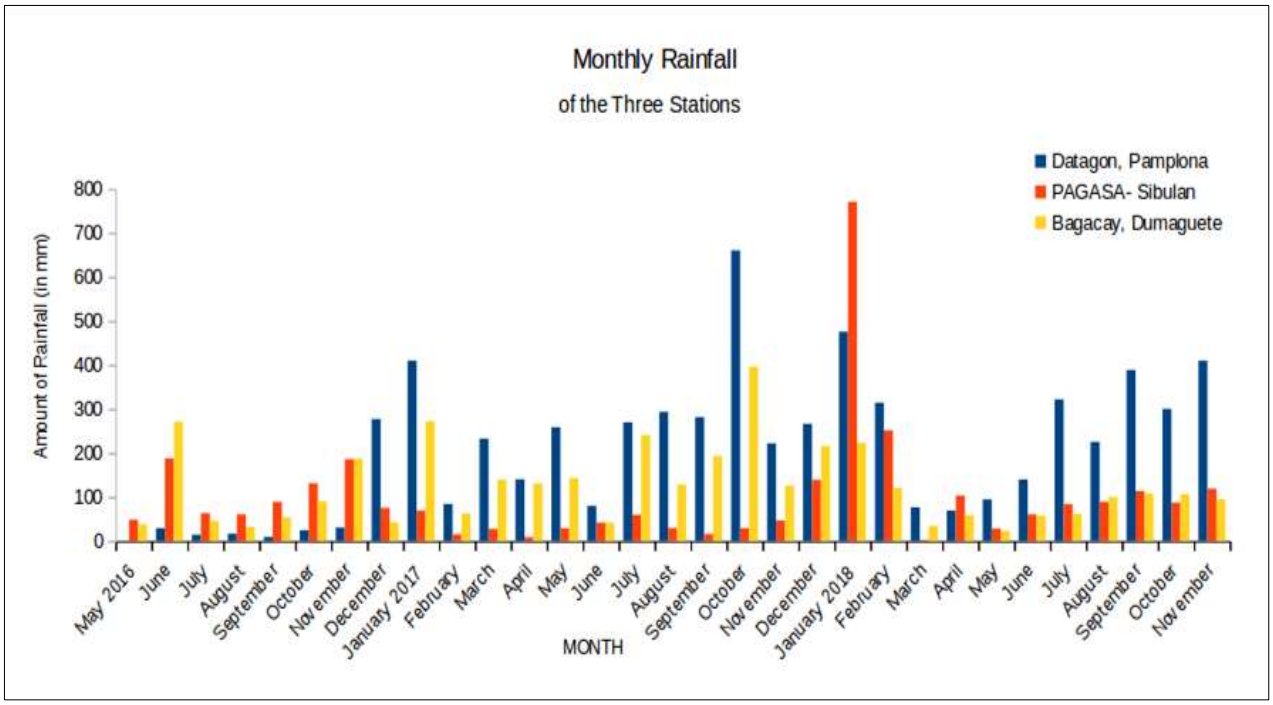


Figure 4.3i *Monthly Rainfall of the Three Stations.*

Climate studies in respective localities are important to contribute to the pool of baseline data in the Philippines. It is the only way for the people to know about the changes in the surroundings and is the best way to tell if climate change exists in the place where the study is conducted. Due to the lack of climate studies center in the Philippines (most of which are the PAGASA stations only), it was suggested that areas other than the central climate stations should also conduct climate studies so that comparisons of data can be made, since, because of local variability, data results from stations, even from the same region, may differ. And because of the latter suggestion, a study in Datagon, Pamplona, Negros Oriental was conducted in which the researcher compared the gathered data to those in PAGASA-Sibulan station and Bagacay, Dumaguete City station.

Along with this study is a reminder that to study climate does not have to be expensive; equipment to be used does not have to be bought- it just needs one's resourceful talent where one is able to make use of the things that are available around or in the community. Gerardo C. Maxino, Ph. D always says that *one should always look into the situation of the community*. In such way, financial problems would not be a hindrance for people who are interested to study climate. To support this practice, the researcher used inexpensive meteorological measuring equipment and locally-constructed rain gauge and thermometer housing.

The data were gathered from May 1, 2016 to November 30, 2018. The results of the study showed that, for temperature, Datagon, Pamplona, PAGASA-Sibulan, and Bagacay, Dumaguete City stations have similarities more particularly on the rise and fall of the graph. But for rainfall, it is only PAGASA-Sibulan and Bagacay, Dumaguete City stations that show similarities on graphs.

The lowest recorded minimum temperature for Datagon, Pamplona and PAGASA-Sibulan station was 22°C while it was 21.5°C for Bagacay. The highest recorded minimum temperature of Datagon, Pamplona station was 31°C, 31.7°C for PAGASA-Sibulan station, and 31°C for Bagacay, Dumaguete City station. The lowest recorded maximum temperature for Datagon, Pamplona station was 23°C, 21.5°C for PAGASA-Sibulan station, and 24.4°C for Bagacay, Dumaguete City station. The highest recorded maximum temperature for Datagon, Pamplona station was 35.5°C, 36.4°C for PAGASA-Sibulan station, and 35°C for Bagacay, Dumaguete City station.

For rainfall, the highest daily amount that Datagon, Pamplona station obtained was 157.47 mm, 438 mm for PAGASA-Sibulan station, and 172 mm for Bagacay, Dumaguete City station. Datagon, Pamplona station holds the highest total amount of rainfall from the whole study having 6,414.552 mm, followed by Bagacay, Dumaguete City station having 3,837.65 mm, and lastly PAGASA-Sibulan station having 3,058 mm. For the number of rainfall occurrences, Datagon, Pamplona station also has the highest total having 419 occurences, followed by 403 occurences from Bagacay, Dumaguete City station, and 340 occurences from PAGASA-Sibulan station.

To calculate the total number of wet and dry days, the consecutive dry days and consecutive wet days, the researcher used the rainfall software of Ms. Reyalyn T. Marimat (2015). For the total wet days, Datagon station

got 419 days, 340 days for PAGASA- Sibulan, and 402 days for Bagacay station. For the total dry days, Datagon station got 525 days, 604 days for PAGASA- Sibulan, and 542 days for Bagacay station. For the total consecutive wet days, Datagon station got 21 days, 17 days for PAGASA- Sibulan, and 17 days for Bagacay station. For the total consecutive dry days, Datagon station got 27 days, 45 days for PAGASA- Sibulan, and 36 days for Bagacay station.

For temperature extremes, results show that there were more temperature values that went beyond mean - 2STDEV. Temperature values that went beyond mean - 2STDEV are considered as extremes. Datagon, PAGASA-Sibulan, and Bagacay have similar trends on the variability graphs. Although similar, Datagon has lesser values that went beyond mean – 2STDEV compared to PAGASA and Bagacay as seen on the third quarter of the study.

Since rainfall is more variable than temperature, mean + 3STDEV is used in taking the rainfall extremes. Datagon and Bagacay have the highest count of rainfall values that went beyond mean + 3STDEV, having 21 (2.2%) and 20 (2.1%), respectively while PAGASA has only only 6 (0.64%). PAGASA-Sibulan station got the highest number of zeros and traces of 604 and also has the highest total percentage of rainfall extreme of 64.64% followed by Bagacay, Dumaguete City station of 541 zeros and traces and a total rainfall extreme percentage of 59.4% while Datagon, Pamplona station has only 525 zeros and traces and a total rainfall extreme percentage of 57.8%.

CONCLUSION

Comparing the temperature and rainfall profiles of the three stations, PAGASA-Sibulan station can represent Bagacay, Dumaguete City station and Datagon, Pamplona station in terms of temperature patterns but in terms of rainfall patterns, only Bagacay station can be represented.

RECOMMENDATION

In order to determine if there is climate change in a specific area, it needs 30 years and above of climate data. The data gathered in the study is too far for us to determine if there is a climate change in the said sites, but the study in Datagon is already a good source since there has never been a climate study in the site. Thus, the researcher recommends that there will be a continuing study in Datagon and in the neighboring places using equipments that can be constructed out of locally available materials. Moreover, the researcher also recommends that there should be more stations of PAGASA specially to rural areas to have more data to compare considering local variability in both temperature and rainfall.

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ACTIVE LEARNING TEACHING SEQUENCE ON THE ENERGY-STORING NATURE OF CAPACITORS: INTERFACING THEORY WITH CONCRETE DEMONSTRATIONS

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ABSTRACT

This article discusses a teaching sequence for capacitance concepts, particularly the energy-storing nature of capacitors. The active learning approach which may be appropriated for secondary and college introductory physics classes underscores the interface of theoretical derivations and discussions with concrete demonstrations that utilize common laboratory materials and equipment. Students are provided with opportunities to derive and validate mathematical relationships between electrical and physical quantities involved in capacitance, and witness these in actual demonstrations. The teaching sequence also integrates *predict-observe-explain* (POE) strategy to facilitate students' investigation of the effects of the physical dimensions of a parallel-plate capacitor to its capacitance; and charging voltage to capacitor voltage and stored electric energy. It is also intended for the enhancement of the higher-order thinking skills of students.

Keywords: *capacitance; charging/discharging capacitors; predict-observe-explain (POE); demonstrations; teaching sequence*

INTRODUCTION

Capacitance is one of the topics under electromagnetism in the senior high school and university physics curricula. However, several studies have shown that students encounter misconceptions and difficulties in understanding concepts and relationships involving direct-current electric circuits (i.e. conductors, insulators, electric potential, electric capacitance, and inductors). [5,6,9,10] In response to the challenges encountered by teachers in facilitating learning of students in electricity topics, several studies on determining the effects of designed and developed teaching strategies, models, and sequences, on student learning (i.e. conceptual understanding, motivation, and academic performance) were conducted. The following are few of the studies that focused on ways to improve the teaching and learning of electrical capacitance.

Student motivation in laboratory engagement was achieved by anchoring a laboratory experiment on a timely technological event context [5]. By the time of the study, the Massachusetts Institute of Technology or MIT launched their "new" nanotechnologically-driven capacitor, dubbed as the battery of the future. The research-proponents utilized this development by incorporating it in their capacitance laboratory activity. With the aid of computer-generated power as function of time graphs, students were motivated to learn about capacitance by doing laboratory work the way real scientists do in normal science. The activity also gave students the opportunity to compare theoretical and actual values. [5]

A similar conceptual framework in teaching capacitors and inductors was conducted where the primary teaching-learning experience was the analysis of the theoretical and experimental values of the potential difference across a capacitor and inductor in DC and AC circuits. Theory was reinforced through actual measurements as one way to address learning difficulty of students in the said physics topics. [4]

Demonstrations, computer-aided simulations, predict-observe-explain, systemic, and explanatory models, as teaching strategies and models, were found to improve students' understanding, motivation, and competencies in topics involving electrical capacitance. [3,5,8,11,12,13]

In the proponent-developed teaching sequence presented in this paper, the theoretical and mathematical discussions of the relationship between parallel-plate capacitance and physical dimensions (i.e. plate separation and area) is interfaced with actual demonstrations. Moreover, the energy storing characteristic of capacitors is also highlighted in the demonstration, emphasizing the interface of theory (as represented by the mathematical definition of electric potential energy stored in a capacitor) and the actual charging and discharging of a capacitor. For the interactivity of the discussion, Socratic method frames the question-and-answer sequence of the integrated predict-observe-explain (POE) strategy.

The designed teaching sequence is one of the ways of employing active learning approach [1]. Such approaches provide students learning experiences where they are "coconstructors" of their own learning. This is made possible by activities where they are encouraged to activate their prior knowledge, connect this with the current information at hand, and reinforce accurate understanding and/or modify misunderstood concepts or mental models [2]. Hence, the designed teaching sequence is framed on constructivist learning theory and puts premium on the enhancement of the higher-order thinking skills. [1]

METHODOLOGY

The proponent's active learning teaching sequence on capacitance is anchored on the principles and phases of instructional design or instructional systems design. It is the systematic process of analyzing students' needs, designing, developing, implementing, and evaluating learning experiences, materials, and assessments, priming on cognition theories, educational psychology, and problem-solving. [7,10]

The research questions are as follows:

1. What teaching sequence can be designed and developed that employs

active learning approach in teaching about the characteristics of a capacitor, especially its energy-storing function?

2. Is the teaching sequence described in research question (1) effective in improving students' conceptual understanding of capacitors and enhancing their high-order thinking skills?

In the context of instructional design, the analysis of student needs and difficulties in learning about capacitance is based on a review of related studies and literature. The design and development of the teaching sequence is anchored on constructivist lens of learning. The implementation and evaluation phases, via a quasi-experimental study to determine the teaching sequence's impact on the levels of student conceptual understanding and higher-order thinking skills, are yet to be conducted as of writing.

RESULTS AND DISCUSSION

The Teaching Sequence

This part describes in detail the three steps in the active learning teaching sequence on the energy-storing nature of capacitors and how theory is interfaced with concrete demonstrations: (i) activating prior knowledge; (ii) constructing new learning and/or modifying prior mental models; and (iii) thinking of one's thinking.

I. Activating prior knowledge

A set of various capacitors (**Figure 1**) is shown to the students. Teacher probes the level of prior knowledge by asking some volunteers to share what they think those presented devices are, where they see these, and how these work. Processing of answers and introducing the topic and purpose of the discussion follow. These are vital prelude to the new learning at hand.

Figure 1. *A set of various capacitors (from L-R: variable air capacitors, electrolytic capacitors, and ceramic capacitors of varied sizes and capacitances)*

II. Constructing new learning and/or modifying prior mental models

An air parallel-plate capacitor, dielectrics, and a digital capacitance meter are shown to students (**Figure 2**). Volunteers are asked to give their observations on the physical characteristics of the capacitor. Expected responses include descriptions of what the plates are made of (metal), what the dimensions are (length, width, and plate separation of the metal plates; the identity and dimensions of the three insulator planes), and how the metal plates are arranged (parallel with no contact with each other). Prompt the students to take note of these physical attributes as they investigate how each affects the capacitance of the parallel-plate capacitor.

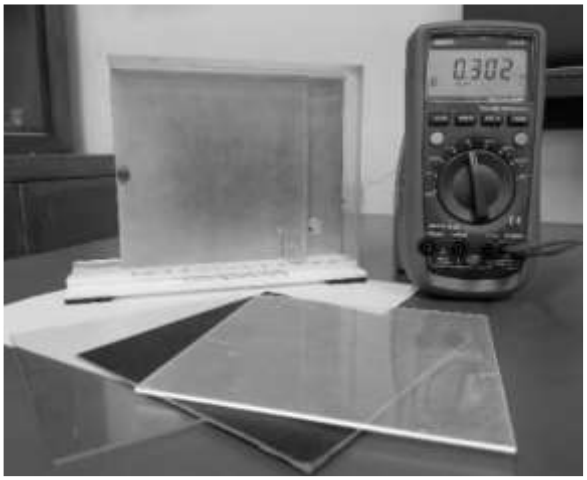

Figure 2. *A parallel-plate capacitor, digital capacitance meter, and three kinds of dielectrics (glass, cardboard, and plastic)*

Introduce the digital capacitance meter as a device that measures capacitance. A brief introduction of capacitance follows. Emphasize that their active participation is crucial in making the learning experience meaningful.

Figure 3. *The digital capacitance meter (right) showing the initial capacitance of an air parallel-plate capacitor at 0.392 nanofarad*

Figure 4*. The digital capacitance meter (right) showing the increased capacitance of an air parallel-plate capacitor at 0.458 nanofarad*

Via POE, ask the students what they think will happen to the capacitance of the parallelplate capacitor if instead of air between them, another insulator is inserted, like cardboard. Ask a few volunteers to express their prediction and justification. Demonstrate then the capacitance reading before (**Figure 3**) and after (**Figure 4**) the dielectric insertion.

Ask some volunteers again to explain the cause of the increased capacitance with the cardboard inserted between the metal plates. Leave the answers unprocessed in the meantime. Students are to refine these explanations after learning about the mathematical relationships among capacitance, electric charge, voltage, and physical dimensions of a capacitor.

Consider two very large parallel plates (area = A) with thin separation (distance = d).

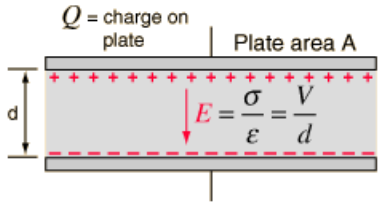

Photo credit: https://i.stack.imgur.com/

The electric potential difference, V, between the plates is given by:

$$\begin{aligned} V &= V_+ - V_- \\ &= -\int_d^0 \vec{E} \cdot \vec{ds} \\ &= -\int_d^0 E\,ds\cos\phi \\ &= -\int_d^0 E\,ds\cos 0^\circ \end{aligned}$$

With the electric field between parallel plates approximately uniform, it is taken out of the integral.

$$\begin{aligned} V &= -E\int_d^0 ds \\ &= -E\,(s|_d^0) \\ &= -E\,(0 - d) \\ V &= Ed \quad \text{(potential difference)} \end{aligned} \qquad (1)$$

Emphasize that with the presence of electric field between the charged plates, electric potential energy is stored between the plates which can be used later.

Pause and ask. Based on the derived equation, ask the students to determine the relationships between voltage and electric field (direct proportion), voltage and plate separation (direct proportion), and electric field and separation (inverse proportion).

Recall that the electric field between planar sheets is related to surface charge density (σ = charge/area = q/A) and permittivity of free space (ε_o) by:

$$E = \frac{\sigma}{\varepsilon_o}$$

, hence, equation (1) becomes:

$$V = \frac{\sigma}{\varepsilon_o} d$$

$$V = \frac{\frac{q}{A}}{\varepsilon_o} d$$

Pause and ask for a volunteer to continue deriving the equivalence of q/V.

$$\begin{aligned} V &= \frac{qd}{A\varepsilon_o} \\ A\varepsilon_o V &= qd \\ \frac{A\varepsilon_o}{d} &= \frac{q}{V} \\ C &= \frac{A\varepsilon_o}{d} \end{aligned} \qquad (2)$$

Equation (2) shows how the physical dimensions (A and d) of a parallel-plate capacitor affect its capacitance (C), with the permittivity of free space or vacuum (ε_o) as proportionality constant. Hence, capacitors come in various sizes and shapes, and thereby, different capacitances.

Ask for volunteers to validate these relationships using the materials presented to them before the derivation. They should see that capacitance increases with decreasing plate separation and increasing parallel area. Moreover, highlight that the magnitude of the electric charge in each plate is directly proportional to the potential difference between the plates and the constant of

proportionality is the capacitance of the capacitor.

$$q = CV \qquad (4)$$

and the SI unit is coulomb/volt (C/V) or farad (F).

Let the students recall the earlier demonstration on parallel-plate capacitance with and without dielectrics. Using equations (1), (2), and (3) that they derive with the teacher, ask some volunteers to explain the cause of the increase in capacitance when a dielectric is inserted. Correct response explains that the presence of the dielectric leads to a decrease in the total electric field between the plates. Consequently, the potential difference decreases, too, (direct proportion). However, with the inverse relation between voltage and capacitance, the final consequence is an increase in the latter. Hence, using dielectric increases the capacity of a capacitor to store electric energy.

The final part of the second step of the teaching sequence emphasizes understanding of the energy-storing characteristic of capacitors. With the electric field between the charged plates, electric potential energy is stored. So, how are capacitors charged? The next demonstration shows charging an electrolytic capacitor. Such capacitor is polarized; hence, proper caution is required in doing correct terminal connections between the capacitor and the power supply. [Warning: Wrong polarity connection causes gas to build up inside an electrolytic capacitor, causing it to possibly explode. Safety precaution is a must in this part of the demonstration.]

Figure 5 illustrates a charged electrolytic capacitor. Ask the students to observe the comparative voltages indicated by the digital capacitance meter (right) and the DC power supply voltmeter indicator (left) a few seconds after both are connected. They will see that the reading of the former does not exceed that of the latter. Charging stops when both voltages are (approximately) equal.

Figure 5. *This part of the demonstration shows that charging a capacitor ends when the capacitor voltage (shown in the digital multimeter at 11.942V) and voltage source (shown in the built-in voltmeter of the DC power supply at 12.00V) are equal.*

Disconnect the power supply and let the students observe the voltage reading across the capacitor. Conduct a quick question-and answer with the following questions: (i) What does the non-zero voltage reading imply? (This implies that there exists a potential difference between the terminals of the capacitor.) (ii) What does this further imply? (Electric potential energy is available for use.)

Ask the students to predict what will happen if a light bulb is connected in closed circuit with the charged capacitor and why they think that would happen. Demonstrate capacitor discharging (**Figure 6**). Guide the students to closely observe the voltage reading as the bulb is connected. They should

notice that it quickly drops to zero or few millivolts and the bulb lights up for only a very short period, too.

Figure 6. *A bulb is shown at the onset of discharging the 30,000-microfarad electrolytic capacitor (digital multimeter showing the initial capacitor voltage at 11.884V).*

Check for student's accurate conceptual understanding by giving more follow-up questions. Reinforce correct models and rectify the wrong ones.

The final discussion is to answer what determines the amount of energy that can be stored in a capacitor. For the students to answer this question, give the mathematical definitions of the electric potential energy of a charged capacitor in terms of total charge (Q), total voltage (V), and capacitance (C).

$$U = \frac{Q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}QV \quad \text{(5, 6 and 7)}$$

Using the same charged electrolytic capacitor in the earlier demonstration (hence, C is kept constant), ask the students to (indirectly and qualitatively) validate the direct-square relationship between capacitor voltage and potential energy. Gradually increase the voltage of the power supply and charge the capacitor. Connect the bulb to it and let them observe the relative brightness of its light. They should notice that the brightness intensity increases as the voltage across the capacitor increases. This implies that the energy in the capacitor has increased, too.

III. Thinking of one's thinking

One of the vital parts of the active learning approach of the presented teaching sequence is a culminating step where students are given opportunities to look back at their learning experiences and think about how these have impacted them (metacognition). Call a few volunteers to share their insights, feelings, and/or realizations as they learned about electrical capacitance in theory that is interfaced with actual demonstrations. This is intended to enhance students' metacognitive skills which is one of the hallmarks of active learning. [2]

CONCLUSION

Presented in this paper is a teaching sequence on the energy-storing characteristic of capacitors. The instructional design process translated active learning approach into a series of logical and cohesive learning opportunities and experiences where theoretical derivation and discussions about electrical capacitance are interfaced with appropriate actual demonstrations. Moreover, the higher-order thinking skills are intended to be enhanced through extensive Socratic or

question-and-answer technique that is integrated in the predict-observeexplain (POE) activities. The effectiveness of the teaching sequence in improving student conceptual understanding and higher-order thinking skills is yet to be determined quasiexperimentally.

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EFFECTIVENESS OF PHET SIMULATION IN IMPROVING SCIENTIFIC LITERACY OF GRADE 10 STUDENTS IN THE TOPIC MIRRORS

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ABSTRACT

Mirrors, a fundamental aspect of optics, present challenges that students often find complex and abstract. The nature of reflection and image formation proved challenging for students to visualize. The intangible nature of light rays and the interaction with mirrors presented difficulties in grasping fundamental principles.

To address these challenges, educators are encouraged to implement more hands-on and visual learning experiences, such as interactive demonstrations and simulations. Additionally, emphasizing realworld applications of mirror principles, such as in optical devices or everyday experiences, can enhance student engagement and understanding.

This research focused on the effectiveness of PhET Simulation in improving the scientific literacy of grade 10 students about mirrors. The study aimed to determine the effectiveness of PhET simulation in improving scientific literacy of Grade 10 students.

The researcher created an achievement test validated by the head teacher, science coordinator and research coordinator. The validated achievement test was administered to Grade 10 students of San Antonio National High School Parañaque.

According to the findings, the calculated t-value of -17.0 indicates a notable and statistically significant difference between the pretest and posttest scores of the students. This suggests an enhancement in the scientific literacy of the students through the utilization of PhET Interactive Simulation. Furthermore, the normalized gain value of 0.55 suggests a moderate gain in effectiveness following the intervention. This underscores the recommendation for science teachers to delve into the potential impact of PhET Interactive Simulations in their classrooms.

Keywords: *Grade 10, Interactive Simulation, PhET, Mirrors*

INTRODUCTION

In the classroom, physics teachers are faced with many challenges to educate students about physics, particularly image formation by plane mirrors (Husin S., 2019). Mirrors often involve concepts related to reflection and optics, which can be challenging to grasp through theoretical explanations alone. Interactive simulations allow users to visualize the behavior of light rays, angles of incidence and reflection, and the formation of images in mirrors. This visual representation can enhance understanding.

Mirrors, whether they be plane, concave, or convex, involve intricate principles of optics that can be challenging for learners to grasp through traditional methods alone. Theoretical concepts related to reflection, focal points, and image formation can be abstract and hard to visualize. Herein lies the need for innovative solutions, and PhET simulations emerge as an effective means to address these challenges.

Scientific literacy holds paramount importance for students as it equips them with the essential skills and knowledge needed to navigate an increasingly complex and technology-driven world. Beyond memorizing facts, scientific literacy cultivates critical thinking abilities, enabling students to analyze information, evaluate evidence, and make informed decisions. This proficiency not only serves them well in academic pursuits but also extends into their everyday lives, fostering a mindset of curiosity and inquiry.

The integration of technology in education has garnered significant attention, and rightfully so, as it holds immense potential to revolutionize learning experiences and elevate student outcomes. Technology facilitates personalized learning experiences. With the help of adaptive learning platforms and educational apps, students can progress at their own pace, receive targeted feedback, and engage with content that aligns with their individual learning styles. This tailored approach not only enhances comprehension but also addresses the diverse needs of students, fostering a more inclusive educational environment. The integration of technology also contributes to the development of essential 21st-century skills. Students gain proficiency in digital literacy, critical thinking, problem-solving, and adaptability-skills that are increasingly vital in a rapidly evolving technological landscape.

Marces, I. I. & Caballes D.G. (2019) highlighted that Carl Wieman established PhET in collaboration with the University of Colorado Boulder in 2002, envisioning a platform that would render physics engaging and accessible to all learners by harnessing their natural curiosity about real-world phenomena. Each PhET simulation creates a game-like environment, providing students with the opportunity to actively explore and discover key concepts in science and math. The design is crafted to support learners in posing questions, conducting experiments, uncovering cause-effect relationships, reflecting on results, and testing their own ideas. This approach is grounded in educational research, specifically tailored to address known difficulties that students may encounter.

In the study conducted by Mallari (2020), it also implies that there is a significant improvement on the academic

performance of students after using the PhET interactive simulation-based activities. It was evident that during the conduct of the study, students were very active, highly motivated, had fun and challenged themselves while doing the activities in class.

METHODS

The objective of the study is to determine the effectiveness of Phet simulation in improving scientific literacy of Grade 10 students. This research utilized the quasi-experimental method of research focusing on one group pretest-posttest design.

$$O_1 \qquad X \qquad O_2$$

Where: O_1 = Observation Pretest (SAT)
X = Treatment (Administration of PhET Simulation)
O_2 = Observation Posttest (SAT)

A one-group pretest-posttest design is a quasi- experimental research design in which the same dependent variable is measured in one group of participants before (pretest) and after (posttest) a treatment is administered.

RESPONDENTS

This study was conducted in San Antonio National High School Paranaque students during the Second Quarter of school year 2023 – 2024. Thirty (30) students from the same section were chosen as part of this study. Each of these students must use PhEt simulation which was utilized during their science subject. In selecting who participated in this study, the researchers used multiple sampling technique particularly convenience and simple random sampling. Convenience sampling is a form of nonprobability sampling when participants are selected based on their availability and convenience whereas simple random sampling is a sampling technique where every individual or element in the population has an equal chance of being selected for the study.

RESEARCH INSTRUMENT

In conducting this study, the researchers created a set of 50 multiple-choice questions specifically designed to assess the understanding of qualitative characteristics of images formed by mirrors. These questions were aligned in the learning competencies given by the Department of Education (DepEd). The questionnaire was validated by Science Coordinator, Language Head teacher and Research Coordinator. The validated questionnaire was given and answered by selected Grade 10 students of San Antonio National High School Parañaque.

DATA GATHERING PROCEDURE

The researchers conducted a pre-test and post-test to assess the knowledge of the participants before and after the conduct of the study. The pre-test was conducted at the start of the second quarter. After the conduct of pretest, the teacher maximized the use of PhEt Simulation for one (1) week. At the end of the implementation period, a post test was conducted to assess if the use of PhEt simulation is effective in improving scientific literacy of selected Grade 10 students of San Antonio National High School Paranaque. Then, the researchers used a statistical treatment to determine the significant difference between the pre-test and the post test scores of students in the topic Mirrors.

STATISTICS

In this study, the researchers used Paired t-test to check the significant difference in the pre-testand post-test scores. Paired t-test is oftentimes used to test if the means of the two paired measurements, such as pre-test and post test scores, are significantly different. In this study, a pre-test and a post-test were conducted before and after the implementation of the study.

$$t = \frac{\sum d}{\sqrt{\frac{n(\sum d^2) - (\sum d)^2}{n-1}}}$$

where:
d = difference per paired value
n = number of samples

Hake Factor

The Hake Factor normalized gain formula is often used in educational assessment to measure the effectiveness of instruction. It is calculated as the difference between the post-test mean and the pre-test mean, divided by the maximum possible difference. (Hake, R. 1998. American Journal of Physics).

Scale:

Range	Interpretation
g > 0.7	High gain
0.7 > g > 0.3	Medium gain
g < 0.3	Low gain

Hake Factor Formula

$$g = \frac{Post - test\ Mean - Pre - test\ Mean}{Maximum\ Possible\ Difference}$$

RESULTS AND DISCUSSION

The study Effectiveness of Phet Simulation in Improving Scientific Literacy of Grade 10 Students in the Topic Mirrors utilizes PhET simulations compared to the existing study Enhancing the Academic Performance of Grade 10 Students in Physics through Interactive Simulation Laboratory Experiments involves hands-on interactive laboratory experiments conducted in a simulated physics laboratory setting.

Both interventions contribute positively to students' understanding of mirror-related concepts and academic performance in physics. However, nuanced differences emerge. The PhET simulation group demonstrates significant improvements in scientific literacy, showcasing a deepened conceptual grasp. On the other hand, the interactive simulation laboratory experiments group exhibits notable advancements in problem-solving skills and practical application of theoretical knowledge.

The outcomes of the mirror assessments indicate a notable range in the scores obtained by the participants, reflecting diverse levels of proficiency in the understanding of mirror-related concepts. In the pre-test phase, participants demonstrated a spectrum of performance, with the highest score recorded at 24 and the lowest at 11. The mean score for the pre-test was calculated to be 17.40, shedding light on the average level of comprehension among the participants prior to any intervention.

Upon completion of the instructional intervention, the post-test results further illustrated the variance in student performance. The highest score in the post-

test reached 39, showcasing an improvement from the pre-test scores. On the other end of the spectrum, the lowest post-test score was 20. The mean score for the post-test, calculated at 32.67, serves as an indicator of the overall enhancement in understanding mirrored phenomena following the intervention.

The study of Marces and Caballes (2019) had two groups of respondents, the control and experimental group. The result revealed that there is significant difference in the performance of two groups of respondents after using interactive simulation on students' achievement and attitude in physics education. Moreover, this study had one group of respondents and the result revealed that there is also significant difference in the pre-test and post-test scores of selected grade 10 students before and after using the PhEt simulation.

The mean of pre-test and post-test are 17.40 and 32.67 respectively. This significant increase in mean scores from the pre-test to the post-test suggests an overall improvement in participants' understanding of the subject matter after the instructional intervention A consistent sample size of 30 for both assessments contributes to the reliability of the findings, ensuring that the observed changes in mean scores are less likely to be influenced by random variations. The standard deviation measures the extent to which individual scores deviate from the mean. The larger standard deviation in the post-test scores indicates a greater spread of individual scores around the mean, suggesting increased variability in performance after the intervention. The standard error of the mean provides an estimate of how much the sample mean might vary from the true population mean. The larger standard error in the post-test scores implies greater variability in the sampling distribution of the mean, potentially reflecting the increased diversity in student performance.

Table 1

Paired Sample Statistics of Pre-test and Post-test

Paired Sample Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-test	17.40	30	3.359	.613
	Post-test	32.67	30	4.795	.875

The mean difference was calculated as -15.267. This negative mean difference indicates a substantial decrease in scores from the pre-test to the post-test, reflecting an improvement in participants' performance. The standard deviation of the difference is 4.734. It reflects how much individual scores varied from the mean difference. The standard error of the mean difference is .864. A smaller standard error generally indicates a more precise estimate of the true mean difference. The 95% confidence interval of the difference is from -17.034 to -13.499. The negative range indicates a significant decrease in scores, and the entire interval is below zero, emphasizing the consistency of improvement. The t-value is -17.664, and the

degrees of freedom are 29. The large negative t-value indicates that the mean difference is significantly different from zero. The one-sided p-value is less than .001. The two-sided p-value is less than .001. Both p-values are highly significant (less than .001), providing strong evidence that the observed change in scores is unlikely to be due to random chance. The two-sided p-value is typically reported and indicates the probability of observing such an extreme result if there were no true difference. This concludes that the researchers need to reject the null hypothesis (H_0). Therefore, the participants improved their scientific literacy and performance though PhET Simulation.

In the study conducted by Batuyong et. al (2018), it also implies that there is a significant improvement in the academic performance of students after using the PhET interactive simulation-based activities. It was evident that during the conduct of the study, students were very active, highly motivated, had fun and challenged while doing the activities in class.

Table 2

Paired Sample Test of Pre-test and Post-test

Paired Samples Test										
					95 % Confidence Interval of the Difference				Significance	
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided p	Two-Sided p
Pair 1	Pre-test-Post-test	-15.267	4.734	.864	-17.034	-13.499	-17.664	29	<.001	<.001

Based on the computed value of the Hake Factor Normalized Gain of 0.55, it shows that the utilization of Phet Simulation in conducting lessons about mirror achieved medium gain in terms of its effectiveness. This medium gain implies a positive impact on student learning outcomes, indicating that learners exposed to the PhET simulations experienced a notable advancement in their understanding of mirror-related concepts.

CONCLUSION

The results of the paired t-test and Hake factor analysis demonstrated a statistically significant improvement in scientific literacy among students who engaged with the PhET simulation. The interactive nature of PhET simulations goes beyond traditional pedagogical methods, offering a dynamic and engaging platform that actively involves students in the exploration and experimentation of complex scientific phenomena. In the case of mirrors, where the principles of reflection and image formation can be challenging to grasp through traditional teaching approaches, the immersive and visual nature of PhET simulations provide students with a tangible and interactive learning experience. By allowing students to manipulate variables, observe outcomes in real-time, and engage in hands-on exploration, PhET simulations cater

to diverse learning styles and facilitate a deeper understanding of abstract concepts.

RECOMMENDATION

Science teachers should use interactive simulation for those topics without enough instructional tools to enhance the effectiveness of their teaching methodologies, embracing video interactive simulations for topics with insufficient instructional tools emerges as a promising avenue for fostering scientific curiosity and comprehension in the classroom.

A similar study may be conducted with longer teaching sessions to cater to all the topics with PhET video interactive simulation. Incorporating various scientific disciplines beyond mirrors, such as electromagnetism, thermodynamics, biology, chemistry, earth science etc. Students can connect concepts across different fields, enhancing their ability to think critically and solve problems in a multidisciplinary context. By extending the teaching sessions, researchers can explore how sustained engagement with PhET simulations influences long-term retention, conceptual mastery, and overall scientific literacy across a broader spectrum of subjects.

A similar study may be conducted with bigger number of respondents in another venue to increase the generalization of the results. By increasing the sample size, researchers aim to obtain a more representative and diverse population, allowing for a broader application of the study's findings. The inclusion of a larger and more varied group of participants ensures that the results are not confined to a specific demographic or context, enhancing the external validity of the research.

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WIND PROFILE OF ILOCOS NORTE WIND FARM INDUSTRY

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ABSTRACT

Wind farms depend on wind, with wind variability driving the fluctuation of their over-all power generation. The Ilocos Norte Wind Farm Industry is one of the main producers of wind power. It is located on the northwest part of Luzon on the seashore of the Bangui Bay where the wind speed is strong. But since the country is located on the tropics, the wind speed varies with season, monsoon and other climate oscillations. This study aims to determine factors that contribute to the variations of wind speed and power production. Specifically, the study determined the relationship between wind speed and different climate driver indices (East Asian Summer Monsoon (EASM), Western North Pacific Summer Monsoon (WNPSM) and El Nino Southern Oscillation (ENSO)). Results show that different climate drivers are significantly correlated with the wind speed and consequently with the power production of the industry. This means that, as the climate driver indices mentioned changes, the wind speed and power production also varies. The results of the study can be used for the effective management of power production and distribution in Ilocos Norte.

Keywords*: wind profile, monsoon, Wind Farm Industry, ENSO, EASM, WNPSM, variability*

INTRODUCTION

In recent years, electricity generation by photovoltaic or wind power has captured considerable attention worldwide (Qing, 2017). It is undeniable that wind energy is now an important player in the generation of electricity. In addition to the growing economic attractiveness of wind energy, there are major ecological arguments for its use—wind-power plants emit absolutely no CO_2, the operation of wind turbines leaves behind no dangerous residues as do nuclear plants, decommissioning costs of wind turbines are much smaller than those of many other types of power plants, especially compared with those of nuclear generators, and land occupied by wind farms can find other simultaneous uses such as in agriculture (da Rosa, A.V., 2011). In 2016, wind power continued to push the boundaries of what many thought was possible. More and more countries around the world are now seeing that choosing renewables, like wind, is not only the most economic pathway, but also the most socially and environmentally advantageous (GWEO, 2016).

Wind energy development in the built environment can help to realize a sustainable city. Development of renewable energy is an important solution to reduce the greenhouse gas, which is proved to contribute greatly to the present dramatic climate change problems. Wind energy is one of the oldest renewable energy sources and its exploitation technology is rather simple and cheap (Wang et.al.,2017).

Overall, by the end of 2015, there were about 433 GW of wind power spinning around the globe, a 17% increase over the previous year; and wind power supplied more new power generation than any other technology (GWEO, 2016). In fact, the global installed capacity has grown at annual rate of 27% since 2000 providing ~425TWh, 2.1% of the world's demand (Andrews and Jelley, 2012).

Wind farms operate often in the changing wind. The wind condition variations in a wide range of time scales lead to the variability of wind farms' power production. This imposes a major challenge to the power system operators who are facing a higher and higher penetration level of wind power. Thus, wind farm developers/owners need to take the variability into consideration in the designing/planning stage, in addition to the conventional main objective of maximizing the expected power output under a fixed wind distribution (Feng & Shen, 2017). Wind energy ingest wind as its raw product to produce power. Wind has mass and it source of energy is the sun (Pandharinath,2007). This means that wind energy solely depends its power production to the moving air, that slight changes on the characteristics of the wind have a big impact of changes on the power that the wind energy can produce for the power production of wind turbine is exponentially related to the magnitude of the wind speed (http://www.raeng.org.uk/publications/other/23-wind-turbine).

Wind variability may define as the changes in the magnitude and direction of the wind speed or both. This is due to some systems that affect the properties of air and wind such as pressure gradient force, Coriolis force and friction. The degree of variations is also very site dependent, as for example sea breezes are much more constant than as land breeze (IEA2005). Wind resource varies greatly from one location to another (Farming the Wind: Wind Power and Agriculture (2003)). But there are only ample of researches with regards to the direct impact of ENSO on the wind patterns and variability. This study will focus on the effect of ENSO on the wind pattern and variability of the location and further discuss the effect on the power production of the wind farm. Furthermore, the researcher will also focus on the effect of the changing indices of Western North Pacific Summer Monsoon and East Asian Summer Monsoon to the wind speed and power production of the Ilocos Norte Wind Farm.

The main objective of this paper was to gain insight into the wind resource of the Ilocos Norte Wind Farm by analyzing the historical wind speed and power production data given by North Wind Power Development (NWPD) Corporation – a private company that manages the Ilocos Norte Wind Farm from 2006-2015. Statistical Analysis and modeling of the data is critical to have an idea of how future system will operate with a higher meteorological penetration.

The result of this research will response to simple queries, such as, which month and

season has the strongest wind speed and largest power production? What is the distribution of wind speed and power production per month, per season and per year? What is the diurnal variation of wind speed? What is the relationship between wind speed and power production?

Furthermore, the researcher will also consider large climate drivers such as Western North Pacific Summer Monsoon (WNPSM), East Asian Summer Monsoon (EASM) and El Nino Southern Oscillation (ENSO) and determine the effects of this climate drivers to the magnitude of the wind speed and power produce by the Ilocos Norte Wind Farm by determining the relationship between wind speed and power production to the different climate driver indices mentioned.

HYPOTHESES

Based on readings and data, the following hypotheses were formulated:

1. the wind speed and power production in the Ilocos wind farm exhibits variability with respect to large scale climate drivers.
2. there is a significant relationship the wind speed and climate indices (East Asian Monsoon, Western North Pacific Monsoon and ENSO).

SCOPE AND DELIMITATION

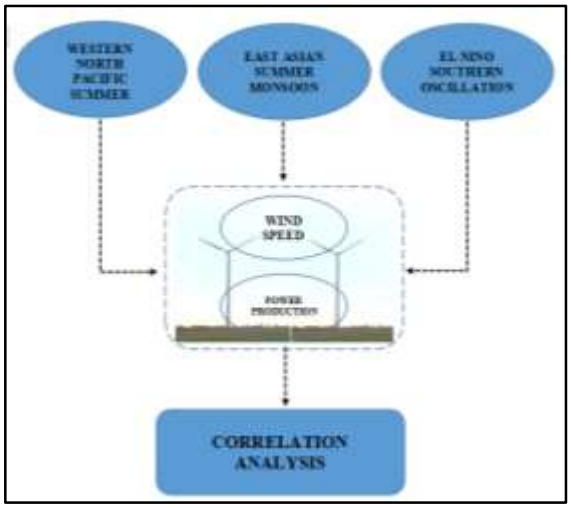
- The study is to be conducted at Ilocos Norte Wind Farm Industry.
- The study will be focusing on the years 2006 to 2015.
- The study will focus on the wind variability of the location and power production of the Ilocos Norte Wind Farm Industry.
- The study will determine the intra-seasonal and inter-annual variations of wind speed.

LOCALE OF THE STUDY

The study is to be conducted at Ilocos Norte Wind Farm Industry. It is located at 18^{o} 32’ 21” North, 120^{o} 45’ 53” East. The wind farm (turbines and control facilities) is located on a stretch of 9 km long, 100 m wide foreshore area which run east-west on the Northern tip of the island of Luzon. The foreshore is an undeveloped, uninhabited sandy beach area for occasional pebbles/gravel gathering and fishing. The wind tower is erected within the inter-tidal zone of the beach, occupying 4-5 km portion of the 9 km stretch foreshore area.

CONCEPTUAL FRAMEWORK

Figure shows the conceptual framework of the study. Wind turbines convert wind’s kinetic energy into useful electricity. And in the process of conversion, there is a modification of some of the factors affecting the weather. While converting wind’s kinetic energy into electricity, wind turbines modify surface-atmosphere exchanges and transfer of energy, momentum, mass and moisture within the atmosphere, which could have important positive implications for farmers by potentially prolonging the growing season (Henschen et.al., 2000).

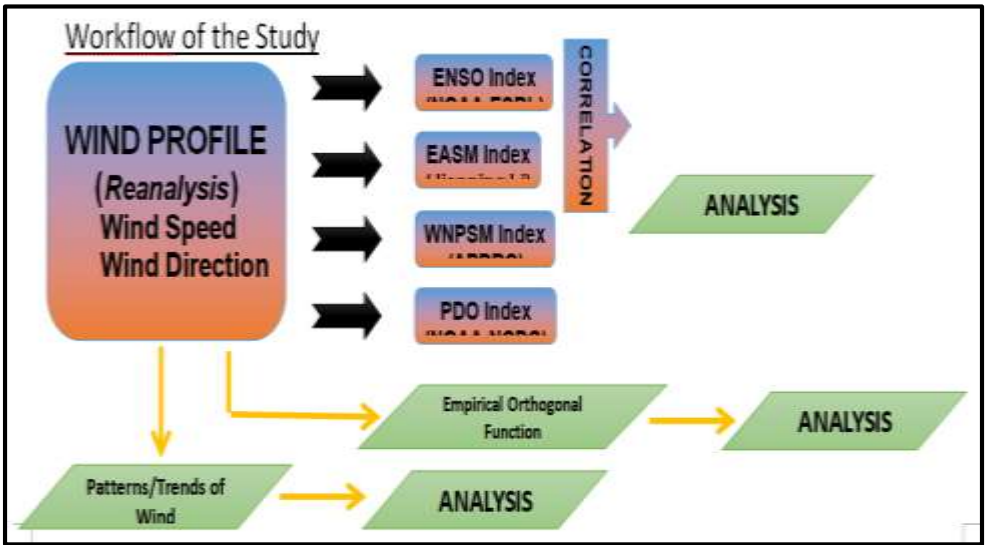


Several factors will be considered on the study such as East Asian Summer Monsoon, Western North Pacific Summer Monsoon and El Nino Southern Oscillation and on how does these factors influenced the wind speed and power production of the said wind farm.

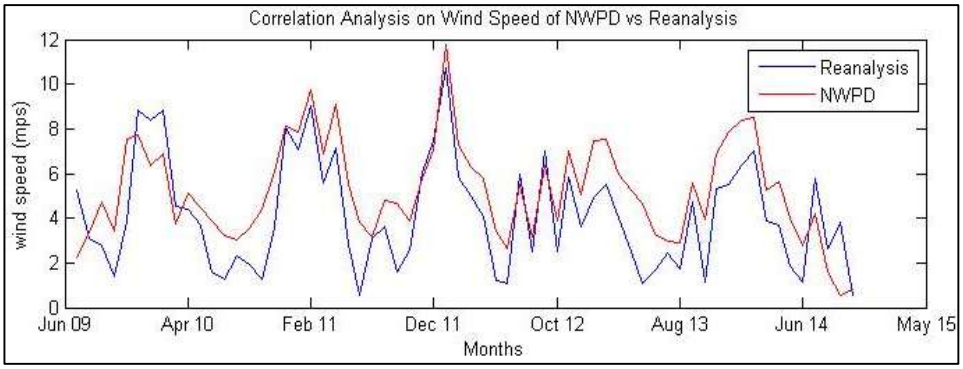
The researcher will determine the trends of the wind speed and power production of the Ilocos Norte Wind Farm. After which, this will serve as the bases of the researcher to determine if there is a significant relationships exist and on how strong the relationships are between the wind speed, power production and the climate indices (WNPSM, EASM, ENSO).

METHODOLOGY

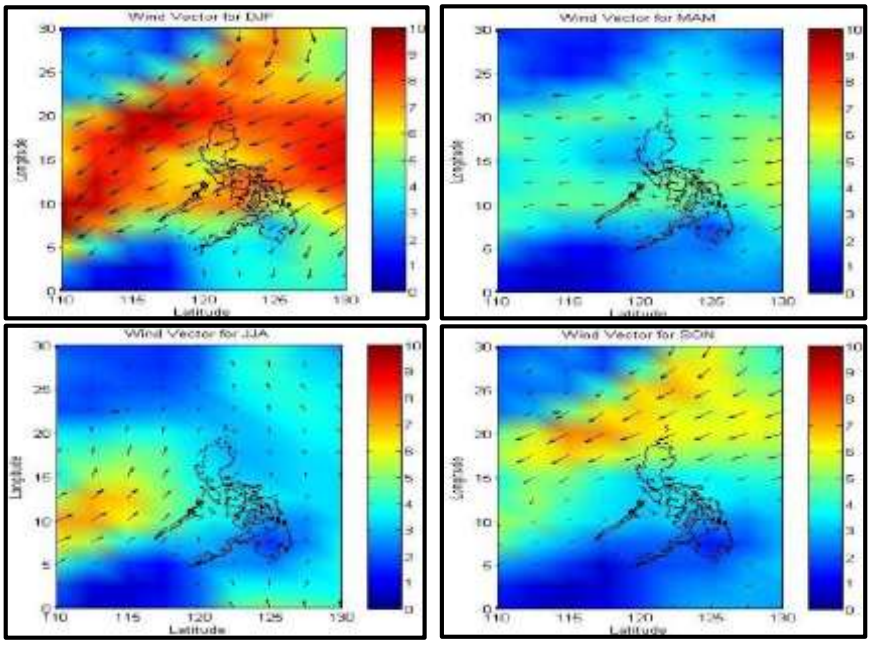
Figure below shows the work flow of the study used in the research. Reanalysis data of wind (both speed and direction) were plotted using MatLab Program to determine the trends and patterns of wind in the site of the study and further analysed using statistical treatments such as EOF and correlation analysis. Same data had been utilized to correlate with the different indices used in the study.



RESULTS AND DISCUSSION

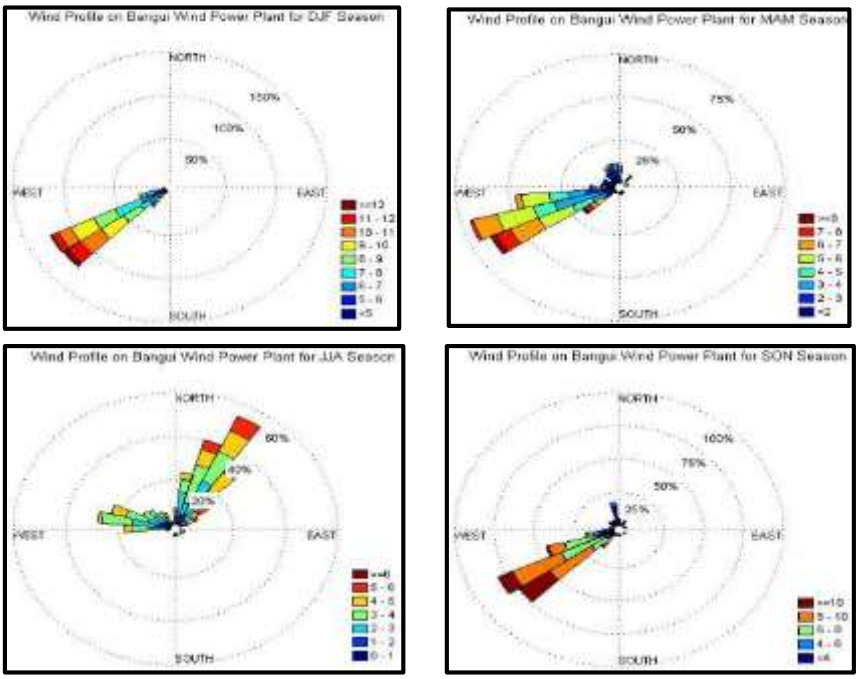


- ✓ increasing our sample size can give us greater chance to detect differences.
- ✓ The larger the sample size the more information we have and so our uncertainty reduces (Marley, 2016).



Distribution of Wind Vector on Different Seasons

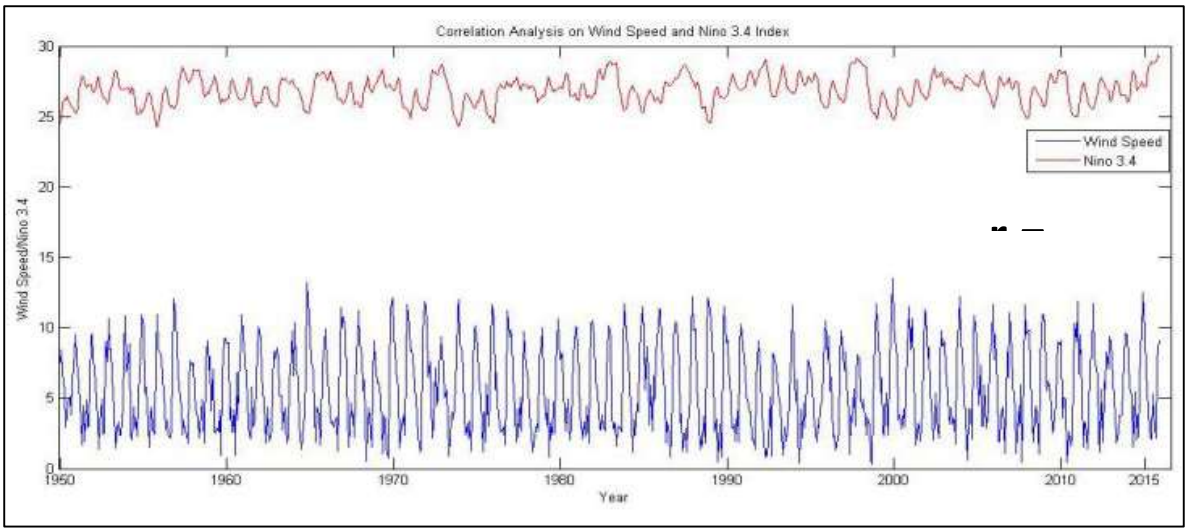
- ✓ DJF shows the highest magnitude of wind speed while JJA exhibits the weakest.
- ✓ SON and DJF displays a northeasterly wind direction, JJA has a prevailing wind speed of southwesterly and MAM exhibits an easterly wind direction



Wind Roses of the Wind Power Plant

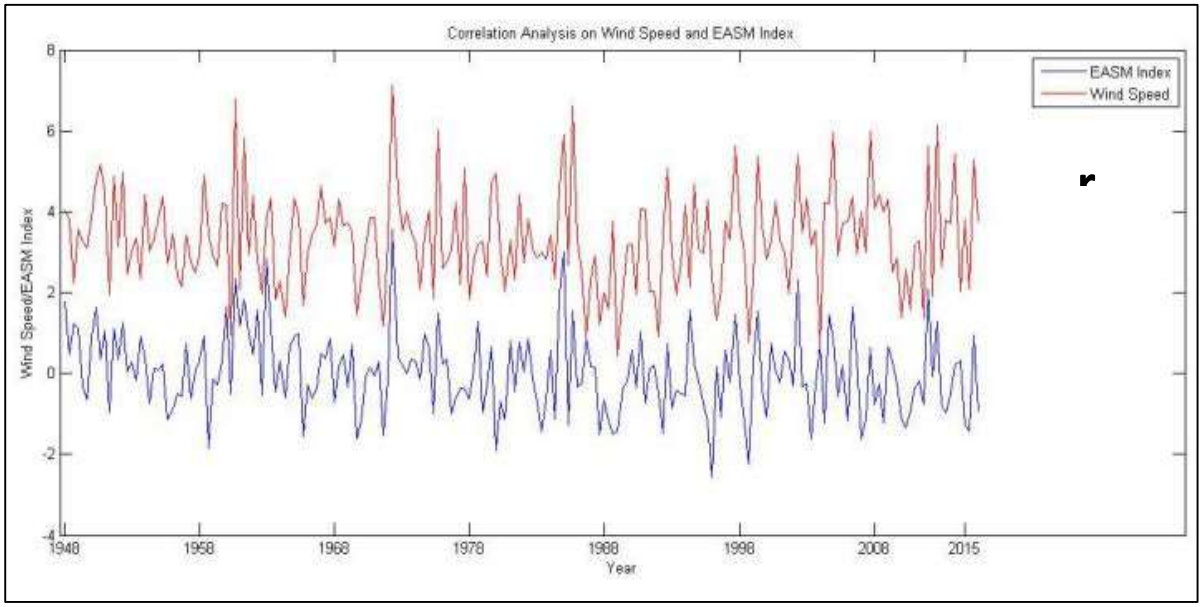
- ✓ JJA prevailing wind direction is Southwesterly while the other three are Northeasterly.
- ✓ Weakest wind speed can be also observed during the JJA season, while the strongest magnitude of wind speed can be observed during the DJF season.

Correlation Analysis



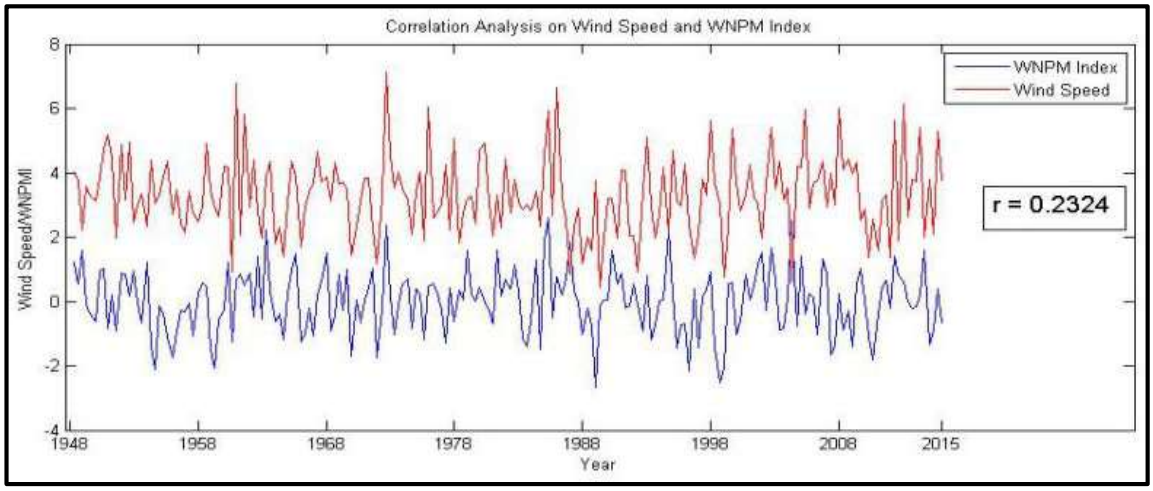
Correlation Analysis on Wind Speed and Nino 3.4 Index

- ✓ ENSO can be greatly affected by intraseasonal variations of surface wind in the Western Pacific and these variations of Western Pacific surface winds have an impacts on the spread of the forecasted Nino 3.4 SST's (Wang, 2011).
- ✓ Harper (2005) concluded that La Ninas' were associated with more frequent occurrence of higher wind speeds and lower probability of low wind.
- ✓ this general effect is persistent throughout all season except June to August when there is decrease in effect (Harper, 2005).
- ✓ Berg (2013) concluded that there's a general increase of wind speeds and wind variability during El Nino across the region of Southern California and an opposite and really strong signal of decreased in wind speed and wind speed variability during La Nina.



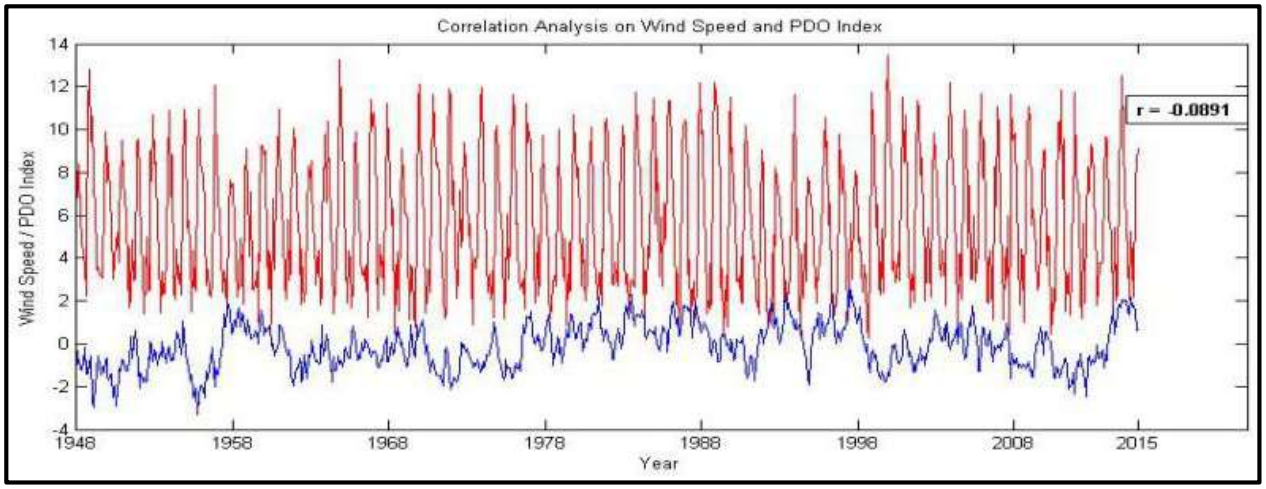
Correlation Analysis on Wind Speed and EASM Index

- ✓ wind speed and EASM follow the same trend.
- ✓ implies that as the continental monsoon (EASM) increases its intensity (index), the wind speed in the location also increases its magnitude.



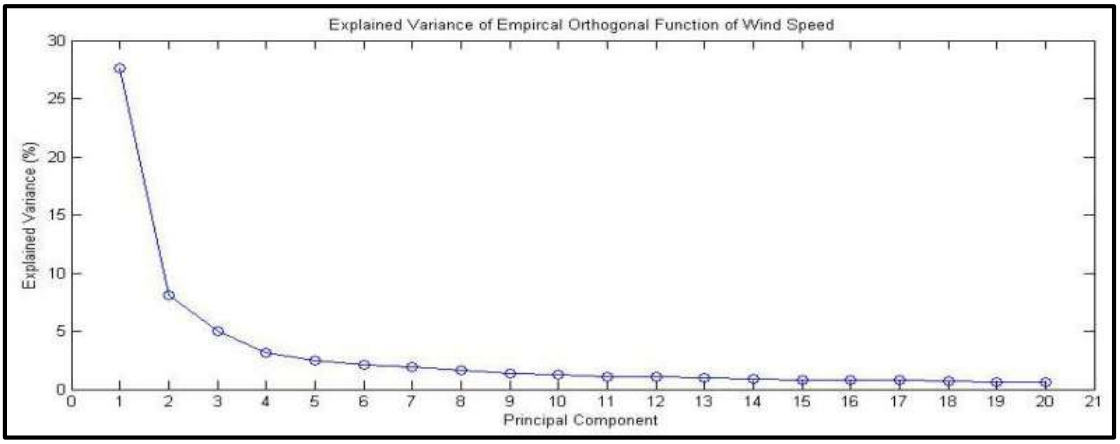
Correlation Analysis on Wind Speed and WNPM Index

- ✓ wind speed and WNPM follow the same trend.
- ✓ implies that as the oceanic monsoon (WNPSM) increases its intensity (index), the wind speed in the location also increases its magnitude.



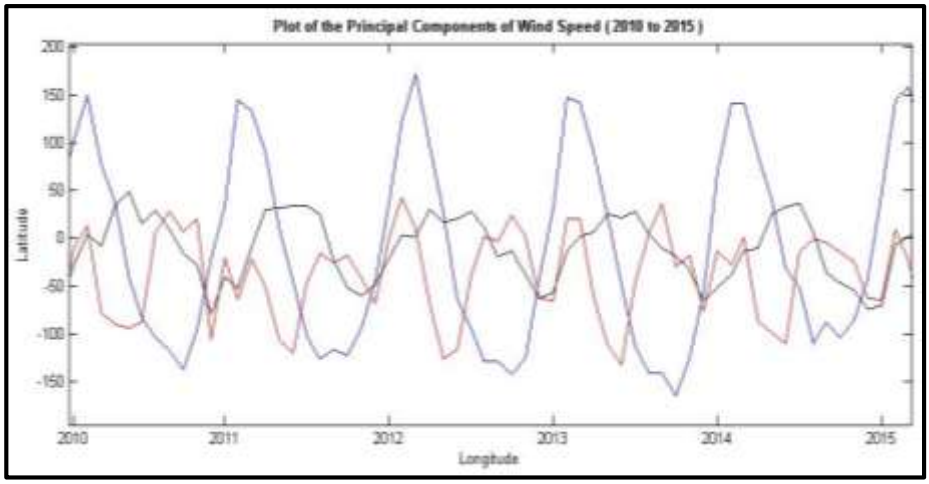
Correlation Analysis on Wind Speed and PDO Index

- ✓ wind speed and PDO follow an opposite trend.
- ✓ implies that as the Pacific Decadal Oscillation (PDO) increases its intensity (index), the wind speed in the location decreases its magnitude.



Explained Variance of EOF

- ✓ 1st PC is 27.6 % of the total variance of the given data. While the 2nd and the 3rd PC's explained only 8.1% and 5% respectively.
- ✓ only the first three EOF's were considered since it already represented 40.7% of the total variance of the wind speed data.



Plot of the First Three Principal Components of Wind Speed Using EOF.

- ✓ the first three components were considered since it has already been represented by more than 40% of the total data.
- ✓ data from 1948 were used in the EOF analysis but only data from 2010 to 2015 has only reflected on the image in order to magnify the trend that each PC in the analysis.
- ✓ Principal Component 1 (blue) shows only one peak in every year.

- ✓ Principal Component 2 (red) has an average peak of 2 peaks per year, and this can be attributed to a biennial cycle or can be considered as monsoonal cycle. This implies that there is a monsoonal change in wind speed.
- ✓ Principal Component 3 (black) has an evident peaks averaging to 4 peaks per year. Wind speed in the location of the wind power plant can be attributed to seasonal cycle (DJF, MAM, JJA and SON).

CONCLUSION

Based on the results, the following conclusions were drawn:

1. Wind profile varies -- seasonal and monsoonal.
2. Higher probability of strong wind speed is observed during the cold phase of ENSO, and lower probability of wind speed is observed on the warm phase of ENSO.
3. Low to moderate negative correlation was observed between ENSO Index (r=-0.38) and wind speed during SON, MAM and DJF seasons.
4. Moderate positive correlation was observed between EASM (r=0.54) and wind speed.

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$PM_{2.5}$ CONCENTRATIONS BETWEEN UNDER AND OVER SPANS OF SKYWALKS IN CEBU SOUTH ROAD OF CEBU CITY

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Bethany Christian School

ABSTRACT

This study evaluated $PM_{2.5}$ mean concentrations on two skywalks in Cebu City to determine whether there are significant differences between the *under* and *over* spans of the skywalk and to determine whether structural elements like skywalk roofs affect air quality. The study emphasizes the complexity of air pollution and provide insight for future traffic management and urban design strategies.

Keywords*: air quality, air pollution, AtmoTube Pro, pandemic, skywalks, $PM_{2.5}$ levels*

INTRODUCTION

Prolonged exposure to air pollution increases risks in heart disease where an increase of 10 µg/m^3 of particulate matter or $PM_{2.5}$ increases heart disease risk by 16% (Hayes, et al., 2019). These pollutants originate from a variety of sources such as vehicle emissions, industrial processes, and not limited to human lifestyle habits such as smoking and vaping. In an urban setting, vehicular exhaust emissions were seen to be the largest contributor to particulate matter (PM) specifically PM_{10} and $PM_{2.5}$ levels (Rodriguez, et al., 2004). Smoking in confined spaces show air quality degradation especially when cigarette smoking or vaping from inside vehicles where $PM_{2.5}$ levels nearly breached the 2000 µg/m^3 mark (Schober, Fembacher, Frenzen, & Fromme, 2019).

In response to increasing air pollution, the Philippine Clean Air Act of 1999 was created to regulate air quality wherein this legislation defines exposure limits for particulate matter specifically PM_{10} and $PM_{2.5}$ levels with safe exposure limits at 35.0µg/m^3 for short term exposure and 25.0µg/m^3 for long term exposure (Cimatu, 2020).

Category	Color	RGB Color Code	Hex Color Code	$PM_{2.5}$ (µg/m^3) BP_{Lo}-BP_{Hi}	Cautionary Statements
Good	Green	(0, 228, 0)	#00E400	0 - 25	None
Fair	Yellow	(255, 255, 0)	#FFFF00	25.1 - 35.0	None
Unhealthy for sensitive groups	Orange	(255, 126, 0)	#FF7E00	35.1- 45.0	People with respiratory disease, such as asthma, should limit outdoor exertion.
Very Unhealthy	Red	(255, 0, 0)	#FF0000	45.1 - 55	Pedestrians should avoid heavy traffic areas. People with heart or respiratory disease, such as asthma, should stay indoors and rest as much as possible. Unnecessary trips should be postponed. People should voluntarily restrict the use of vehicles.
Acutely unhealthy	Purple	(143, 63, 151)	#8F3F97	55.1 - 90	People, should limit outdoor exertion. People with heart or respiratory disease, such as asthma, should stay indoors and rest as much as possible. Unnecessary trips should be postponed. Motor vehicle use may be restricted. Industrial activities may be curtailed.
Emergency	Maroon	(126, 0, 35)	#7E0023	Above 91	Everyone should remain indoors, (keeping windows and doors closed unless heat stress is possible). Motor vehicle use should be prohibited except for emergency situations. Industrial activities, except that which is vital for public safety and health, should be curtailed.

Figure 1.1 *Categorized $PM_{2.5}$ levels as an amendment to the Clean Air Act of 1999.*

Cebu City roads have long been challenging to navigate with narrow roads and annual increases in the number of private cars and motorcycles on the roads. The Cebu City Transportation Office (CCTO) acknowledges the surge in the number of vehicles as the main cause of traffic although the office still considers traffic to be manageable (Piquero, 2023). Commonly, smoke belching vehicles are seen navigating the streets. During the first quarter of 2021 alone, CCTO apprehended more than 500 smoke belching violators (Letgio, 2021) and in February 2022, more than 700 violators (Magsumbol, 2022). Additionally, the city has experienced air quality issues brought by haze due to forest fires in neighboring countries like Indonesia in September 2019 where $PM_{2.5}$ levels were nearing 56 $\mu g/m^3$ which were above the threshold for fair air quality levels (Valeria, 2021).

Cebu City's infrastructure includes roads and bridges connecting various provinces and cities within the island of Cebu. Additionally, the city features elevated footbridges, commonly referred to as skywalks. These structures are strategically designed and located in busy and wide streets to enhance pedestrian convenience by allowing individuals to traverse busy streets safely without having to navigate the main roads. Skywalks offer some protection from street-level pollution (Rotmeyer, 2006) adverse weather conditions, and uneven pavement, thereby improving urban mobility and pedestrian safety (Spurr & Kwok, 2013). Air pollution is also said to decrease with an increase in height (Li, et al., 2019). However, skywalks have become more of socializing spots as a loitering or vendor area for disadvantaged groups (Villani & Talamini, 2020).

This study investigated whether skywalks provide some protection against air pollution, focusing on $PM_{2.5}$ mean concentrations for *under* and *over* spans of skywalks. Other factors were also explored that could influence $PM_{2.5}$ readings with an aim in understanding how their design and usage impact pedestrian exposure to particulate matter.

MATERIALS AND METHODS

An affordable air quality sensor was used in this study, the AtmoTube Pro. The focus was on $PM_{2.5}$ data as this device is known for being accurate in measurement in a variety of laboratory and field situations (Technical Certification, 2017).

Two selected skywalks were selected located along Cebu South Road in Pardo. One skywalk was near Pardo church labelled as "Pardo" while the other was directly outside a university labelled as "Outside University". Data was captured in real time where the device was held near the torso level. Data collection was from November to December 2023, focusing on the two spans per skywalk—under and over—with two points on each: Northbound and Southbound sides resulting in four points per skywalk. For endpoints below the skywalk, this was labelled as Under Northbound (UN) and Under Southbound (US) *under* span endpoints whereas Over Northbound (ON) and Over Southbound (OS) were at the *over* span endpoints. Each location was visited thrice, with each endpoint recorded for fifteen (15) minutes per visit, totaling one hour per visit. Post-collection, the device converted the data into a CSV file which was then transferred to Microsoft Excel for processing. A one-way Analysis of Variance (ANOVA) was used to

determine if significant differences existed between the points, followed by a Tukey Test to identify where these differences occurred. Finally, the mean $PM_{2.5}$ levels at each point were compared against the Department of Environment and Natural Resources (DENR) safety levels to determine if observed $PM_{2.5}$ levels are within the fair air quality levels.

RESULTS AND DISCUSSION

3.1 Overview for the Two Skywalks $PM_{2.5}$ Concentrations

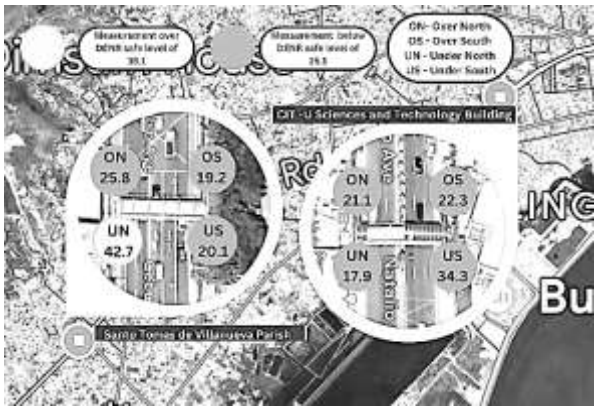

Figure 3.1 *Overview of the mean $PM_{2.5}$ levels after three visits for the four endpoints in the two selected skywalks for both upper and lower spans.*

Figure 3.1 shows mean $PM_{2.5}$ levels for the different spans of the skywalk which were generally within the 35.0µg/m^3 fair levels except Under Northbound (UN) for the Pardo skywalk and hovering near the threshold is Under Southbound (US) for the Outside University skywalk.

3.2 <u>Under-span</u> $PM_{2.5}$ mean concentrations and Structural differences between Skywalks

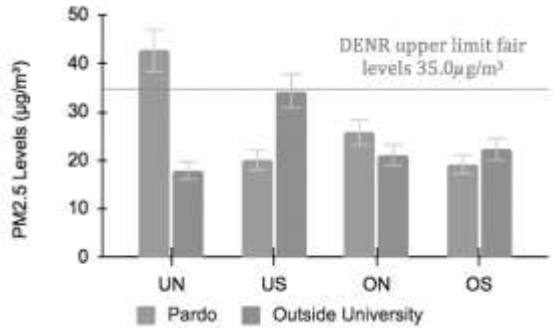

Figure 3.2 *Mean $PM_{2.5}$ levels on the under spans of the skywalk with reference to Fair air quality levels under the Clean Air Act of 1999.*

Figure 3.2 and statistical tests show significant differences for mean $PM_{2.5}$ concentrations for *under* spans of the skywalk specifically Pardo UN compared to Pardo US and Outside University US and UN *under* spans of the skywalk.

Figure 3.3 *Pardo skywalk including mean $PM_{2.5}$ levels and the general condition of the skywalk.*

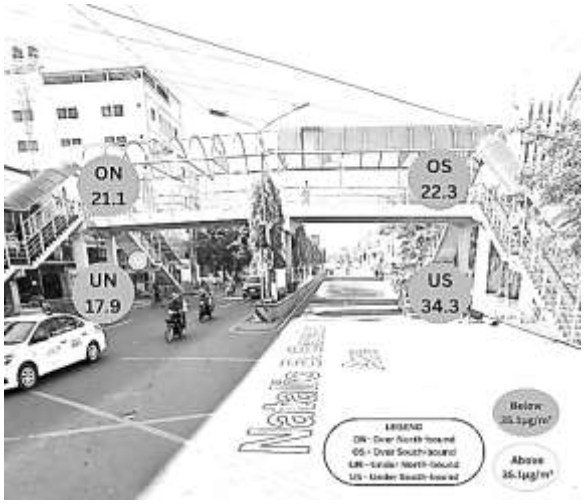

Figure 3.4 *Outside University skywalk including mean $PM_{2.5}$ levels and the general condition of the skywalk.*

The structural differences between the two skywalks also were observed during data collection. Figure 3.3 shows Pardo skywalk lacking a roof unlike the roofed section over on the southbound point of the Outside University skywalk (Figure 3.4). Furthermore, the southside Pardo skywalk featured numerous trees with foliage extending above the skywalk, whereas there were no trees present in the northbound point in the same skywalk. In contrast, the Outside University *over* span skywalk only had a roof halfway covering the southbound point. The southbound point is near the school zone and opposite is the northbound point near convenience stores and small shops.

Notably, Figure 3.3 shows Pardo UN area, being devoid of trees, recorded highest $PM_{2.5}$ levels at 42.7 $\mu g/m^3$ well above the fair air quality levels. It is not conclusive to suggest that the absence of physical barriers such as trees and railings, which were present at Outside University US (Figure 3.4), may contribute to higher pollution exposure but the high $PM_{2.5}$ levels were most likely influenced by the proximity of parked vehicles to the sensor. Specifically, data collection at Pardo UN was closer to vehicle exhaust emissions compared to Outside University US, where railings made a physical separation between pedestrians and the street potentially reducing exposure to direct vehicle emissions, where in Pardo these railings were missing. Pardo UN was a frequent stopping point for vehicles loitering often for more than two minutes, which included smoke-belching jeepneys stopping to pick up passengers with a disregard for traffic rules and may have further contributed to higher pollution levels.

Outside University US, which is near the school zone, was close to breaching the fair air quality threshold where $PM_{2.5}$ levels were at 34.3 $\mu g/m^3$ and these levels were likely influenced by prolonged vehicles idling in the area during student pick-up times. This scenario mirrors Pardo UN but with fewer smoke-belching jeepneys and more privately parked vehicles.

Pardo US and Outside University UN had significantly lower mean $PM_{2.5}$ concentrations. Vehicles at these locations tended to stop farther away from the data collection points hence farther away from the sensor. This increased distance between the sensor and vehicles likely contributed to the reduced $PM_{2.5}$ readings observed at these sites.

3.3 Over-span $PM_{2.5}$ mean concentrations

Figure 3.2 shows that the mean $PM_{2.5}$ concentrations for the *over* spans of each skywalk remain within fair air quality levels suggesting that the presence or absence of physical barriers, such as roofs or trees, may have a negligible impact on $PM_{2.5}$

concentrations. Initially, it was hypothesized that a roof on the skywalk might increase $PM_{2.5}$ levels compared to open skywalks; however, this may not be the case. The $PM_{2.5}$ mean concentration at Outside University's OS point, which has a roof, does not significantly differ from the ON endpoint, which is unroofed. Similarly, the presence or absence of trees at the Outside University's US and OS points shows no significant difference in $PM_{2.5}$ levels compared to the Pardo skywalk except for Pardo's UN point. This suggests that other factors, such as the proximity of the sensor to pollution sources, as discussed in Section 3.2, are more likely to influence $PM_{2.5}$ readings.

3.4 Difference between Under and Over Spans of the Skywalks

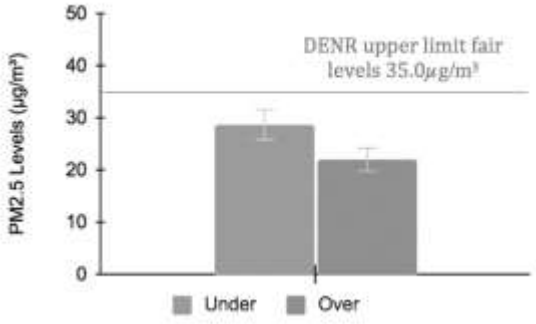

Figure 3.5 *Mean $PM_{2.5}$ levels of the over and under spans of both skywalks.*

Figure 3.5 indicates that there is no statistically significant difference in $PM_{2.5}$ concentrations between the *under* and *over* spans of the skywalks. However, the data may suggest that $PM_{2.5}$ concentrations tend to be higher in the *under* spans compared to the *over* spans. Notably, both skywalks maintain mean $PM_{2.5}$ levels within the 'fair' air quality range as defined by the Clean Air Act of 1999.

This pattern may be influenced by several factors. The *under* spans of skywalks are closer to road traffic and are more likely to be exposed to direct vehicle emissions. This proximity could account for the elevated $PM_{2.5}$ levels observed in these areas. Additionally, the structural design and dynamics of airflow of the skywalks might also play a role. Since *over* spans are more open and elevated, they are likely to experience better air circulation, which may help in dispersing particulate matter more effectively than the enclosed under spans.

CONCLUSION

This study assessed the $PM_{2.5}$ concentrations in two different skywalks in Cebu City focusing on variation between upper and lower spans and examining if their structural elements would have an effect on air quality.

Air quality in general were well within the fair air quality level except Under Northbound (UN) at Pardo and the Under Southbound (US) at Outside University. These locations showed $PM_{2.5}$ levels approaching or exceeding the fair air quality standard set by DENR. Structural elements like roofs and proximity to trees did not necessarily influence $PM_{2.5}$ levels across all points for each skywalk and instead is likely attributed to the close proximity to vehicle emissions rather than the presence or absence of physical barriers.

The findings also align with broader environmental studies suggesting that vertical dispersion and dilution of pollutants generally improve with height (Ding, et al., 2005). Thus, even though the differences in $PM_{2.5}$ concentrations are not statistically significant, the trend towards lower concentrations at

higher elevations is consistent. This further emphasizes the complexity of air pollution dynamics in urban settings and highlights the importance of considering structural and environmental factors when assessing air quality in areas like skywalks.

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$PM_{2.5}$ MEAN CONCENTRATIONS AT INTERSECTIONS IN CEBU CITY DURING THE PRE-PANDEMIC, POST PANDEMIC, AND POST LOCKDOWN PERIODS

Joanna Liza Go, Bryan Vincent King, Kyran Antoine Ong, Mary Nadine Chua, and Maria Lourdes Anne Lee

Bethany Christian School

ABSTRACT

This study examined the $PM_{2.5}$ mean concentrations across four sites assessing air quality and its correlation with urban infrastructure across three time periods. Results showed high levels of $PM_{2.5}$ at intersections with high commercial density. The study also determined if flyovers inherently impacted $PM_{2.5}$ levels. Temporal analysis was also done showing $PM_{2.5}$ concentrations trends from the pre-pandemic to post-pandemic periods across all sites where construction activities The findings highlight the importance of urban design and traffic management in mitigating air pollution and the need for targeted strategies to address $PM_{2.5}$ emissions in populated commercial areas.

Keywords*: air quality, air pollution, AtmoTube Pro, $PM_{2.5}$ levels*

INTRODUCTION

Low-cost air quality sensors including the Atmotube Pro are increasingly being used for environmental monitoring and modeling studies. The Atmotube Pro was used in a study measuring particulate matter levels and analyzing meteorological variables and the time-delayed interactions between them toward the effects of air pollutants in Baguio City (Liponhay, Valerio, & Monterola, 2024). A community-engaged study in Santa Ana, California tracked particulate matter levels across different neighborhoods and were able to identify areas of higher concentrations of air pollution while able to highlight social and policy-making impacts their research could provide (Masri, Cox, Flores, Rea, & Wu, 2022).

Air pollution, consisting of a mix of particulates and gases where some of these include carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), and Particulate Matter (PM) which may include tiny particles and liquid droplets of metals, chemicals, soils, acids and dust particles. PM is classified by its aerodynamic diameter into categories: coarse thoracic (PM_{10} to $PM_{2.5}$), fine ($PM_{2.5}$), and ultrafine (PM_1) and these are known to have detrimental effects on human health (Zu, et al., 2020) especially on young children who are vulnerable to air pollution where an increase in 10μg/m^3 of PM increases pneumonia risk from 1.10% to 10.28% (Wang, et al., 2021). Existing literature points to $PM_{2.5}$ exposure as

a global health concern due to $PM_{2.5}$'s small diameter and a positive association with the lung cancer process (Lee, et al., 2020).

As a response to rising air pollution, the Philippine Clean Air Act of 1999 aims to manage air quality by identifying thresholds of air pollution levels indicated by particulate matter (PM) levels setting exposure limits for PM_{10} and $PM_{2.5}$ levels with safe exposure limits at 35.0µg/m^3 for short term exposure and 25.0µg/m^3 for long term exposure (Cimatu, 2020).

This study examined the trends in $PM_{2.5}$ concentrations during the three periods: pre-pandemic (2019-2020), post-pandemic (2022-2023), and post-lockdown (2023-2024) using the Atmotube Pro in four randomly selected intersections in Cebu City. Two of the intersections feature flyovers and the study also aimed to determine whether the presence of flyovers had significant contributions to $PM_{2.5}$ levels.

Category	Color	RGB Color Code	Hex Color Code	$PM_{2.5}$ ($\mu g/m^3$) BP_{Lo} - BP_{Hi}	Cautionary Statements
Good	Green	(0, 228, 0)	#00E400	0 - 25	None
Fair	Yellow	(255, 255, 0)	#FFFF00	25.1 - 35.0	None
Unhealthy for sensitive groups	Orange	(255, 126, 0)	#FF7E00	35.1- 45.0	People with respiratory disease, such as asthma, should limit outdoor exertion.
Very Unhealthy	Red	(255, 0, 0)	#FF0000	45.1 - 55	Pedestrians should avoid heavy traffic areas. People with heart or respiratory disease, such as asthma, should stay indoors and rest as much as possible. Unnecessary trips should be postponed. People should voluntarily restrict the use of vehicles.
Acutely unhealthy	Purple	(143, 63, 151)	#8F3F97	55.1 - 90	People, should limit outdoor exertion. People with heart or respiratory disease, such as asthma, should stay indoors and rest as much as possible. Unnecessary trips should be postponed. Motor vehicle use may be restricted. Industrial activities may be curtailed.
Emergency	Maroon	(126, 0, 35)	#7E0023	Above 91	Everyone should remain indoors, (keeping windows and doors closed unless heat stress is possible). Motor vehicle use should be prohibited except for emergency situations. Industrial activities, except that which is vital for public safety and health, should be curtailed.

Figure 1.1 *Breakpoints of $PM_{2.5}$ levels as an amendment to the Clean Air Act of 1999.*

MATERIALS AND METHODS

The AtmoTube Pro was used which is a low-cost air quality sensor capable of measuring PM_1, $PM_{2.5}$, and PM_{10} concentrations. $PM_{2.5}$ was the specific particulate matter data being collected and analyzed as the Atmotube Pro is capable of accurately measuring this in a variety of laboratory and field situations (Technical Certification, 2017). The device was held 1.25 meters above the ground to gather data from the breathing zone. The data were collected during the months of December and January from three time periods: 2019-2020 (pre-pandemic), 2022-2023 (post-pandemic), and 2023-2024 (post-lockdown). Four locations were chosen categorized as follows: Intersection 1 which is the intersection between Salinas Drive and Transcentral highway; Intersection 2 which is the intersection between Pope John Paul II Avenue, Cardinal Rosales Avenue, and F. Cabahug Street; Flyover 1 which is the intersection and flyover in Archbishop Reyes Avenue, Salinas Drive, and Pope John Paul II Avenue; and Flyover 2 which is the intersection between Archbishop Reyes Avenue, N. Escario Street, and Mindanao Avenue. Each site was visited four times with twenty minutes of data gathering per corner per intersection—a total of eighty minutes per intersection for a single visit throughout the three periods. Humidity levels during data collection were ranging between 40%-70% and data collection was done during non-rainy days. The spreadsheet files were then exported to Microsoft Excel for data analysis using one-way Analysis of Variance (ANOVA), and followed-up by the Tukey Tests.

RESULTS AND DISCUSSION

3.1 $PM_{2.5}$ Concentrations for the four sites

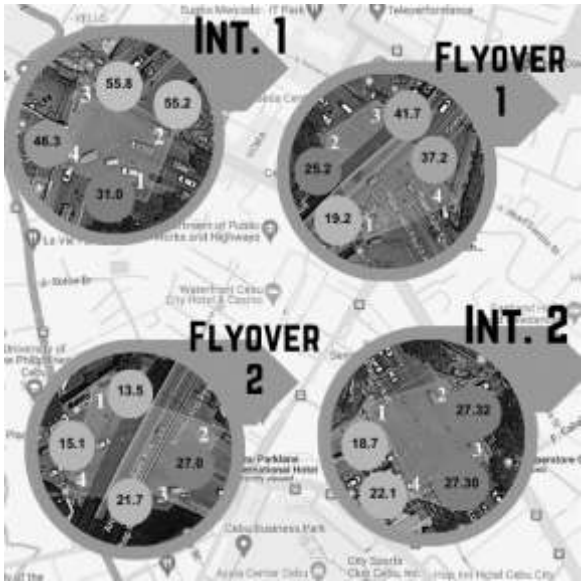

Figure 3.1 *$PM_{2.5}$ means (in µg/m^3) for the four corners for every site.*

Figure 3.1 shows the $PM_{2.5}$ mean concentrations for the four sites, with values above the 'Fair' air quality threshold of 35.0 µg/m³ in red. It is apparent that Intersection 1 (Int. 1) has readings that are consistently above this threshold, indicating a level of concern for air quality. Specifically, Int. 1 has values reaching up to 55.81 µg/m³, which significantly exceeds the threshold, suggesting acutely unhealthy air quality where outdoor physical activity should be limited according to the Clean Air Act of 1999.

Both Flyover 1 and Intersection 2 (Int. 2) show mixed results, with some measurements above and others below the threshold, indicating variability in air quality that may fluctuate between fair and poor conditions. Flyover 2, in contrast, remains below the threshold in all corners, which is indicative of relatively better air quality compared to the other locations.

The $PM_{2.5}$ mean concentrations highlight critical air quality issue at Intersection 1, notably due to higher traffic congestion and industrial activity with the presence of not only larger business the area but also micro businesses including barbeque stalls, vape stands, and street vendors where they were seen actively cooking contributing to elevated smoke emissions causing spikes in $PM_{2.5}$ concentrations over time. For Flyovers 1, 2, and Intersection 2, the presence of micro business was notably missing compared to Intersection 1.

3.2 Intersections and Flyovers

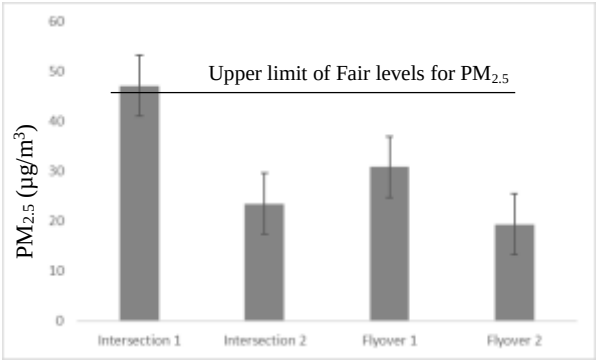

Figure 3.2 *$PM_{2.5}$ means (µg/m^3) for the four sites*

Comparative analysis between intersections and flyovers suggests that the presence of flyovers does not significantly influence $PM_{2.5}$ concentrations further indicating there are no statistical differences in the mean $PM_{2.5}$ concentrations between these two types of sites. However, a notable exception was found at Intersection 1, where the mean $PM_{2.5}$ concentration significantly exceeded the observed $PM_{2.5}$ mean concentrations at the two flyovers, which was

far above the Fair categorization of $PM_{2.5}$ concentration in the air. This deviation is likely attributable to the higher density of commercial and micro businesses in Intersection 1 compared to the areas surrounding the flyovers.

3.3 $PM_{2.5}$ measurements across the three time periods

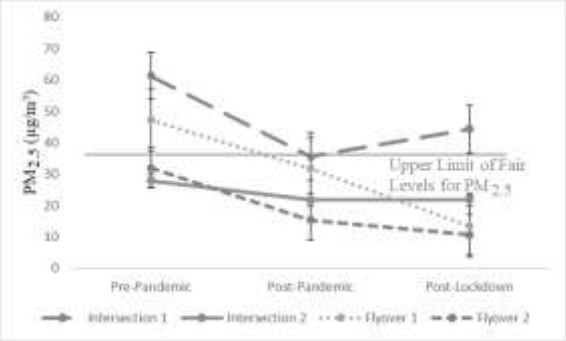

Figure 3.3 *$PM_{2.5}$ means ($\mu g/m^3$) for the four sites across the three time periods.*

Over the three time periods, Figure 3.3 shows there were reductions in the mean $PM_{2.5}$ concentrations for Flyover 1 and Flyover 2 decreased. Similarly, at Intersections 1 and 2, the $PM_{2.5}$ mean concentrations show declines during the post-pandemic period from the pre-pandemic period followed by a slight increase after the post-lockdown period.

Interestingly, the variation in traffic patterns during road maintenance in Flyover 1 had an impact in $PM_{2.5}$ mean concentration The absence of roadworks pre-pandemic allowed for unimpeded traffic flow, which resulted in higher vehicular emission levels due to the greater volume of vehicles passing through the area. However, the construction activities in the post-pandemic and post-lockdown periods modified traffic movement through traffic lanes reduction to one or two-way flows thereby diminishing the vehicle count. This reduction in traffic density would naturally lead to a decrease in vehicular emissions, correlating with the lower $PM_{2.5}$ levels observed in these periods. The construction has created alterations in vehicular traffic flow which could explain the lower $PM_{2.5}$ readings post-pandemic, especially when comparing to the higher concentrations documented in the pre-pandemic era when traffic was at its peak.

Across all sites, statistical tests confirmed the decreased $PM_{2.5}$ mean concentrations were statistically significant between the pre-pandemic period and both the post-pandemic and post-lockdown periods. However, no statistical differences were shown in the changes between the post-pandemic and post-lockdown periods. The variations between the pre-pandemic and post-periods could have been due to decreased vehicular traffic and the reduced presence of micro businesses in the area.

CONCLUSION

There are significant air quality challenges after analysis of $PM_{2.5}$ concentrations across the four sites particularly Intersection 1 where the presence of micro businesses which include barbeque and vape shops emit particulate matter in the air contributing to higher $PM_{2.5}$ concentrations which exceed the safe air quality levels set in the Philippine Air Act of 1999. Though flyovers do not inherently cause increased $PM_{2.5}$ levels, the specific conditions at Intersection 1, marked by high commercial density and limited space for air dispersion, lead to substantially higher $PM_{2.5}$ readings compared to the other sites.

Temporal shifts in $PM_{2.5}$ concentrations during pre-pandemic, post-pandemic, and post-lockdown periods further highlight the impact of traffic volume and road construction on air quality. Vehicular traffic patterns changed due to ongoing construction and while it was believed construction may increase $PM_{2.5}$ mean concentrations, it resulted in the reduction in vehicle flow especially at Flyover 1 corresponding with a notable decrease in $PM_{2.5}$ levels during the post-pandemic and post-lockdown periods, as opposed to the pre-pandemic era with unimpeded traffic. Statistical tests across all sites validate the significance of the decrease in $PM_{2.5}$ concentrations from the pre-pandemic periods compared to the post-periods, emphasizing the need for strategic urban and traffic management to improve air quality particularly in high-density urban environments.

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MEASUREMENTS OF $PM_{2.5}$ IN CEBU CITY DURING AFTERNOON RUSH HOURS ALONG INTERSECTIONS OF A SCHOOL DISTRICT, V. RAMA AVE., AND CEBU PROVINCIAL CAPITOL SITE

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ABSTRACT

$PM_{2.5}$ levels in Cebu City were measured during afternoon rush hours along intersections of a School District, V. Rama Ave., Cebu Provincial Capitol Site, and a Hospital District using Atmotube Pro. Data was collected from 4:00 p.m. to 7:00 p.m. on weekday afternoons in 2023 and 2024 across two distinct seasons: the cool dry season from December to February and the warm dry season from March to May spanning the years 2023 and 2024. The study aimed to determine if seasonal variations and other urban activities influenced $PM_{2.5}$ concentrations. Additionally, the impact of ongoing urban developments, such as the construction of Cebu City's Bus Rapid Transit system, on local air quality is also considered.

Keywords*: air quality, air pollution, AtmoTube Pro, $PM_{2.5}$, road intersections*

INTRODUCTION

Air pollution poses health risks worldwide and specifically in southeast Asia, which is mostly due to smoke belching vehicles (Lu, 2022) where exposure leads to negative impacts on the human cardiovascular system the longer people are exposed to air pollutants (Meo & Suraya, 2015). Interestingly, since the pandemic, air pollution exposure adds to the detrimental effects on people with viral infections including COVID-19 (Zu, et al., 2020).

Studies have pointed to vehicle age and its emissions which vehicles' quantity and concentration in a given area (Halek, Kavouci, & Montehaie, 2007). Poorly maintained vehicles tend to smoke belch which has been recognized as a significant contributor to air pollution (Gilaga & Pallega, 2010).

Air pollution comprises a diverse mixture of substances including dust, fumes, gases, and various chemical compounds such as carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and ozone (O_3) (Popelll, et al., 2003). Particulate Matter (PM), a component of air pollution, consists of tiny particles and liquid droplets containing chemicals, acids, metals, and soil or dust. The impacts of air pollutants vary depending on their characteristics, chemical composition, and individual genetic factors and PM is categorically based on its aerodynamic diameter, with particles falling into coarse

thoracic ($PM_{2.5-10}$ mm), fine ($PM_{2.5}$), and ultrafine (PM_1) categories.

The Philippine Clean Air Act of 1999 (RA 8749) was established as a policy for addressing air quality matters outlining the provisions on the extent, analysis, identification, and recommendation for air quality monitoring. This law establishes specific exposure thresholds for PM_{10} with 150μg/m^3 for daily and 60μg/m^3 for annual means (Zhu, et al., 2012). As of 2020, the Air Quality Indices (AQI) included levels for $PM_{2.5}$ and their different breakpoints (see Fig. 1.1) wherein safe short-term exposure (24 hours) is 35μg/m^3 and long-term exposure (1 year) is 25μg/m^3 (Cimatu, 2020).

Category	Color	RGB Color Code	Hex Color Code	$PM_{2.5}$ (μg/m^3) BP_{Lo} - BP_{Hi}	Cautionary Statements
Good	Green	(0, 228, 0)	#00E400	0 - 25	None
Fair	Yellow	(255, 255, 0)	#FFFF00	25.1 - 35.0	None
Unhealthy for sensitive groups	Orange	(255, 126, 0)	#FF7E00	35.1- 45.0	People with respiratory disease, such as asthma, should limit outdoor exertion.
Very Unhealthy	Red	(255, 0, 0)	#FF0000	45.1 - 55	Pedestrians should avoid heavy traffic areas. People with heart or respiratory disease, such as asthma, should stay indoors and rest as much as possible. Unnecessary trips should be postponed. People should voluntarily restrict the use of vehicles.
Acutely unhealthy	Purple	(143, 63, 151)	#8F3F97	55.1 - 90	People, should limit outdoor exertion. People with heart or respiratory disease, such as asthma, should stay indoors and rest as much as possible. Unnecessary trips should be postponed. Motor vehicle use may be restricted. Industrial activities may be curtailed.
Emergency	Maroon	(126, 0, 35)	#7E0023	Above 91	Everyone should remain indoors, (keeping windows and doors closed unless heat stress is possible). Motor vehicle use should be prohibited except for emergency situations. Industrial activities, except that which is vital for public safety and health, should be curtailed.

Figure 1.1 *Breakpoints of $PM_{2.5}$ levels as an amendment to the Clean Air Act of 1999.*

In the Philippines, Manila's average $PM_{2.5}$ levels average between 18.7μg/m^3 to 58.4μg/m^3 during the dry season surpassing the fair air quality range (Alas, Müller, & Birmili). One factor contributing to the elevated air pollution levels in Manila may come from the still-running diesel-powered public utility jeepneys operating throughout Metro Manila (Kecorius, et al., 2017).

This study focused on gathering $PM_{2.5}$ measurements in Cebu City targeting intersections and roads that represent a portion of the city's industrial areas including a school district, a main highway access road in Guadalupe area in V. Rama Avenue; a hospital district, Cebu Capitol Site where the current Bus Rapid Transit (BRT) System is being built. Previous studies on air quality have been done measuring PM_{10} and determining trace metals concentrations (Alburo, Gabrillo, & Villegas, 2023), and PM_{10} measurements in three sampling locations around Cebu and Mactan Island where the PM_{10} levels exceeded healthy breakpoints (Manatad & Sinogaya, 2020).

MATERIALS AND METHODS

The Atmotube Pro was used which can provide continuous monitoring of PM_{10}, $PM_{2.5}$ and PM_1 concentrations (measured in μg/m^3), volatile organic compounds (VOC) levels (in ppm), atmospheric pressure (in mbar), temperature (in Celsius), relative humidity (in %), as well as provide latitude and longitude coordinates. It is able to connect to a Bluetooth-enabled smartphone and features self-calibration; it has been certified to deliver precise and reliable measurements for $PM_{2.5}$ and PM_{10} under various conditions, as confirmed by controlled experiments and field tests (Technical Certification, 2017).

The study concentrated on PM2.5 measurements because they are recognized for their reliability when recorded using the AtmoTube (Technical Certification, 2017) . Although the device can monitor various data

attributes, including PM10, the focus on PM2.5 was driven by its comparatively higher health risk (Polichetti, Coccoa, Spinali, Trimarcoa, & Nunziata, 2009).

Four (4) Cebu City sites were selected specifically in areas where it would represent busy areas of Cebu: a school district, a hospital district, a highway access road (V. Rama Avenue) and Capitol Site, where $PM_{2.5}$ readings were measured during rush hours from 4:00 p.m. to 7:00 p.m. on weekday afternoons from February to March 2023, and from November 2023 to February 2024.

The dry season, spanning November to March, is characterized by reduced rainfall and is further divided into two: the cool dry season from December to February followed by the warm dry season extending from February to May. Total of six (6) visits per site on non-consecutive days where data collection was done on four (4) corners of each intersection for 20 minutes for a total of one (1) hour and twenty (20) minutes recorded data per site.

Furthermore, Microsoft Excel was used to convert the data into a compatible spreadsheet file for analysis. Statistical tests, the One-Way Analysis of Variance (ANOVA) and Tukey tests, identified significant differences within the study using the averaged values of the four corners for each location.

RESULTS AND DISCUSSION

3.1 Seasonal Differences in $PM_{2.5}$ Measurements

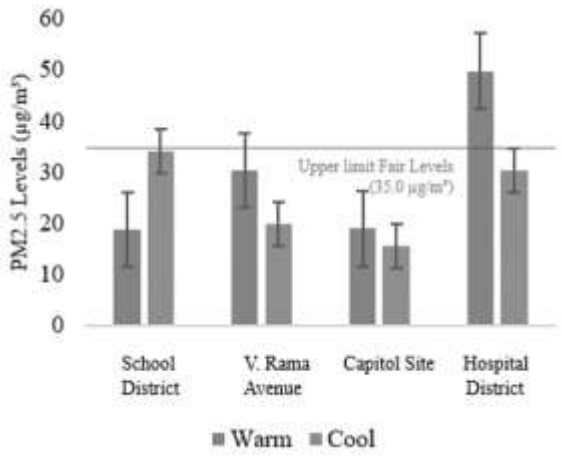

Figure 3.1 *PM2.5 Measurements (µg/m³) Between Warm and Cool Dry Season.*

Figure 3.1 shows the mean $PM_{2.5}$ measurements between the warm dry season (March to May) and cool dry season (November to February). Statistical tests indicate there are no significant differences between the readings for both seasons which would imply $PM_{2.5}$ levels would remain consistent regardless of the season during the dry months. Additionally, School District, V. Rama Ave., and Capitol Intersections all fell under the "Fair" category of $PM_{2.5}$ levels during both seasons according to the Clean Air Act of 1999 standards. On the other hand, the $PM_{2.5}$ levels of the Hospital District Intersection during the cool dry season fell under the "Fair" category, while levels were above the "Very Unhealthy" category during the warm dry season.

Although no significant differences were observed, it is worth considering $PM_{2.5}$ levels for the Hospital District Intersection

during the warm dry season are much larger compared to the cool dry season as well as the rest of the intersections during both seasons. This could likely be due to the ongoing BRT project in the area (see 3.2).

During the cool dry season, the $PM_{2.5}$ means were nearly at the upper limit of the Fair category air quality index. Notably, there were more vehicles passing through the area as some nearby business establishments were opening in time for the holiday season.

3.2 Effects of BRT Project on $PM_{2.5}$ Measurements in Capitol and Hospital District

Figure 3.2 *Changes in vehicular lanes pre-construction where 3 lanes on both directions were available whereas during the construction of the BRT project, only 1 lane was available for both directions; a comparison of the means of $PM_{2.5}$ measurements during those times.*

Figure 3.2 shows the road lane changes and the means of $PM_{2.5}$ measurements in the Hospital District Intersection during the warm dry season, which levels could likely be attributed to the BRT construction and the lessening of vehicles moving through the roads. When construction had not yet started during the warm dry season, the roads had all six lanes open. However, once construction began, several lanes were barricaded shifting into one lane traffic for both directions. Traffic volume and vehicular emissions were much larger during the construction and had much larger means on the $PM_{2.5}$ levels than prior to the construction where the car lanes were less restricted.

3.3 Differences in $PM_{2.5}$ Measurements Between Sites

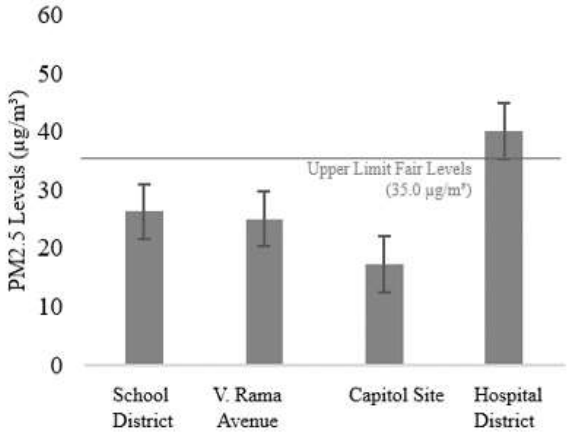

Figure 3.3 *$PM_{2.5}$ (µg/m³) means between each site.*

Figure 3.3 shows only a significant difference of $PM_{2.5}$ levels between Capitol Site and the Hospital District. It is interesting to note the BRT project spans the hospital district and Capitol site but the BRT project ends just before Capitol. This suggests that location and human activity may be a determining factor of $PM_{2.5}$ measurements. The $PM_{2.5}$ levels at the School District, V. Rama Ave., and Capitol Intersections all fell under the "Good" to "Fair" category. On the other hand, the $PM_{2.5}$ levels at the Hospital District Intersection fell under the "Unhealthy

for Sensitive Groups" category where the mean was above 35.0μg/m^3.

Figure 3.3 also shows that Capitol had the lowest PM2.5 levels; the Hospital district Intersection had the highest; while the School district and V. Rama Avenue fell somewhere in between. Factors such as trees, foot traffic volume, traffic volume, human activity, and yellow box junctions are location-specific and may have affected $PM_{2.5}$ levels. Additionally, Capitol Site shows significantly less levels of $PM_{2.5}$ possibly due to the much larger junction box allowing efficient vehicular movement letting air flow more freely thereby reducing measured air pollution by the sensor. In contrast, the Hospital district had heavier vehicular and foot traffic due to road restrictions for the BRT project.

CONCLUSION

Seasonality may not be a significant factor in the changes of $PM_{2.5}$ levels as the measurements remained within the 'Fair' category for most intersections as per the Clean Air Act of 1999 standards. However, an exception was noted at the Hospital District where $PM_{2.5}$ levels were categorized as 'Very Unhealthy' during the warm dry season, which contrasted with the 'Fair' levels during the cool dry season, potentially due to the BRT project underway during the warmer period.

The BRT project, specifically, seems to have escalated $PM_{2.5}$ levels at the Hospital District Intersection due to increased traffic congestion caused by lane reductions. Conversely, the Capitol Site, situated outside the BRT project area, recorded the lowest $PM_{2.5}$ levels, possibly due to more efficient traffic flow facilitated by a larger junction box. This suggests that infrastructure design may have significantly contributed to the variance in air quality across different urban sites while the Hospital District's air quality was greatly affected by construction-related disruptions. These findings show the importance of considering environmental health impacts in urban development and traffic management.

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RISK-BASED APPROACH IN REGULATING THE SAFETY OF FACILITIES AND ACTIVITIES INVOLVING RADIOACTIVE MATERIAL

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ABSTRACT

Radioactive materials have many applications that are beneficial ranging from uses in medicine, industry, agriculture, research, and power generation. The radiation risks that may arise from the use of radiation and radioactive materials must be assessed and must be controlled by applying safety regulations and standards for the purpose of protecting people and the environment from the harmful effects of radiation exposure. There is an increased use of radioactive materials in the Philippines, especially in medicine for diagnostic imaging and cancer therapy, and in industry for level gauging, non-destructive testing, and sterilization. There is now local production of certain radionuclides by cyclotron for diagnostic imaging. Nuclear material is now utilized for research and training purposes and maybe more nuclear material will be utilized for power generation in the country.

The risk-based approach to radiation and nuclear safety will be presented by giving examples of the degree of regulatory control and complexity of radiation and nuclear safety requirements of the various applications of radioactive materials, including transport and radioactive waste safety.

INTRODUCTION

The radioactive materials in facilities (e.g. nuclear medicine, radiotherapy nuclear installations such as research reactor and nuclear power plant) and in activities (e.g. the production, use, import and export of radiation sources for industrial, research and medical purposes; transport of radioactive material; radioactive waste management) are of various types, forms, and quantities. Hence, the facilities and activities pose varying degree of risks to people and the environment. The application of a graded approach entails that the safety requirements are commensurate to the risks associated with the radioactive material involved in the facilities and activities. The factors that may have significant impact on the assessment of risk associated with facilities and activities are: a) factors specific to the radioactive material such as the activity, half-life, dispersibility, physical and chemical properties, and the characteristics of the ionizing radiation; b) factors specific to the facility and activity such as purpose of use (e.g. medical or industrial

application, production of radionuclides), complexity of operating procedures, training requirements of staff, and condition of use (whether the source remain within or is removed from a shielded container, design of the facility and equipment and shielding devices; and whether use in the field or in a fixed facility (IAEA, 2021.a). These factors require certain level of competence both from the facility and regulatory staff to be able to perform a balanced risk assessment and apply the graded approach. The higher the risk associated with the facility or activity, the more stringent the safety requirements that apply to it.

The radiation protection and safety requirements for facilities and activities involving radioactive material in the Philippines are prescribed in the regulations of the Philippine Nuclear Research Institute (PNRI) and are codified into Parts of the Code of PNRI Regulations (CPR). The PNRI is the regulatory authority for radioactive materials in the Philippines.

FACILITIES AND ACTIVITIES IN THE PHILIPPINES, RELATIVE RISKS, AND REGULATORY REQUIREMENTS

A. Distribution of PNRI Licensees

The geographic distribution of PNRI licensees for facilities and activities as of 2020 is shown in Table1. Most of the licensees are in the National Capital Region. Table 2 shows the distribution of licensees according to the types of use of radioactive material, as of 2020.

Table 1. *Geographic distribution of PNRI licensees, 2022 (Source: Licensing Review and Evaluation Section, PNRI).*

Region	No. of Licensees
I	11
II	8
III	44
IV	78
V	6
VI	15
VII	20
VIII	2
IX	7
X	16
XI	16
XII	4
XIII	4
Cordillera Adm Region	5
National Capital Region	229
Total	**471**

Table 2. *Distribution of PNRI licensees by type of use, 2022 (Source: Licensing Review and Evaluation Section, PNRI).*

Types of Use	No. of Licensees
Medical Cyclotron (PA)	5
Commercial (C)	48
Industrial Radiography (I)	34
Medical (M)	176
Industry (Y)	166
Research (R)	42
Total	**471**

B. Examples of uses of radioactive material in medicine and industry

Below are some examples of uses of radioactive materials in medicine and in industry.

1. Medical Uses
   a. Examples of unsealed radioactive materials used in nuclear medicine a) for diagnostic imaging are technetium-99m, thallium-201, fluorine-18, and iodine-131; and b) for therapy are iodine-131, lutetium-177, strontium-89. The half-lives range from few hours to days and the activities range from megabecquerel (MBq) – giga-becquerel (GBq).
   b. Examples of sealed radioactive materials used in radiotherapy a) for teletherapy, cobalt-60; and b) for brachytherapy, cobalt-60 and iridium-192. The half-lives are from months to years, and the activities ranges from gigabecquerel-terabecquerel.
   c. Example of unsealed source for radioimmunoassay is iodine-125, half-life is 59.48 days and activity in kilobecquerel.

2. Industrial Uses
   a. Example of sealed source used in field industrial radiography is iridium-192, half-life is 74 days; activity is in terabecquerels.
   b. Example of sealed source used in large gamma irradiation facility is cobalt 60, half-life, 5.2 years; activity in petabecquerels.
   c. Example of sealed sources used in manufacturing industry: for level gauges-cesium-137 or cobalt-60 with activity of 1-2 gigabecquerels; for density gauges-americium-241, cesium-137 with activity of 20-30 megabecquerels; for thickness gauges-krypton-85 and strontium-90 with activity of 1-30 megabecquerels.

3. Particle accelerators – e.g. cyclotrons for the production radionuclides for medical use e.g. fluorine-18, in terabecquerels.

C. Relative risks of facilities and activities

The factors that have significant impact on the assessment of risks are as follows: 1) for radioactive sources, the activity, half-life, dispersibility, physical and chemical properties, and the characteristics of the emitted ionizing radiation; 2) specific to the facility and activity, such as: a) purpose or use (e.g. medical use, industrial applications, production of radionuclides; b) complexity of activities, operating procedures, training requirements of personnel, conditions of use (e.g. whether the radiation source remains inside or removed from its shielded container when in use; c) design of the facilities and equipment and shielding devices (e.g. whether the protection and safety can largely be ensured by the design of facilities and equipment); d) whether use in a fixed facility or in the field; and 3) additional factors that impact the level of regulatory control and requirements, such as: a) the maturity of the facility or activity; b) the knowledge and expertise of the licensee's staff; c) the compliance history of the facility or activity; d) the level of safety culture existing in the organization; and e) the adequacy of financial and human resources related to safety (IAEA, 2021).

Considering the above factors, and the potential for radioactive sources to cause deterministic health effects such erythema,

tissue burns, acute radiation sickness and death when not managed safely and securely, the radioactive sources are categorized (IAEA, 2005; PNRI, 2014) as shown in Table 3.

The criteria for determining the overall risk associated with facilities and activities is primarily based on the assessment of the level of potential dose received when near the source. Other factors such as those specific to the radioactive source, as well as the factors specific to the facility may influence the primary factor thus increasing the overall risk. An example of the relative ranking of risks associated with facilities and activities is shown in Table 4.

The above categorization of radioactive sources and the relative ranking of risks associated with facilities and activities are used as the basis in the application of graded approach in imposing regulatory control and requirements and in the implementation of the regulatory functions, such as authorization and inspection. The graded approach in applying authorization are notification, registration, and license. Notification to the regulatory body suffices for exempt activity concentration and activities of radionuclides listed in Table A.1, [DOST-PNRI] Code of PNRI Regulations (CPR) Part 3, Standards for protection against radiation, Rev.02. Few examples of exempt activities of radionuclides are: $1x10^7$ becquerel of C-14, $1x10^6$ becquerel of F-18, $1x10^5$ becquerel of I-131, $1x10^7$ becquerel of Tc-99m. I-125 used in radioimmunoassay and check sources also fall under notification as described in the criteria of Appendix A. Exemption and Clearance, [DOST-PNRI] CPR Part 3. With these listed activities of the radionuclides, the radiation risks are sufficiently low so that regulatory control would not yield net benefit, no reduction of individual doses or of health risks. Registration as a form of authorization is suitable for sources with low/moderate risks, and license as a form of authorization for facilities and activities with high risks.

Table 3*. Categories of radioactive sources.*

Source Category	Type of Application	Risk when near the source	Possible health effects/ time of exposure
1	Large irradiators, teletherapy sources, gamma knife sources	Extremely dangerous	Permanent injury to death in few minutes to an hour
2	Industrial radiography sources, High/medium dose rate brachytherapy sources	Very dangerous	Permanent injury to death in a period of hours to days
3	High activity source in fixed industrial gauges, well logging sources	Dangerous	Permanent injury, but unlikely to cause death in period of days to weeks
4	Low dose rate brachytherapy sources, low activity industrial gauges	Unlikely to be dangerous	Temporary injury is possible in many weeks of exposure
5	Permanent implant sources, radioimmunoassay sources, electron capture sources, check sources	Most unlikely to be dangerous	No injury

Table 4. *Relative ranking of risks associated with selected facilities and activities (IAEA, 2021).*

Facilities and activities	Level of exposure	Factors specific to radioactive source	Factors specific to facilities and activities	Overall risk
Radiation therapy (Co-60)	high	high	high	high
Gamma knife (Co-60)	moderate/high	high	high	high
High dose rate (HDR) brachytherapy	high	high	high	high
Low dose rate (LDR) brachytherapy	moderate	moderate	high	moderate
Nuclear medicine-therapy	moderate/high	moderate	high	high
Nuclear medicine-diagnosis	moderate	moderate	high	moderate/high
Radioimmunoassay	low	low	low	low
Cyclotron (radioisotope production)	high	high	high	high
Large gamma irradiation	high	high	high	high
Industrial gamma radiography	high	high	high	high
Fixed industrial gauges	low	moderate/high	low	low/moderate
Mobile industrial gauging	moderate	moderate	moderate	moderate
Well logging devices	low	high	moderate	moderate
Radioactive lightning rods	low	low/moderate	low	low
Fluorescence with radioactive sources	low	low	low	low
Calibration check sources	low	low	low	low

D. Graded Approach in Regulatory Requirements

The regulatory requirements that ensure the protection and safety of the people and the environment from the potential hazards from exposure to ionizing radiation from facilities and activities are provided in the Code of PNRI Regulations (CPR). Listed below are some of the PNRI codified parts (PNRI, 2017):

Part 2- Licensing of Radioactive Materials and Facilities
Part 3- Standards for Protection Against Radiation
Part 4- Rules and Regulations on the Safe Transport of Radioactive Material in the Philippines
Part 5- Requirements for Siting of Nuclear Installations
Part 7- Licensing of Nuclear Installations
Part 11- Licensing Requirements for Radiographic Operations in Industrial Radiography
Part 12- Licenses for Medical Use of Radioactive Sources in Teletherapy
Part 13- Licenses for Medical Use of Unsealed Radioactive Material
Part 15- Regulations for the Design and Safe Operation of Gamma Irradiation Facilities
Part 16- Licenses for the Use of Radioactive Sources Contained in Industrial Devices
Part 23- Licensing Requirements for Land Disposal of Radioactive Waste
Part 28- Licensing Requirements for Predisposal Management of Radioactive Waste Facilities and Activities
Part 30- Safety Requirements for Research Reactors

Across these Parts of the Code of PNRI Regulations are administrative and technical requirements to be complied with by applicants and licensees. The requirements become more complex and stringent as the risk ranking of the facility and activity increases. In general, the licensing requirements comprise of the following:

- Description/design specification of radioactive material/device/facility
- Purpose or use of radioactive material/device/facility
- Lay-out/shielding design of facility and location of the radioactive material
- Safety assessment
- Description/specification of radiation protection instruments
- Training and experience of RSO and Asst. RSO and other required technical personnel
- Radiation protection and safety procedures and programs
- Radioactive waste management
- Security measures
- License fees

The regulatory requirements are anchored on the fundamental radiation protection principles of justification, optimization, and dose limits, the primary objectives of which are to prevent deterministic (clinical radiation injury) and to reduce the occurrence of stochastic effect (i.e. cancer) (ICRP 2007, IAEA, 2014, DOST-PNRI, 2021). The dose limits for occupationally exposed workers and the members of the public are summarized in Table 5.

A comparison of the degree of stringency of regulatory requirements of some facilities and activities is shown Table 6.

E. Graded Approach of Radiation Protection and Safety Requirements of Nuclear Installations

Nuclear installations include research reactors (including subcritical and critical assemblies), nuclear power plants, storage facilities for spent fuel, facilities for the enrichment of uranium, nuclear fuel fabrication facilities, conversion facilities, and facilities for the reprocessing of spent fuel. The nuclear installation is characterized in accordance with its level of radiological hazard and whether the nuclear installation poses radiation and nuclear hazard within the building, on-site and surrounding the building, or outside its site boundary. The graded approach of the general requirements for radiation protection and safety of the research reactors (subcritical and critical), and nuclear power which the Philippines has experiences are presented in Table 7.

Table 5. *Dose limits for planned exposure situation.*

	Whole body	**Extremities (hands and feet), skin**	**Lens of the eyes**
Adult workers (above 18 y old)	Effective dose of 20 mSv/y averaged over five consecutive years, 50 mSv in any single year	500 mSv in a year	Equivalent dose of 20 mSv/y averaged over five consecutive years, 50 mSv in any single year
Apprentice 16-18y old)	6 mSv in a year	150 mSv in a year	20 mSv in a year
Public	1 mSv in a year	50 mSv to the skin in a year	15 mSv
Patient comforters and cares	Use of dose constraint to be set by the licensee and approved by the regulatory body to optimize radiation protection and safety		

Table 6. *Comparison of Requirements for Technical Personnel, Radiation Protection and Safety Program, License Validity Period and License Fees of some Facilities and Activities*

Facilities and Activities/Risk Category/CPR	**Required Technical Personnel**	**Education/Specific Training and Experience**	**Source/ Facility/ Shielding**	**Min No. of Radiation Protection and Safety Procedures and Programs**	**License Validity Period (years) /Fee for 1st license (Pesos)**
Fixed level gauges/Low/Part 16	RPO/Asst RPO Authorized operator	24h/practical manufacturer/s training program	Shield in device suffices	11	5/12,500
Field Industrial Radiography/High/ Part 11	RPO/Asst RPO Radiographers Asst. radiographer	2000h hands on training as radiographer/ Formal training in the establishment and maintenance of rad safety program Certified by certifying body or company certified/received radiation safety training Radiation safety training/under direct supervision	Shield in device suffices (Design approved by competent authority)	14	3/16,000
Radioimmunoassay/ low Part 2	RPO/Asst RPO	Appropriate training and experience	Not specified	Not specified	5/8,000
Nuclear Medicine-diagnosis and therapy/High/Part 13	RPO/Asst RPO Authorized user-physician Medical Physicist Nuclear Medicine Technologist	BSc or Eng/200 h/1y PRC/Specialty Board certified; 200 h/2y BSc Phys/200h/1y 200h/6mo BSc allied health courses/PRC Certified/200h/6mo	Adequate source shielding	22	3/25,000
Co-60 HDR brachytherapy/ High/Part 14	RPO/Asst RPO Authorized user-physician MedPhysicist Radiotherapy Technologist	BSc or Eng/200h/3mo PRC/Specialty Board certified physician /200h/3y BSc Phys or Engr/200h/6mo BSc Rad Tech, PRC certified/40h/6mo	Equipment shielding and adequate room shielding	12	3/15,500
Co-60 Teletherapy/high/ Part 12	RPO/Asst RPO Authorized user (physician) Med Physicist Radiotherapy Technologist	BSc or Engr/200h/3mo PRC/Specialty Board certified/200h/3y BSc Phys or Engr/200h/6mo BSc Rad Tech, PRC certified 40h/6mo	Source shielding and adequate room shielding	12	3/15,500
Particle Accelerator (Cyclotron)/High/ Part 23	RPO/Asst RPO Authorized Operator Radiochemist/ radiopharmacist	BSc or Engr PRC certified/200 h/1y BSc or Engr, PRC certified/40 h/6mo BSc Chem, Pharm, Engr PRC certified/40h/6mo	Adequate Facility shielding	17	5/120,000

Table 7. *Graded approach in regulatory requirements of nuclear installations in the Philippines*

Research reactor		Nuclear Power Plant
Philippine Research Reactor-1 Subcritical Assembly for Training, Education and Research (PRR-1 SATER)	Philippine Research Reactor-1	Bataan Nuclear Power Plant
0 power with 44 slightly used PRR-1 fuel rods, started operation in 2023	1 MW TRIGA (Training, Research, Isotopes General Atomics) fuel elements (stopped operation in 1984), upgraded to 3 MW in 1984, reached criticality in 1988 but never operated due to some structural and administrative issues. 71 slightly irradiated fuel in wet storage, 15 fresh-fuel in storage (Astronomo, et. al, 2019)	620 MW (never loaded with fuel), mothballed in 1986, maintained by the National Power Corporation. Designed for: 121 fuel assemblies, 235 fuel rods per assembly (Personal communication from Joe Manalo, National Power Corp, May 2024)
For nuclear-related training, education, and research.	Previously used for training, research, and production of radioisotopes	For power generation
Water moderator also serves as shielding, inherently safe, housed in the PRR-1 containment building.	Water-cooled pool type reactor, thick concrete pool wall for additional shielding within the PRR-1 containment building	Pressurized water reactor (PWR); with several layers of defense in depth
Hazard within the building	Hazard on on-site	Hazard on-site and off-site of the building
Applicable regulatory requirements: CPR Parts 5, 7, 30		CPR Parts 5, 7, vendor country regulatory requirements, and IAEA relevant safety requirements

For nuclear power plants, the regulatory requirements of significant safety areas and their corresponding risk ranking (IAEA, 2021) are tabulated in Table 8. The detailed components of these safety areas are discussed in the IAEA publication on Application of a Graded Approach in Regulating Nuclear Installations.

F. Graded approach in the safe transport of radioactive material

An example of graded approach in the safe transport of radioactive is the application of design requirements of the different types of packages based on the intended radioactive content limitation. The content limits of the packages are based on the basic radionuclide values of A1 (activity value of special form radioactive material i.e. indispersible solid or sealed capsule containing radioactive material) and A2 (activity of radioactive material other than special form) (PNRI, 2017).

The types of packages that are commonly used in the Philippines are:

1**.** *Excepted packages* – can withstand routine conditions or incident free; the radioactive contents are limited to small fractions of the A1 and A2 values.
2. *Type A Packages* – can withstand normal conditions or minor mishaps; contents are limited up to A1 and A2 values.
3. *Type B Packages* – can withstand accident conditions; contents are more than the A1 and A2 values; engineered package designs are approved by competent authority.

Table 8. *Significant safety areas of nuclear power plant and relative weighting factors.*

Safety Areas	Weighting factors (%)
Management System	10
Human Performance Management	10
Operating Performance	12.5
Safety Analysis	7.5
Physical Design	10
Fitness for Service	7.5
Radiation Protection	10
Conventional Health and Safety	2.5
Environmental Protection	5.0
Emergency Preparedness and Fire Protection	7.5
Waste Management	2.5
Security	7.5
Safeguards and Non-proliferation	5.0
Packaging and Transport	2.5

G. Graded approach in the safe disposal of radioactive wastes

At various steps in the predisposal management of radioactive wastes, it is required that the radioactive waste is characterized in terms of its physical, mechanical, chemical, radiological, and biological properties, and is classified from the perspective of its future disposal (PNRI, IAEA, 2009.a). The most common classification of radioactive wastes are as follows (IAEA, 2009.b):

1. *Exempt wastes* - contains such small concentrations of radionuclides that do not require any radiation protection measures and can be cleared from regulatory control.
2. *Very short-lived waste* - contains radionuclides of very short half-life with activity concentrations above the clearance levels. Such waste can be stored until the activity has fallen beneath the levels for clearance, allowing for the cleared waste to be managed as conventional wastes.
3. *Very low-level wastes* - waste that does not necessarily meet the criteria of exempt waste, suitable for disposal in near surface landfill type facilities with limited regulatory control.
4. *Low level waste (LLW)* - waste that is above clearance levels, but with limited amounts of long-lived radionuclides that requires robust isolation and containment for periods of up to a few hundred years and is suitable for disposal in engineered near surface facilities.
5. *Intermediate level waste (ILW)* - waste that contain long-lived radionuclides, requires a greater degree of containment and isolation than that provided by near surface disposal; requires disposal at greater depths, of the order of tens of meters to a few hundred meters.
6. *High level waste (HLW)* - waste with high levels of activity concentration high enough to generate significant quantities of heat by the radioactive decay process or waste with large amounts of long-lived radionuclides that need to be considered in the design of a disposal facility. Disposal is required in deep, stable geological

formations usually several hundred meters or more below the surface of the ground.

The regulatory requirements for disposal become more stringent as the level of radioactivity of the radionuclide increases and the half-life is longer.

The radioactive wastes in the Philippines are mostly from medical and industrial uses. The very short-lived wastes from medical uses are stored to decay and disposed of as conventional wastes. The disused sealed sources from medical and industrial uses are either returned to the supplier abroad or are transferred to the PNRI waste management facility for proper predisposal management. The Philippines has no final disposal facility for radioactive wastes.

SUMMARY

The level of risks associated with facilities and activities involving radioactive material vary from very low to very high depending on the activity and characteristics of the radioactive material, the purpose of use, complexity of operations, and some other factors. Correspondingly, the regulatory requirements for radiation protection and safety become stringent as the risk increases. The competence of the licensees' staff to comply with the regulatory requirement and implement the radiation protection and safety programs is important. Also important is the competence of the regulatory staff to apply the graded approach in the regulation of the facilities and activities according to their level of risks. The regulatory requirements for nuclear power plants are the most stringent and there are safety areas with relatively high weighting factors that must be given due attention by both licensees and regulators.

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AN EXPERIMENTAL DETERMINATION OF SOME PHYSICAL PROPERTIES OF SEAWATER SAMPLES IN SEVEN SOUTHERN COASTAL TOWNS OF NEGROS ORIENTAL

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ABSTRACT

The study aimed to determine seven physical properties of seawater samples from seven southern coastal towns of Negros Oriental; namely, Poblacion and San Miguel of Bacong, Poblacion and Masaplod of Dauin, Poblacion and Dumandan of Zamboanguita, Poblacion of Siaton, Poblacion of Sta. Catalina, Poblacion of Bayawan, and Poblacion of Basay. The seawater samples were taken twenty (20) meters away from the shoreline. The properties were Density, Surface Tension, Specific Heat, Boiling Point, Conductance, Coefficient of Volume Expansion, and Index of Refraction. The seawater's index of refraction ranges from 1.34 to 1.36. The result of seawater's density ranges from 1.00 g/cm3 to 1.01 g/cm3. Boiling point of the seawater samples ranges from 96.16 °C to 96.83°C. The surface tension of seawater ranges from 74.19 dynes /cm to 76.80 dynes /cm. The seawater's specific heat capacity ranges from 0.93 cal/gC° to 0.96 cal/gC° and actually lower than the specific heat capacity of distilled water (1 cal/gC°). The coefficient of volume expansion ranges from 354.53 (1 x 10-6 /C°) to 376.47 (1 x 10-6 /C°). Distilled water has lower coefficient of volume expansion compared to seawater samples. The result for seawater samples' conductance was 0.05 S.

STATEMENT OF THE PROBLEM

This study aimed to determine some physical properties of seawater samples from seven southern coastal towns of Negros Oriental. Specifically, the study aimed:

1. to construct inexpensive and simple apparatus; namely,
   a. Double–walled Calorimeter (Specific Heat)
   b. Conductance Meter (Conductance)
   c. Volume Expansion Apparatus (Coefficient of Volume Expansion)
2. to collect seawater samples from seven southern coastal towns of Negros Oriental; namely, Poblacion and San Miguel of Bacong, Poblacion and Masaplod of Dauin, Poblacion and Dumandan of Zamboangita, Poblacion of Siaton, Poblacion of Sta. Catalina, Poblacion of Bayawan, and Poblacion of Basay.
3. to determine for each sample, the values of the following properties at room temperature:

a. Density
b. Surface Tension
c. Specific Heat
d. Boiling Point
e. Conductance
f. Coefficient of Volume Expansion
g. Index of Refraction

REVIEW OF LITERATURE

Dales (2014) studied some physical properties of hot spring water from four areas of Valencia, Negros Oriental, namely, Barangay Puhagan – Sitio Sogongon; Barangay Caidiocan – Sitio Ticala; Barangay Caidiocan – Sitio Mag-aso; and Barangay Palinpinon II – Depot. The researcher constructed an inexpensive apparatus out of recyclable materials. These were the calorimeter, conductance meter, and volume expansion apparatus. The density was measured using a graduated cylinder and a digital weighing scale - dividing the mass by the volume. For the boiling point, the researcher used a mercury thermometer for the temperature while it was boiling. For the index of refraction, the researcher used the apparent depth formula.

The researcher suspected that the hot spring water samples could have other chemical properties and contain other substances that cause impediments to the water due to inconsistent ambient temperature, measuring factors, the gathering method, and the way of using the water samples. The error might occur when using the sample after shaking it. Thus, data provides a sneak peek at the qualities that are useful in people's daily lives and assists them in learning about the various hot springs in the area.

Maxino and Sanchez (2011) conducted an experimental study on measuring the salinity of seawater in four municipalities of southern Siquijor Island. In measuring the salinity of the samples, each was subjected to the following methods: Total Dissolved Salts and Electrical Conductivity. On the first method (Total Dissolved Salt), Barangay Lalao, San Juan got the highest salinity of 66.12 ± 0.2 gm/L as well as in method 2 (Measuring Electrical Conductivity) with the highest conductance of 0.31 ± 0.019 S/m, while Paliton, San Juan got the lowest salinity in both methods with 28.13 ± 0.2 gm/L and a conductance of 0.2 ± 0.016 S/M respectively.

Maxino and Baseleres (1996 – 1997) studied density, rate of flow, specific heat, surface tension and viscosity. Researchers used a Cenco Tensiometer to measure the surface tension in their study. The instrument allows a platinum ring to be submerged into the liquid of interest and measured the amount of tension needed to rupture the surface and the pull off the ring. Cooking oil can be distinguished from other liquids by their physical characteristics, according to research findings, but different types of cooking oil and brands cannot be distinguished from one another.

METHODOLOGY

The seawater samples used in this study were taken from the seven southern coastal towns of Negros Oriental; namely,

Poblacion and San Miguel of Bacong, Poblacion and Masaplod of Dauin, Poblacion and Dumandan of Zamboanguita, Poblacion of Siaton, Poblacion of Sta. Catalina, Poblacion of Bayawan, and Poblacion of Basay.

Gathering the samples

The seawater samples were taken twenty (20) meters away from the shoreline. In every sampling site, the researcher got three liters.

The Apparatus

Construction of the Double-walled Calorimeter Apparatus

The researcher constructed a Calorimeter Apparatus using inexpensive and recyclable materials in measuring the specific heat of a substance. It is a double-walled calorimeter to make sure that transfer of heat from and to the surroundings are minimized.

Materials:

- cylindrical plastic container (d =10.5cm; h = 14.5cm)
- circular wooden slab (d =10.5cm; t=1.5cm)
- Epoxy
- 1 soft drink aluminum can (d =5cm; h =11.5cm)
- Thermometer
- rubber mat1 (d = 10.5cm; t =1.5cm)
- rubber mat2 (d=5cm; t=1cm)
- ply wood (d = 13cm; h =0.4cm)

For the cover, the rubber mat1 was put on the plywood. The rubber mat2 was placed at the center of rubber mat1. Holes were made for the thermometer and stirrer at the center part of the cover.

For the inner vessel, the soft drink aluminum can be used.

For the outer vessel, the plastic cylindrical container was used. For the stand, the circular wooden slab was used with insulation foam and a rubber mat design.

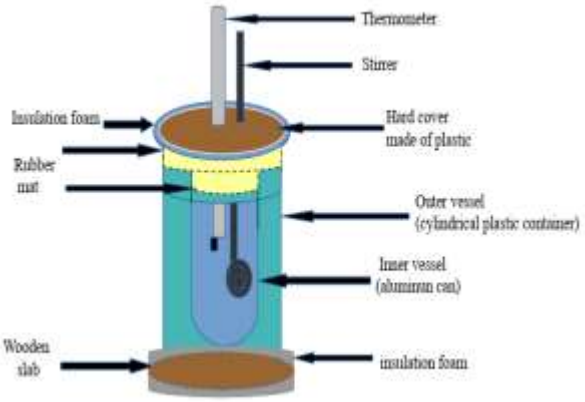


Figure 4.3-1 *The Double-walled Calorimeter Apparatus.*

Testing the Double-walled Calorimeter Apparatus

To determine the latent heat of fusion of ice, the researcher used the following equation:

$$L_f = \frac{m_{IV}C_{IV}(T_i - T_f) + m_{ST}C_{ST}(T_i - T_f) + m_w C_w (T_i - T_f) - m_I c_w (T_f - 0)}{m_I}$$

m_{IV} - mass of inner vessel
m_{ST} - mass of stirrer
m_W - mass of distilled water
m_I - mass of ice
T_i - initial temperature of inner calorimeter, stirrer and water
T_f - final temperature of the mixture

c_{IN} - specific heat of inner calorimeter (aluminum can) = 0.22 cal/g C°
c_{ST} - specific heat of stirrer (made of iron) = 0.11 cal/g C°
c_W - specific heat of water = 1cal/g C°
L_f - latent heat fusion of ice

For its accuracy, percent error was calculated using the formula:

$$\% e = (| T_v - E_v |) / T_v) \times 100\%$$

where,

T_v - Theoretical value of the latent heat of fusion of ice = 80 cal/g
E_v - Experimental value of the latent heat of fusion of ice (value obtained in the experiment)
% e - Percent error (at least ten percent)

For its reliability, standard deviation will be calculated. The researcher used the formula:

$$\sigma = \sqrt{x}$$

$$x = \frac{\Sigma |X_{seawater} - X_{average}|^2}{N}$$

where,
x = variance
N = no. of trials

To test the functionality of the apparatus, the researcher used distilled water as the subject of the experiment.

Construction of the Conductance Meter Apparatus

The conductance meter was made up of plywood with an attached battery holder. The holder could hold three D-size batteries. A positive wire was connected to the positive probe of the multimeter using an alligator clip. One electrode was connected to the negative wire while the other to the negative probe.

Materials:

- plywood (l =20.30cm; w =4.40cm; h =2.50cm)
- wire (l =19.30cm)
- three batteries (size D)
- digital multimeter
- two copper rings
- alligator clips
- metal strips (l =5.4cm; w =0.8cm)
- glass container

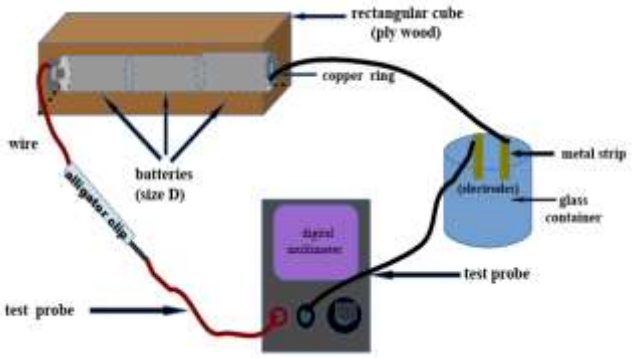


Figure 4.3-2 *The Conductance Meter Apparatus.*

Testing the Conductance Meter Apparatus

For its reliability, standard deviation will be calculated. The researcher used the formula:

$$\sigma = \sqrt{x}$$

$$x = \frac{\Sigma |X_{seawater} - X_{average}|^2}{N}$$

where,
x = variance
N = no. of trials

To test the functionality of the apparatus, the researcher used distilled water as the subject of the experiment.

Construction of the Volume Expansion Apparatus

The researcher constructed a simple volume expansion apparatus.

Materials:

- thermometer
- rubber cap (d =5cm; t = 1cm)
- stop juice straw (d = 0.25cm; l = 13.5cm)
- aluminum can (d = 5.2cm; h =12.8cm)
- wooden cover (s = 8.5cm)
- tape measure

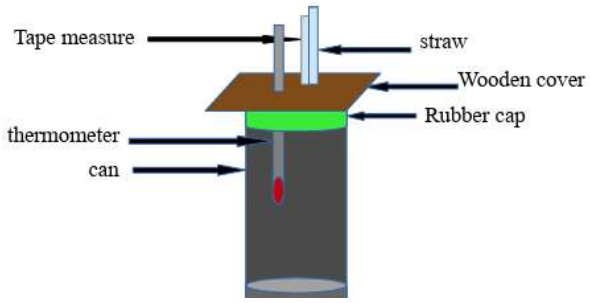


Figure 4.3-3 *The Volume Expansion Apparatus.*

Testing the Volume Expansion Apparatus

For its reliability, standard deviation will be calculated. The researcher used the formula:

$$\sigma = \sqrt{x}$$

$$x = \frac{\Sigma \left| X_{seawater} - X_{average} \right|^2}{N}$$

where,

x = variance

N = no. of trials

To test the functionality of the apparatus, the researcher used distilled water as the subject of the experiment.

The Experiment

Specific Heat Capacity

The constructed calorimeter was used to determine the specific heat capacity of the seawater samples. In getting the mass of the substances, a digital weighing scale was used.

Materials:

- Double-walled Calorimeter Apparatus
- blocks of ice
- 2 thermometers
- seawater sample
- aluminum can (d=5.7cm; h=11cm)
- digital weighing scale
- plastic cylindrical container (d=13.3cm; h=14.5cm)
- distilled water (Absolute)

Procedure:

1. All the materials needed were prepared.
2. The calorimeter's inner vessel (soft drink aluminum can) and stirrer were weighed individually.
3. An amount of distilled water was poured into the inner vessel and weighed together.
4. The mass of distilled water was computed by subracting the $mass_{inner\ vessel}$ from $mass_{distilled\ and\ inner\ vessel}$.
5. The inner vessel with water was placed in the outer vessel and covered properly.
6. Using the calorimeter's thermometer, the initial temperature was noted.
7. The aluminum can was weighed.
8. An amount of seawater sample was poured into the aluminum can and weighed together.

9. The mass of seawater was computed by subtracting the $mass_{aluminum\ can}$ from the $mass_{seawater\ and\ aluminum\ can}$
10. The aluminum cup was partially submerged with seawater in a container filled with water and ice.
11. When the seawater was cold, the initial temperature was noted.
12. After getting the initial temperature, the seawater sample was poured quickly into the distilled water inside the calorimeter and then covered properly.
13. Using the calorimeter's thermometer, the final temperature of the mixture was noted.
14. The specific heat capacity was computed using the formula:

$$c_{SW} = \frac{m_{DW} c_{DW} (T_0 - T_f)_{DW} + m_{IV} c_{IV} (T_0 - T_f)_{IV} + m_{ST} c_{ST} (T_0 - T_f)_{ST}}{m_{SW} (T_f - T_0)_{SW}}$$

where,
DW = Distilled water
IV = Inner vessel
ST = Stirrer
SW = Seawater

Conductance

The conductance meter was used to obtain the electrical conductivity of seawater samples.

Materials:

- Conductance Meter Apparatus
- glass container
- seawater sample

Procedure:

1. The materials were prepared.
2. An amount of seawater was poured into the glass container.
3. The electrodes were dipped into the seawater sample (250ml) in the glass.
4. The current and voltage were noted using the digital multimeter.
5. The resistance was computed using the relationship resistance = voltage / current.
6. Using the computed resistance, the conductance was computed using the formula: conductance = 1 / resistance or C = 1 / R.
7. The same procedure was done for each sample.

Coefficient of Volume Expansion

The volume expansion apparatus was used to determine the coefficient of volume expansion of seawater samples. In heating the sample, the heater was used.

Materials:

- Volume Expansion Apparatus
- seawater sample
- electric heater

Procedure:

1. The can was filled fully with seawater.
2. The volume of seawater was calculated using the formula:

$$V = \pi r^2 h$$

where,
r = radius (diameter /2)
h = height of the aluminum can

3. Can was heated and the rise in temperature was noted reading the thermometer inserted into the hole of the cap.
4. When the temperature raised by 1 °C, the height of the water in the straw was determined.
5. The change in volume expansion was computed using the formula:

$$\beta = \frac{\Delta V}{V_o \Delta T}$$

where,

ΔV = change in volume
$[\Pi (r_{straw})^2 (h_f - h_i)]$
V_o = original volume ($\Pi r_{can}^2 h$)
ΔT = change in temperature ($T_f - T_i$)

6. The same procedure was done until ten trials.

Boiling Point

The electric heater was used to boil the seawater sample. In measuring the temperature, the thermometer was used.

Materials:

- electric heater
- thermometer
- seawater sample

Procedure:

1. The materials were prepared.
2. An amount of seawater sample was poured into the heater.
3. The electric heater was plugged to boil the seawater.
4. While the sample is boiling, the thermometer was dipped into the seawater sample and the temperature was noted.
5. The thermometer was removed from the sample and waited until minimum temperature was attained.
6. To attain ten (10) trials, procedures 4 and 5 were repeated.

Density

In getting the density, the graduated cylinder was used to measure the volume of seawater sample. The digital weighing scale was used to get the mass of the sample.

Materials:

- graduated cylinder
- digital weighing scale
- seawater sample

Procedure:

1. The materials were prepared.
2. The graduated cylinder was weighed.
3. An amount of seawater sample was poured into the graduated cylinder and the volume was noted.
4. The seawater in the graduated cylinder was weighed.
5. The mass of seawater was computed by the formula:

$$m_{SW} = (m_{SW} + m_{GC}) - m_{GC}$$

where,

m_{SW} = mass of seawater
$(m_{SW} + m_{GC})$ = mass of seawater and graduated cylindrical
m_{GC} = mass of graduated cylinder

6. The density was computed by dividing the mass (g) by volume (cm^3) or $\rho = m / V$.
7. To attain ten (10) trials procedure 3 to 6 were repeated.

Index of Refraction

Materials:

- seawater sample
- coin
- transparent glass container
- ruler
- bamboo stick
- card board

Procedure:

1. An amount of seawater sample was poured into the glass container.
2. The coin was dropped into the glass.
3. The height was measured from the bottom of the glass to the water level using a ruler.
4. The bamboo stick was measured similar from the height measured in procedure 3, and then was cut.
5. The cut bamboo stick was dipped into the seawater sample.
6. The cut bamboo stick was used in measuring the actual depth by marking the level of the stick that was wet. The unwet part was the change of height (ΔH).
7. For the apparent depth, an eye was focused to the water locating the position of coin and then it was marked. The height from the bottom of the glass to the marked point on the glass was measured. Then the apparent depth was computed by the formula:

apparent depth = actual depth – [(measured height in procedure 7) - ΔH].

8. The seawater's index of refraction was calculated using the formula:

$$n_1 = \frac{n_2(d)}{d'}$$

where
n_1 = index of refraction ($n_{seawater}$)
n_2 = index of refraction (n_{air})
d = actual depth
d' = apparent depth

9. A small amount of seawater was added into the glass. Then the procedure 3, 7, and 8 was repeated to attain ten (10) trials. Adding or reducing an amount of seawater were both applicable.

Surface Tension

Materials:

- Optico – Capillary Tensiometer
- Ruler
- Protractor
- seawater sample
- bottle

Procedure:

1. All the materials were prepared.
2. To find the radius of the capillary tube, the radius was measured.
3. An amount of seawater was poured into the bottle.
4. The bottle was placed between the lens and light source of optico – capillary tensiometer.
5. The capillary tube was then being inserted into the bottle. It could be noticed that seawater gets inside the tube.
6. The lens was moved back and forth until sharp image formed on the screen.
7. Using the image formed, a diagonal line along the curve surface was drawn. Then the angle was measured.
8. The height of the displaced water will be calculated by subtracting the height of the water in the tube from the height of the capillary tube.

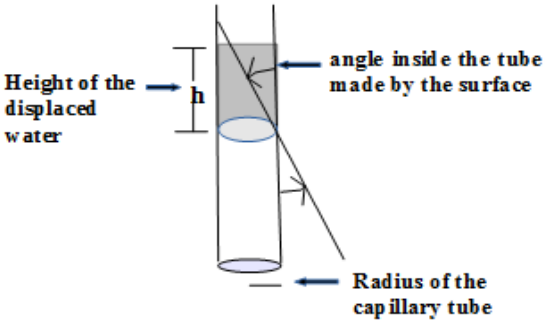
9. Using the optical method, the surface tension was calculated by the formula:

$$T = \frac{h\rho r g}{2\ cos\theta}$$

where,

T – is the surface tension
ρ – density of the water
g – acceleration due to gravity (980 cm/s^2)
r – radius of the tip of the capillary tube
h – height of the displaced water
θ – angle inside the tube made by the surface of the water touching the capillary wall.

It was noted that when the angle is greater than 90°, the cosine was negative and the liquid went down in the tube. When the liquid failed to wet the tube, it descended.



RESULTS AND DISCUSSION

This section discussed the results of measuring the seven physical properties of seawater samples. Table 5.1k showed the data for the seawater samples' index of refractions. Table 5.2k showed the results for the seawater samples' densities. Table 5.3 showed the data for the distilled water and seawater samples' boiling points. Table 5.4k showed the data for the seawater samples' surface tensions. Table 5.5h showed the data obtained for the conductance of the seawater samples. Table 5.6k showed the results for the seawater samples specific heat. Table 5.7k displayed the results for the seawater samples' coefficient of volume expansions. Table 5.8 showed the average values of all seawater samples for the seven (7) physical properties. Sample computations in getting the seven physical properties of seawater samples were presented below.

Index of Refraction

Room Temperature: 29 °C

Table 5.1k *Index of Refraction of Seawater from Poblacion, Basay.*

Trial	$n_{2\ (air)}$	Actual Depth (cm)	Apparent Depth (cm)	Index of Refraction n_1 (seawater)
1	1.00	7.40	5.30	1.39
2	1.00	10.20	7.60	1.34
3	1.00	6.80	4.90	1.38
4	1.00	7.90	5.80	1.36
5	1.00	8.90	6.60	1.34
6	1.00	10.50	8.00	1.31
7	1.00	10.90	8.00	1.36
8	1.00	11.40	8.50	1.34
9	1.00	11.70	8.90	1.31
10	1.00	8.20	6.00	1.37
			Average:	1.35

Variance = 0.00066
Standard Deviation = 0.026

Sample Computation:

$$n_1 = \frac{n_2(actual\ depth)}{apparent\ depth}$$

$$n_1 = \frac{1.00(8.20\ cm)}{6.00\ cm}$$

$$n_1 = 1.37$$

Seawater's Index of Refraction

Trial 10:

Actual Depth = 8.20cm

Apparent depth = actual depth – [(height from the bottom of the glass to the marked point) - ΔH]

= 8.20cm – (3.2cm - 1cm)
Apparent depth = 6.00cm

Calculation for Variance:

$$x = \frac{\Sigma\,|n_{seawater} - n_{average}|^2}{N}$$

$\sigma^2 = \Sigma\,(n_{seawater} - n_{average})^2 / N$
$\sigma^2 = [(1.39 - 1.35)^2 + (1.34 - 1.35)^2 + (1.38 - 1.35)^2 + (1.36 - 1.35)^2 + (1.34 - 1.35)^2 + (1.31 - 1.35)^2 + (1.36 - 1.35)^2 + (1.34 - 1.35)^2 + (1.31 - 1.35)^2 + (1.37 - 1.35)^2] /10$
$\sigma^2 = 0.00066$

Calculation for Standard Deviation:
$\sigma = \sqrt{x}$
$\sigma = 0.026$

Four seawater samples from Poblacion, Bacong; Poblacion, Zamboanguita; Poblacion, Bayawan; and Poblacion, Basay have equal results which is 1.35. Two other samples from Poblacion, Siaton and Poblacion, Sta. Catalina have 1.34 index of refraction. The three samples from San Miguel, Bacong; Masaplod, Dauin; and Dumandan, Zamboanguita have 1.34 index of refraction. From the results, seawater's index of refraction ranges from 1.34 to 1.36. The distilled water has 1.31 which is lower than the index of refraction of seawater samples.

The calculated variance and standard for each table have small differences. The smallest variance is 0.00025 from Dumandan, Zamboanguita with a standard deviation of 0.016. The highest variance is 0.00066 from Poblacion, Basay with a standard deviation of 0.026.

Density
Room Temperature: 30 ºC

Table 5.2k *Density of Seawater from Poblacion, Basay.*

Trial	mass (g)	Vol (cm^3)	Density p (g/ cm^3)
1	53.40	53.00	1.01
2	73.50	73.10	1.01
3	90.60	90.20	1.00
4	80.40	80.00	1.01
5	88.30	88.00	1.00
6	43.00	42.80	1.00
7	40.50	40.10	1.00
8	50.80	50.20	1.01
9	90.10	89.80	1.00
10	60.30	60.00	1.01
		Average:	1.01

Variance = 0.0001
Standard Deviation = 0.003

Sample Computation:

$m_{cylinder + water} - m_{cylinder} = m_{water}$
192.60 g – 132.3g = 60.30g

Conversion: $1cm^3 = 1ml$

v_{water} = 60ml or $60cm^3$

Trial 10:

ρ = mass / vol
ρ = 60.30g / 60.00 cm^3

$\rho = 1.01\ g / cm^3$

Seawater's Density

Calculation for Variance:

$$x = \frac{\Sigma \mid \rho_{seawater} - \rho_{average} \mid^2}{N}$$

$\sigma^2 = \Sigma (\rho_{seawater} - \rho_{average})^2 / N$

$\sigma^2 = [(1.01 - 1.01)^2 + (1.01 - 1.01)^2 + (1.00 - 1.01)^2 + (1.01 - 1.01)^2 + (1.00 - 1.01)^2 + (1.00 - 1.01)^2 + (1.00 - 1.01)^2 + (1.01 - 1.01)^2 + (1.00 - 1.01)^2 + (1.01 - 1.01)^2] /10$

$\sigma^2 = 0.00001$

Calculation for Standard Deviation:

$\sigma = \sqrt{x}$

$\sigma = 0.003$

Poblacion, Bacong; Poblacion, Dauin; Poblacion, Basay; San Miguel, Bacong; Masaplod, Dauin; and Dumandan, Zamboanguita have similar density values which is 1.01 g /cm^3. Poblacion, Zamboanguita; Poblacion, Siaton; Poblacion, Sta. Catalina; and Poblacion, Bayawan have also similar values which is 1.00 g /cm^3. The density values of all the seawater samples are very close to each other. From the results gathered, density ranges from 1.00 g /cm^3 to 1.01 g /cm^3. The distilled water has 0.99 g /cm^3 which is lower than the density values of the seawater samples.

The calculated variance and standard deviation show results that are close to each other. The smallest variance is 0.00001 from Poblacion, Basay with a standard deviation of 0.003. The highest variance is 0.00004 from Poblacion, Siaton); Poblacion, Sta. Catalina; and Poblacion, Bayawan with their standard deviations of 0.006.

Boiling Point

Table 5.3 *Boiling Point of the Liquid Samples.*

Room Temperature	**29°C**	**28.5°C**	**29°C**	**28.5°C**	**29°C**	**28°C**	**29°C**	**28°C**	**29°C**	**28.5°C**	**28°C**
Trial	**Distilled Water**	**Poblacion, Bacong**	**San Miguel, Bacong**	**Poblacion, Dauin**	**Masaplod, Dauin**	**Poblacion, Zamboaguita**	**Dumandan, Zamboanguita**	**Poblacion, Siaton**	**Poblacion, Sta. Catalina**	**Poblacion, Bayawan**	**Poblacion, Basay**
1	94.30	96.50	96.10	96.50	96.50	96.50	96.30	96.50	97.00	96.50	96.30
2	94.00	96.50	96.50	96.50	96.50	96.30	96.10	96.80	97.00	96.50	96.30
3	94.00	96.50	96.50	96.50	96.50	96.00	96.10	96.30	97.00	96.50	96.30
4	94.00	96.50	96.40	96.30	96.30	96.10	96.50	96.30	96.80	96.10	96.30
5	94.30	96.50	96.10	96.50	96.70	96.10	96.50	96.30	96.80	96.10	96.30

6	94.50	96.50	96.10	96.30	96.50	96.30	96.50	96.10	96.80	96.60	96.30
7	94.50	96.10	96.10	96.30	96.50	96.10	96.10	96.00	96.80	96.60	96.10
8	94.70	96.10	96.50	96.30	96.30	96.10	96.30	96.50	96.80	95.90	96.10
9	94.70	96.10	96.50	96.30	96.10	96.00	95.90	96.30	96.80	95.90	96.10
10	94.50	96.10	96.30	96.30	96.50	96.10	96.10	96.10	96.50	95.90	96.10
Average:	**94.35**	**96.34**	**96.31**	**96.38**	**96.44**	**96.16**	**96.24**	**96.32**	**96.83**	**96.26**	**96.22**
Variance	0.07	0.038	0.033	0.01	0.024	0.02	0.072	0.05	0.02	0.008	0.01
Standard Deviation	0.26	0.196	0.181	0.098	0.156	0.15	0.269	0.223	0.142	0.092	0.098

Calculation for Variance:

$$x = \frac{\Sigma\,|BP_{seawater} - BP_{average}|^{2}}{N}$$

$\sigma^2 = \Sigma\,(BP_{seawater} - BP_{average})^2 / N$

$\sigma^2 = [(96.30 - 96.22)^2 + (96.30 - 96.22)^2 + (96.30 - 96.22)^2 + (96.30 - 96.22)^2 + (96.30 - 96.22)^2 + (96.30 - 96.22)^2 + (96.10 - 96.22)^2 + (96.10 - 96.22)^2 + (96.10 - 96.22)^2 + (96.10 - 96.22)^2] / 10$

$\sigma^2 = 0.010$

Calculation for Standard Deviation:

$\sigma = \sqrt{x}$

$\sigma = 0.098$

Among all the seawater samples, Poblacion, Sta. Catalina has the highest boiling point of 96.83 ºC. The lowest was Poblacion, Zamboanguita that has 96.16 ºC. Ranking from highest to lowest, Poblacion, Sta. Catalina - 96.83 ºC got the highest and then Masaplod, Dauin – 96.44ºC, Poblacion, Dauin - 96.38 ºC, Poblacion, Bacong - 96.34 ºC, San Miguel, Bacong – 96.31ºC, Poblacion, Bayawan – 96.26ºC, Poblacion, Basay - 96.22 ºC, Dumandan, Zamboanguita has 96.24ºC and lastly got the smallest value is Poblacion, Zamboanguita - 96.16 ºC. From the results, boiling point ranges from 96.04 ºC to 96.83 ºC. Distilled water has 94.35 ºC which is the lowest boiling point compare to the values of seawater samples.

The calculated variance and standard deviation show results that are not so close to each other. The smallest variance calculated is 0.008 Poblacion, Bayawan with a standard deviation of 0.092. The highest variance is 0.072 from Dumandan, Zamboanguita with a standard deviation of 0.269.

Surface Tension
Room Temperature: 28 ºC

Table 5.4k *Surface Tension of Seawater from Poblacion, Basay.*

Trial	h (cm)	Angle (degree)	Surface Tension (dynes/cm)
1	0.50	57.00	77.92
2	0.50	54.50	74.57
3	0.50	57.50	80.60
4	0.50	56.80	79.08
5	0.50	55.50	76.45
6	0.52	54.80	78.13
7	0.50	54.00	73.67
8	0.50	56.00	77.44
9	0.55	52.00	77.37
10	0.50	53.50	72.80
		Average:	**76.80**

Variance = 5.43
Standard Deviation = 2.33

Sample Computation:

$$T = \frac{h\rho r g}{2cos\theta}$$

$$T = \frac{(0.50)(0.175)(1.01)(980)}{2\cos(54.50)}$$

$$T = 74.57\ dynes/cm$$

Seawater's Surface Tension

Trial 10:

g = 980 cm/s^2
ρ = 1.01 g/cm^3
r = 0.175 cm
h = 0.50 cm
θ = 53.50°

Calculation for Variance:

$$x = \frac{\Sigma\ |T_{seawater} - T_{average}\ |^2}{N}$$

$\sigma^2 = \Sigma\ (T_{seawater} - T_{average})^2\ /N$
$\sigma^2 = [(77.92 - 76.80)^2 + (74.57 - 76.80)^2 + (80.60 - 76.80)^2 + (79.08 - 76.80)^2 + (76.45 - 76.80)^2 + (78.13 - 76.80)^2 + (73.67 - 76.80)^2 + (77.44 - 76.80)^2 + (77.37 - 76.80)^2 + (72.80 - 76.80)^2]\ /10$
$\sigma^2 = 5.43$

Calculation for Standard Deviation:

$\sigma = \sqrt{x}$
$\sigma = 2.33$

From the results, no seawater samples have the same values of surface tension. Ranging from 74.37 dynes/cm to 76.80 dynes/cm. San Miguel, Bacong – 74.19 dynes/cm; Poblacion, Bacong -74.37 dynes/cm; Poblacion, Siaton – 74.59 dynes/cm; Masaplod, Dauin – 74.60 dynes/cm; Poblacion, Zamboanguita – 74.99 dynes/cm; Dumandan, Zamboanguita – 75.37 dynes/cm; Poblacion, Dauin – 75.44 dynes/cm; Poblacion, Bayawan – 75.81 dynes/cm; Poblacion, Sta. Catalina – 76.22 dynes/cm; and Poblacion, Basay – 76.80 dynes/cm. The distilled water has 72.35 dynes /cm.

The calculated variance and standard deviation show how close were the values for each table. From the results, the smallest variance is 4.69 from Poblacion, Bacong with a standard deviation of 2.17. The highest variance is 11.46 from Poblacion, Siaton with a standard deviation of 3.39.

Conductance

Room Temperature: 28 ºC

Table 5.5.h *Conductance of Seawater from Poblacion, Basay.*

Trial	Voltage (V)	Current (A)	Resistance (Ω)	Conductance (S)
1	4.43	0.2400	18.4583	0.05
2	4.43	0.2400	18.4583	0.05
3	4.43	0.2300	19.2609	0.05
4	4.42	0.2300	19.2174	0.05
5	4.40	0.2200	20.0000	0.05
6	4.41	0.2300	19.1739	0.05
7	4.40	0.2200	20.0000	0.05
8	4.40	0.2200	20.0000	0.05
9	4.40	0.2100	20.9524	0.05
10	4.40	0.2200	20.0000	0.05
			Average:	**0.05**

Variance = 0

Standard Deviation = 0

Sample Computation:

$$V = IR$$

$$R = \frac{V}{I} = \frac{4.40\ V}{0.2200\ A}$$

$$R = 20.00\ \Omega$$

$$C = \frac{1}{R}$$

$$C = \frac{1}{20.00\ \Omega}$$

$$C = 0.0512\ \text{S}$$

Seawater's Conductance

Calculation for Variance:

$$x = \frac{\Sigma\ |C_{seawater} - C_{average}|^{\ 2}}{N}$$

$\sigma^2 = \Sigma\ (C_{seawater} - C_{average})^2 / N$

$\sigma^2 = [(0.05 - 0.05)^2 + (0.05 - 0.05)^2 + (0.05 - 0.05)^2 + (0.05 - 0.05)^2 + (0.05 - 0.05)^2 + (0.05 - 0.05)^2 + (0.05 - 0.05)^2 + (0.05 - 0.05)^2 + (0.05 - 0.05)^2 + (0.05 - 0.05)^2] /10$

$\sigma^2 = 0$

Calculation for Standard Deviation:

$\sigma = \sqrt{x}$

$\sigma = 0$

The values for conductance are very close to each other. All seawater samples such Poblacion, Bacong; San Miguel, Bacong; Poblacion, Dauin; Masaplod, Dauin; Poblacion, Zamboanguita; Dumandan, Zamboanguita; Poblacion, Siaton; Poblacion, Sta. Catalina; Poblacion, Bayawan; and Poblacion, Basay have the same conductance of 0.05 S. As you can see, distilled water has 5.52 (1 x10 $^{-6}$) S conductance.

The calculated variance and standard deviation display values for conductance that are close to each other. The variance of zero for three samples such Poblacion, Siaton; Poblacion, Sta. Catalina; and Poblacion, Basay is the smallest value with a standard deviation of zero. The highest variance is from Poblacion, Bacong that has 0.00007 with a standard deviation of 0.008.

Specific Heat
Room Temperature: 29.50 ºC

Table 5.6.k *Specific Heat of Seawater from Poblacion, Basay*

Trial	m_{DW} (gram)	m_{SW} (gram)	m_{ST} (gram)	m_{IV} (gram)	$\Delta T_{(DW,IV, \&ST)}$ (C°)	ΔT_{SW} (C°)	Specific Heat c (cal/gC°)
1	88.40	39.30	3.20	12.60	4.50	10.50	1.00
2	85.30	41.20	3.20	12.60	4.70	10.30	0.98
3	57.50	30.10	3.20	12.60	4.30	9.00	0.96
4	84.30	42.20	3.20	12.60	4.50	10.50	0.89
5	68.10	32.30	3.20	12.60	4.50	10.50	0.95
6	81.10	38.40	3.20	12.60	4.00	10.00	0.88
7	89.60	39.40	3.20	12.60	4.50	10.50	1.01
8	82.90	41.70	3.20	12.60	4.50	9.50	0.98
9	76.40	38.60	3.20	12.60	4.40	9.10	0.95
10	94.30	46.70	3.20	12.60	4.70	10.30	0.95
						Average:	**0.96**

Variance = 0.0020 Standard Deviation = 0.04

Sample Computation:

$$c_{sw} = \frac{mc(T_o - T_f)_{DW} + mc(T_o - T_f)_{inner\ vessel} + mc(T_o - T_f)_{ST}}{m(T_f - T_o)_{SW}}$$

Trial 1:

$$c_{sw} = \frac{(94.30)(1)(4.50) + (12.60)(0.22)(4.50) + (3.20)(0.11)(4.50)}{(46.70)(10.50}$$

$$c_{sw} = 1.00$$

Seawater's Specific Heat

Calculation for Variance:

$$x = \frac{\Sigma\ |c_{seawater} - c_{average}|^2}{N}$$

$\sigma^2 = \Sigma\ (c_{seawater} - c_{average})^2 / N$

$\sigma^2 = [(1.00 - 0.96)^2 + (0.98 - 0.96)^2 + (0.96 - 0.96)^2 + (0.89 - 0.96)^2 + (0.95 - 0.96)^2 + (0.88 - 0.96)^2 + (1.01 - 0.96)^2 + (0.98 - 0.96)^2 + (1.02 - 0.96)^2 + (0.95 - 0.96)^2] / 10$

$\sigma^2 = 0.0020$

Calculation for Standard Deviation: $\sigma = \sqrt{x}$

$\sigma = 0.04$

The specific heat capacity of seawater samples is lower than the specific heat of distilled water (1 cal/gC°). Ranking all the average values for seawater's specific heat from highest to lowest; we have Poblacion, Basay – 0.96 cal/gC°; Poblacion, Bayawan – 0.95 cal/gC°; Poblacion, Sta. Catalina – 0.95 cal/gC°; San Miguel, Bacong – 0.95 cal/gC°; Poblacion, Bacong – 0.94 cal/gC°; Dumandan, Zamboanguita – 0.94 cal/gC°; Poblacion, Siaton – 0.94 cal/gC°; Poblacion, Zamboanguita – 0.93 cal/gC°; Poblacion, Dauin – 0.93 cal/gC°; and Masaplod, Dauin – 0.93 cal/gC°.

The variance of distilled water is 11.01 with a standard deviation of 3.32. The smallest variance calculated for seawater samples is 0.00008 from Poblacion, Siaton with a standard deviation of 0.03. The highest variance of 0.0034 is from San Miguel, Bacong with a standard deviation of 0.06.

Coefficient of Volume Expansion

Room Temperature: 29.00 °C

Table 5.7h *Coefficient of Volume Expansion for Seawater from Poblacion, Basay*

Trial	V_0 (cm^3)	T_i (°C)	T_f (°C)	ΔT(C°)	Δh_{straw} (cm)	ΔV (cm^3)	β ($1x10^4$/C°)
1	251.66	27.00	28	1	1.80	0.0956	379.75
2	251.66	28.00	29	1	1.60	0.0849	337.55
3	251.66	29.00	30	1	1.60	0.0849	337.55
4	251.66	30.00	31	1	1.90	0.1009	400.84
5	251.66	31.00	32	1	1.60	0.0849	337.55
6	253.78	27.00	28	1	1.70	0.0903	366.65
7	253.78	28.00	29	1	1.80	0.0956	376.58
8	253.78	29.00	30	1	1.60	0.0849	334.73
9	253.78	30.00	31	1	1.60	0.0849	334.73
10	253.78	31.00	32	1	1.70	0.0903	355.65
						Average:	**355.06**

Variance = 4.92×10^{-10} Standard Deviation = 2.22×10^{-5}

Sample Computation:

$$\beta = \frac{\Delta V}{V_o \Delta T}$$

$$\beta = \frac{0.0956}{(251.66)(1)}$$

$$\beta = 379.75$$

Seawater's Coefficient of Volume Expansion

Calculation for Variance:

$$x = \frac{\Sigma \, |\beta_{seawater} - \beta_{average}|^{\,2}}{N}$$

$\sigma^2 = \Sigma\,(\beta_{seawater} - \beta_{average})^2 / N$

$\sigma^2 = [(355.06(1 \times 10^{-6}) - 379.75(1 \times 10^{-6}))^2 + (355.06\,(1 \times 10^{-6}) - 337.55(1 \times 10^{-6}))^2 + (355.06(1 \times 10^{-6}) - 337.55(1 \times 10^{-6}))^2 + (355.06(1 \times 10^{-6}) - 400.84(1 \times 10^{-6}))^2 + (355.06(1 \times 10^{-6}) - 337.55(1 \times 10^{-6}))^2 (+ (355.06(1 \times 10^{-6}) - 355.65(1 \times 10^{-6}))^2 + (355.06\,(1 \times 10^{-6}) - 376.58(1 \times 10^{-6}))^2 + (355.06(1 \times 10^{-6}) - 334.73(1 \times 10^{-6}))^2 + (355.06\,(1 \times 10^{-6}) - 334.73(1 \times 10^{-6}))^2 + (355.06\,(1 \times 10^{-6}) - 353.65(1 \times 10^{-6}))^2] /10$

$\sigma^2 = 4.92 \times 10^{-10}$

Calculation for Standard Deviation:

$\sigma = \sqrt{x}$

$\sigma = 2.22 \times 10^{-5}$

Distilled water has lower coefficient of volume expansion compared to seawater samples. The results of the experiment show that seawater's coefficient of volume expansion ranges from 354.53 (1 x 10^{-6} /C°) to 376.47 (1 x 10^{-6} /C°).

Ranking from lowest to highest; we have Poblacion, Dauin – 354.53 (1 x 10^{-6} /C°) got the lowest value then Poblacion, Basay – 355.06 (1 x 10^{-6} /C°); Masaplod, Dauin – 357.86 (1 x 10^{-6} /C°); Poblacion, Bayawan – 357.94 (1 x 10^{-6} /C°); Dumandan, Zamboanguita – 364.26 (1 x 10^{-6} /C°); Poblacion, Sta. Catalina – 364.43(1 x 10^{-6} /C°); San Miguel, Bacong) – 365.05 (1 x 10^{-6} /C°); Poblacion, Siaton – 365.29 (1 x 10^{-6} /C°); Poblacion, Zamboanguita – 365.46 (1 x 10^{-6} /C°); and lastly Poblacion, Bacong – 376.40 (1 x 10^{-6} /C°) got the highest value for coefficient of volume expansion. The distilled water has 308.01 (1 x 10^{-6} /C°) which is lower than the coefficient of volume expansion of the seawater samples.

Table 5.8 *Some Physical Properties of Seawater Samples.*

Samples	Index of Refraction	Density	Boiling Point	Surface Tension	Conductance	Specific Heat	Coefficient of Volume Expansion
Distilled Water (% error)	1.31 (2%)	0.99 (0.01%)	94.35 (5.65%)	72.35 (3.25%)	0 (0.03%)	Lf = 78.36 (3.99%)	308.01 (4.83%)
Poblacion, Bacong	1.35	1.01	96.34	74.37	0.05	0.94	376.47
San Miguel, Bacong	1.34	1.01	96.31	74.19	0.05	0.95	365.05
Poblacion, Dauin	1.36	1.01	96.38	75.44	0.05	0.93	354.53
Masaplod, Dauin	1.34	1.01	96.44	74.60	0.05	0.93	357.86
Poblacion, Zamboanguita	1.35	1.00	96.16	74.99	0.05	0.93	365.46
Dumandan, Zamboaguita	1.34	1.01	96.24	75.37	0.05	0.94	364.26
Poblacion, Siaton	1.34	1.00	96.32	74.59	0.05	0.94	365.29
Poblacion, Sta. Catalina	1.34	1.00	96.83	76.22	0.05	0.95	364.43
Poblacion, Bayawan	1.35	1.00	96.26	75.81	0.05	0.95	357.94
Poblacion, Basay	1.35	1.01	96.22	76.80	0.05	0.96	355.06
Average for Seawater	**1.35**	**1.01**	**96.35**	**75.24**	**0.05**	**0.94**	**362.64**

CONCLUSION

The researcher concludes that

1. Based on the measurements of reliability and accuracy, the locally-constructed apparatuses were reliable. The Electric Conductance Meter had a very low standard deviation of 1.89×10^{-7}. The Double-walled Calorimeter Apparatus had a standard deviation of 3.32, and the Volume Expansion Apparatus had a standard deviation of 7.58×10^{-6}. Additionally, the standard deviations for seawater samples were close to each other, indicating consistent measurements.

2. In terms of accuracy, the Electric Conductance Meter had a percent error of 0.03%, while the Double-walled Calorimeter Apparatus and the Volume Expansion Apparatus had percent errors of 3.99% and 4.83%, respectively. These accuracy levels are acceptable for practical applications. Therefore, the data confirms that the locally-constructed apparatuses are both reliable and accurate.

3. The index of refraction of seawater and distilled water are relatively close to each other.

4. The seawater's average value of 1.35 for index of refraction is 0.02 higher than the distilled water's 1.33 index of refraction.

5. The average value of 1.01 g /cm^3 for seawater's density is 0.01 g /cm^3 higher than the distilled water's density (1.01 g/cm^3) considering the other substances that the seawater contains.

6. the average value of 0.94 cal/gC° for seawater's specific heat is 0.06 cal/gC° lower than the distilled water's specific heat (1 cal/gC°).

7. the average value of 0.05 S for seawater's conductance is 0.05 S higher than the distilled water (5.5×10^{-6} S).

8. the average value of 362.64 (1×10^{-6} /C°) for seawater's coefficient of volume expansion is 68.84 (1×10^{-6} /C°) higher than the distilled water's coefficient of volume expansion (293.80×10^{-6} /C°).

RECOMMENDATIONS

Throughout the study done by the researcher, the following recommendations may help you in doing the experiment and the construction of the apparatus. It may help you think what are other techniques in measuring the physical properties of seawater.

Conductance

For the Conductance Meter Apparatus, it must be fixed. The wires must be properly attached to the batteries to avoid disconnection from the source. In doing the experiment, the amount of water samples must be consistent and metal strips should be wiped.

Coefficient of Volume Expansion

For the Volume Expansion Apparatus, the two holes on the cover must fit to the sizes of the thermometer and straw. The rubber must be thick and hard compare to ordinary rubber. Using rubber slipper is better.

Specific Heat

For the Double-walled Calorimeter Apparatus, the two holes on the cover must fit to the sizes of the thermometer and straw. The cover must be fixed and the insulation foam and rubber mat inside must be arranged and attached properly. Avoid wetting the inside part of the apparatus. In doing the experiment, see to it that all the materials are already set and organized to avoid some lapses. Ice bucket is needed so that ice will not melt fast.

Surface Tension

In getting the angle, practice is needed when using the Optico – Capillary Tensiometer. The drawing of the line must be exactly tangent to the meniscus of the liquid.

Boiling Point

In the experiment, holding the thermometer while waiting the seawater sample to boil is good. But it is better to have a stand for the thermometer.

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ABSTRACTS OF PRESENTATIONS

P1. TRANSFORMING IDEAS TO PRODUCTS: DESIGN THINKING ON LEARNERS' CONCEPTUAL UNDERSTANDING AND PERFORMANCE TASK RATING IN PHYSICS

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This quasi-experimental study aimed to determine the effect of design thinking on students' conceptual understanding and performance task rating in Physics. Specifically, it sought to compare the conceptual understanding and performance task rating in Physics of Grade 8 students prior and after exposure to non-design thinking and design thinking methodologies. Moreover, this study aimed to find out the learnings and challenges of students from both groups. The study adopted Fraenkel and Wallen's Quasi Experimental - Matching Only Pretest-Posttest Control Group Design. Control group was exposed to non-design thinking methodology while the experimental group was exposed to design thinking methodology. Results revealed that prior to the intervention, both groups had "low" conceptual understanding in Physics but after the intervention, design thinkers had significantly high conceptual understanding compared to non-design thinkers. Results of t-test revealed that there was a significant difference on the conceptual understanding in Physics before and after exposure to non-design thinking methodology and design thinking methodology. Although both methodologies were proven to be effective in improving the

conceptual understanding, design thinking was more effective as the effect size and mean gain in conceptual understanding were significantly higher than the other. The performance task rating in

Physics was also noted to be significantly higher for design thinkers than non-design thinkers. Further investigation about learners' learnings and challenges revealed that non-design thinking was a guided construction of knowledge where learners learned after constructing the output and cooperating without questioning. Although guided with activity sheets, most of them failed to interpret correctly the procedure. On the other hand, design thinking was an avenue for active learning where learners develop scientific skills and attitudes, learned while doing the outputs, and cooperated well through brainstorming. Design thinkers' biggest challenge was conflict among members due to diversity of ideas. Thus, design thinking is an effective methodology in improving learners' conceptual understanding and performance task rating of learners in Physics making it an opportunity worth the risk. (1hr)

P2. DEMONSTRATIONS, PHENOMENA, AND FUN WITH PLANE MIRRORS

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With a set of plane mirrors, the following will be discussed/shown/demonstrated: Law of Reflection; Image Formation in Plane Mirrors; Truth Mirror; Infinity Tunnel; Pentagonal Reflection; Periscope. (2 hrs)

P3. AN EXPERIMENTAL DETERMINATION OF SOME PHYSICAL PROPERTIES OF SEAWATER SAMPLES IN SEVEN SOUTHERN COASTAL TOWNS OF NEGROS ORIENTAL

ANNA ROSE RESOMADERO

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Junob National High School, Junob/Talay, Dumaguete City

The study aimed to determine seven physical properties of seawater samples from seven southern coastal towns of Negros Oriental; namely, Poblacion and San Miguel of Bacong, Poblacion and Masaplod of Dauin, Poblacion and Dumandan of Zamboanguita, Poblacion of Siaton, Poblacion of Sta. Catalina, Poblacion of Bayawan, and Poblacion of Basay. The seawater samples were taken twenty (20) meters away from the shoreline. The properties were Density, Surface Tension, Specific Heat, Boiling Point, Conductance, Coefficient of Volume Expansion, and Index of Refraction. The seawater's index of refraction ranges from 1.34 to 1.36. The result of

seawater's density ranges from 1.00 g/cm3 to 1.01 g/cm3. Boiling point of the seawater samples ranges from 96.16 °C to 96.83°C. The surface tension of seawater ranges from 74.19 dynes /cm to 76.80 dynes /cm. The seawater's specific heat capacity ranges from 0.93 cal/gC° to 0.96 cal/gC° and actually lower than the specific heat capacity of distilled water (1 cal/gC°). The coefficient of volume expansion ranges from 354.53 (1 x 10-6 /C°) to 376.47 (1 x 10-6 /C°). Distilled water has lower coefficient of volume expansion compared to seawater samples. The result for seawater samples' conductance was 0.05 S. (1 hr)

P4. INEXPENSIVE DESALINATION APPARATUS FOR SMALL ISLAND COMMUNITIES

HANNA ROSE ANCES

Maxino College, Bagacay, Dumaguete City
Basac National High School, Basac, Larena, Siquijor

Water is essential for human survival. However, issues on water shortage become rampant and due to them the death toll has continued to rise. One of the answers may lie in the ocean. The oceans hold about 320 million cubic miles (1.35 billion cubic kilometers) of water, which is roughly 97 percent of Earth's water supply. The water is about 3.5 percent salt and contains traces of all chemical elements found on Earth.

But the problem is that it cannot be consumed because it is over saturated with salt. Removing the dissolved salt is the challenge that has to be overcome in turning seawater into freshwater Living cells do depend on sodium chloride (salt) to maintain the body's chemical balances and reactions; however, too much sodium can be deadly. Human kidneys can only make urine that is less salty than salt water. We have to put seawater in a process so that we can provide freshwater in a community, like a small island community.

Desalination is the process of purifying saline water into a potable fresh water. Desalination technologies could be the key to resolve the continually growing freshwater scarcity in society.

The researcher constructed an inexpensive desalination apparatus commonly named as passive solar still. It only used the heat coming from the sun to desalinate the seawater. It was found out that this is positively effective in producing drinkable water using seawater water. Using Total Dissolved Salt experiment (TDS) and Electrical Conductivity method (EC) it was proven that the water is distilled and the existence of salt concentration can only be identified as a trace. The apparatus is affordable for the small island communities due to its resources that is being used that can be found only in their locality and everything comes in a low cost. Based on the survey that was conducted in Apo Island, the primary target community of the study it was determined that a passive solar still with a dimension of 2ft by 4ft still can affirmatively support the weekly drinkable water needs of a household with 2 family members in it.

The researcher recommended that further study about this passive solar still desalination should be conducted to improve the efficiency of the total production of the still. (1 hr)

P5. MEASUREMENT OF VISCOSITY OF LIQUIDS USING A VISCOMETER APPARATUS

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Catulayan National High School, Catulayan, San Juan, Siquijor

BRANDO PIÑERO, MS

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The teaching of Physics of liquids can be more interesting and understandable using inexpensive experiments and demonstrations. A locally-made Viscometer (measurement of viscosity) was designed, constructed, and tested for accuracy and reliability. It was then used to measure the viscosity of some commonly available liquids such as Corn Syrup, Pure Coconut Oil, Dishwashing Liquid A and Dishwashing Liquid B. Pure Coconut Oil and Dish-washing Liquid B got a percentage difference of 0% on its velocity coefficient. Corn Syrup and Dish-washing Liquid A had a percentage difference of 0.31% and 0.90% respectively. (1 hr)

P6. PERCEPTIONS ON THE EXTENT OF COCOS NUCIFERA TODDY COLLECTORS' FOOD SAFETY PRACTICES: A BASIS FOR INTEGRATION OF FOOD SAFETY IN THE SCIENCE CURRICULUM

NOVA MARIE E. ANTIQUANDO

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Negros Oriental State University-Guihulngan City Campus
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This study intends to determine the extent of food safety practices as perceived by the *Cocos nucifera* toddy collectors where one hundred forty (140) coconut toddy collectors from the different areas of Guihulngan City serve as respondents. The study is descriptive and correlational in nature and based from the results of the respondents – toddy collectors' responses. The set of questionnaires is based on the Good Manufacturing Practices (GMP) of the Philippine National Standards. Frequency Distribution, Percentage, Weighted Mean, t-test, and Pearson Product-Moment Correlation Coefficient are the statistical tools.

The findings reveal that the respondents' average age is 53 years old, and of low literacy. The least experienced of whom have worked in 1-5 years, the rest 17-24 years. The average

household size is about 5.5 and most depend on toddy collection for their livelihood. Two groups of respondents are examined as to their hygienic practices perceptions and their actual practices. As the number of work experience increases, the use of the more modern and hygienic metal screw cap is used as lid for toddy containers, the rest use guava (*Psidium guajava*) leaves. Both groups do not essentially differ in their perception on safety practices except the one cited on container lids. Neither does their profile, except that the more experienced use the more hygienic metal screw cap, as cited earlier.

In summary, according to the respondents' perceptions, their hygienic practice, in all facets of their toddy collection, is quite high. But if we take into account, their hygienic practices have still a lot to be improved. (1 hr)

P7. FOLK TOYS IN TEACHING ROTATIONAL MOTION

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This study investigates how well-integrated folk toys may teach students about rotational motion. The study offers instructors a demonstration guide designed to help them create a fun and exciting learning environment. Several familiar toys are compared to the fundamental ideas of physics that underlie rotational motion. A thorough inventory of these toys is also included in the research, along with in-depth observations that demonstrate how they relate to particular physical concepts. This project intends to improve students' comprehension of rotational motion through practical and interactive learning by using these folk toys as instructional materials. (1 hr)

P8. SMARTSCOPE-INTEGRATED ONE-CLOSED-END (OCE) RESONANCE TUBE FOR SPEED OF SOUND MEASUREMENT

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MA. CHONA Z. FUTALAN

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RYAN G. TUBOG

Cebu Technological University - Main Campus, Cebu City

This study focuses on designing and constructing a one-closed-end (OCE) resonance tube integrated with the SmartScope smartphone application for measuring the speed of sound in air at two different room temperatures using the resonance method. The apparatus includes a transparent plastic tube with a metric scale, a speaker connected to a smartphone with a sound frequency generator for producing pure-tone sound, a movable piston indicating the effective length of the

tube, and a mini-microphone connected to a smartphone with the SmartScope application. By precisely adjusting the movable piston, resonance conditions are established, with the maximum sound signal clearly indicated in the SmartScope app. Experimental error values are found to be significantly small when compared to the calculated speed of sound at the two different temperatures. The apparatus proves effective and can efficiently demonstrate the physics of acoustics, particularly longitudinal standing waves and speed of sound experiments. By precisely adjusting the movable piston, resonance conditions are established, with the maximum sound signal clearly indicated in the SmartScope app. Experimental error values are found to be significantly small when compared to the calculated speed of sound at the two different temperatures. The apparatus proves effective and can efficiently demonstrate the physics of acoustics, particularly longitudinal standing waves and speed of sound experiments. (1 hr)

P9. DEVELOPMENT AND EVALUATION OF MODULES FOR SENIOR HIGH SCHOOL PHYSICS TEACHERS

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The purpose of this study was to design, develop and evaluate instructional modules for Senior High School Physics teachers. ADDIE Model was used as the developmental design. Inputs from 34 senior high school physics teachers of the 20 DepEd Public Schools, Private Schools, Colleges and Universities and State Colleges and Universities in the City and Province of Iloilo were sought. A duly validated and reliability tested researcher-made questionnaire was utilized to gather data needed which included the level of readiness of the physics teachers and their coverage of the learning competencies in Physics as required by the Department of Education. Findings revealed that the physics teachers had low level of readiness in Electricity and Magnetism, and Modern Physics. Likewise, the physics teachers had low extent of coverage of the learning competencies in Physics. Furthermore, the physics teachers were found to be mostly master's degree graduate of other fields but not of physics program, teaching physics for less than 5 years, and had not attended any of Physics-related seminars. The modules were found to be excellent by both the experts and physics teachers in terms of the objectives, content, format and language, presentation, and usefulness. They showed high potential in terms of its usage and effective instructional materials in improving the quality of instruction and in improving students' performances in Physics. (1 hr)

P10. RISK-BASED APPROACH TO RADIATION AND NUCLEAR SAFETY

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Radioactive materials have many applications that are beneficial ranging from uses in medicine, industry, agriculture, research, and power generation. The radiation risks that may arise from the use of radiation and radioactive materials must be assessed and must be controlled by applying safety regulations and standards. There is an increased use of radioactive materials in the Philippines, especially in medicine for diagnostic imaging and cancer therapy, and in industry for level gauging, non-destructive testing, and sterilization. There is now local production of certain radionuclides by cyclotron for diagnostic imaging. Nuclear material is now utilized for research and training purposes and maybe utilized for power generation.

The risk-based approach to radiation and nuclear safety will be presented by giving examples of the degree of regulatory control and complexity of radiation and nuclear safety requirements of the various applications of radioactive materials, including transport and radioactive waste safety. (2hrs)

P11. OHM'S LAW

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The presentation discusses the principle of Ohm's Law. It specifically tackles the relationship of resistance, current, and voltage to one another. Included in the presentation is an experiment on Ohm's Law, where participants are given a chance to gain hands-on experience with the measurement of voltage, current, and resistance and eventually calculate the resistance of a given resistor with the use of the Ohm's Law equation. (Lab-2hrs)

P12. COMBINATION OF RESISTORS

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The presentation talks about the nature of resistance when several resistors are combined, either in series or parallel. Principles will be discussed as part of the introduction to the presentation. It specifically aims to provide the participants with a hands-on experiment when resistors are combined. Due to time constraints, the experiment will focus only on when the resistors are connected in series and when they are connected in parallel. There will be no series and parallel connections combined in one circuit. (Lab-2hrs)

P13. FREELY-FALLING BODY

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The presentation introduces a simple experiment with a freely falling body. The experiment utilizes a computer app called Phyphox that can measure the time of a falling body using sound. It is a simple experiment that requires less effort to obtain the materials and is easy to perform. (Lab-1 hr)

P14. RESISTOR AS A CURRENT LIMITER

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The presentation discusses the function of a resistor as a current limiter. It includes a little discussion on what a resistor is and its functions. A hands-on experiment will be done by the participants after important concepts are introduced, and therefore, included is the breadboarding of the different materials involved. (Lab-1 hr)

P15. VULNERABILITY OF MARGINALIZED COMMUNITY DUE TO CLIMATE CHANGE: A CASE OF NAVOTAS CITY

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One pressing global concern is addressing the impact of climate change, a challenge that resonates across nations due to its widespread effects. Numerous studies are actively investigating the root causes of climate change, as well as assessing risks and developing strategies for mitigation. Particularly vulnerable to these weather shifts are marginalized communities, often residing in hazard-prone areas and facing heightened risks from natural disasters.
This study focused on selected communities within Navotas City, situated along the Manila Bay in the extreme Northwest of Metro Manila. This location exposes its residents to recurrent flooding during typhoons, heavy rains, and high tides. Compounding the issue, inadequate ventilation contributes to heat-related diseases, disproportionately affecting both the young and elderly residents. According to the 2020 PSA Census, Navotas has a population of around 247,000, with a poverty incidence of 11.7%.

Utilizing numerical simulation (Weather Research and Forecasting), historical data on rainfall and temperature were generated. Employing Geographic Information System (GIS), flood and temperature maps of the study areas were created. The study also incorporated a researcher-made survey to gauge the community's awareness and adaptability.

The findings underscore a significant impact of climate change on the local population. Residents are acutely aware of and susceptible to health-related issues arising from flooding and high temperatures. Their adaptive measures are often necessitated by a lack of alternatives, emphasizing the reliance on local government actions. This research sheds light on the urgent need

for targeted interventions and underscores the crucial role of local governance in building resilience within vulnerable communities. (1 hr)

P16. DOPPLER EFFECT OF SOUND: LEARNING WITH COMPUTER INTERACTIVE SIMULATION

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An interactive computer simulation on the Doppler Effect of Sound will not only motivate learners but also provide accessible ways for students to develop an understanding of how the shift in wavelength and frequency of sound is produced by the motion of the source of the sound wave, the observer, or both. The concept will be presented through an integrated computer simulation.

The downloadable simulation from the internet visually presents the changes in the wave produced by the motion of the source and/or observer. It allows users to view the situation from the perspective of the medium (the standard reference frame), the source, or the observer. (1 hr)

P17. EFFECTIVENESS OF PHET SIMULATION IN IMPROVING SCIENTIFIC LITERACY OF GRADE 10 STUDENTS ABOUT MIRRORS

MARY WIENYLYN P. TIBAYAN

San Antonio National High School

JERVIE M. OLIVEROS

Technological University of the Philippines

Mirrors, a fundamental aspect of optics, present challenges that students often find complex and abstract. The nature of reflection and image formation proved challenging for students to visualize. The intangible nature of light rays and the interaction with mirrors presented difficulties in grasping fundamental principles.

To address these challenges, educators are encouraged to implement more hands-on and visual learning experiences, such as interactive demonstrations and simulations. Additionally, emphasizing real-world applications of mirror principles, such as in optical devices or everyday experiences, can enhance student engagement and understanding.

This research focused on the effectiveness of PhET Simulation in improving the scientific literacy of grade 10 students about mirrors. The study aimed to determine the effectiveness of PhET simulation in improving scientific literacy of Grade 10 students.

The researcher created an achievement test validated by the head teacher, science coordinator and research coordinator. The validated achievement test was administered to Grade 10 students of San Antonio National High School Parañaque. The results of pretest and posttest were collected and interpreted using T-test for significant difference and Hake Factor Normalized Gain.

According to the findings, the calculated t-value of -17.0 indicates a notable and statistically significant difference between the pretest and posttest scores of the students. This suggests an enhancement in the scientific literacy of the students through the utilization of PhET Interactive Simulation. Furthermore, the normalized gain value of 0.55 suggests a moderate gain in effectiveness following the intervention. This underscores the recommendation for science teachers to delve into the potential impact of PhET Interactive Simulations in their classrooms. (1 hr)

P18. THE HYDROGEN GAS

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The hydrogen atom, the simplest atom in nature, is an important starting point for studying atoms and atomic structure. Niels Bohr, for example, a notable physicist, even used the hydrogen atom for his model in understanding the atomic structure and in the quantization of light. As such, it is interesting to study the properties of the hydrogen element. Hydrogen naturally occurs in nature as a diatomic molecule, H2, which is hydrogen gas. In this presentation, some properties of hydrogen gas will be discussed and demonstrated. (Lab -2hr)

P19. CHROMATOGRAPHY

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The presentation includes a straightforward chromatography experiment. It delves into the fundamental physics (capillary action, solvent movement) and chemistry (solubility, intermolecular forces) principles that underpin the chromatographic technique. (Lab - 2 hr)

P20. EXPLORING BUOYANCY: DENSITY AND FLOATING DYNAMICS

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The presentation covers the essential concepts of buoyancy and density. It incorporates a basic experiment employing various liquids and objects to illustrate their buoyancy and its correlation with their density. (1 hr)

P21. THERMODYNAMIC EXPLORATION OF CITRIC ACID AND SODIUM BICARBONATE REACTIONS

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The presentation explores the thermodynamics of a chemical reaction, focusing on temperature measurements, heat transfer, and reaction rates. The accompanying experiment examines the correlation between temperature and reaction rate using two reactive substances: citric acid and sodium carbonate. (1 hr)

P22. FOREST RISK ANALYSIS VIA MONTE-CARLO SIMULATION

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This study determined the probabilistic risk of the 64 intact forest landscapes. A Monte-Carlo simulation of 1000 iterations was performed from generated data using Bernoulli random Sampling. The five forest treats are as follows: natural disaster, mining, urban development, logging, and farming. The data was analyzed using a scatter plot and Principal Component Analysis (PCA). Results revealed a positive nonlinear relationship between the forest threats and the number of intact forest landscapes at risk. The intensification of the five treats gives rise to the increase of Intact Forest Landscape at Risk. (1 hr)

P23. PHYSICAL AND BACTERIOLOGICAL CHARACTERISTICS OF SPRING WATER IN BARANGGAY CANTAPOY, MALIMONO, SURIGAO DEL NORTE

ROLDAN O. JUGATAN
ELANIE P. CABALLERO
DONNAVEL DELA CALSADA
ZAIRAH M. MALAZA, ALNIE E. NEMENZO

Surigao del Norte State University

Access to safe drinking water is a significant challenge in remote areas with inaccessible treated water supplies, leading to health risks due to water quality degradation from human activities. This study aims to assess the Physicochemical and Bacteriological Characteristics of Hagdan-Hagdan Water Spring in Barangay Cantapoy, Malimono, Surigao Del Norte. A descriptive method was used for a pre-assessment visual survey, followed by quantitative analysis of physicochemical and bacteriological parameters. In-situ measurements revealed pH (5.87), Temperature (22.2°C), Dissolved Oxygen (4.76 ppm), and Conductivity (443 μS). Bacteriological analyses indicated elevated levels of Fecal Coliform (>8.0 MPN/100ML), Total Coliform (>3.03 MPN/100ML), and Heterotrophic Plate Counts (1,682.44 CFU/ml). Comparison with water standard values (DAO 2016) showed non-compliance, suggesting degradation of both

physicochemical and bacteriological parameters. This study underscores the urgent need for interventions to restore and safeguard water quality in adherence to national and international standards. (1 hr)

P24. PHYSICS AS A SOCIAL SCIENCE TEACHER SEES IT

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Physics from the point of view of a social science teacher: The growth of physics may be able to shed light on world development, especially the technology that physics has enabled, which in turn brought out the industrial revolution with its changes in social structure like the working conditions of laborers and the development of capitalism. The improvement of transportation brought cultural exchange, geographical expansion, and economic development. Indeed, physics has influenced much of social development. (1 hr)

P25. DEVELOPMENT OF A WORKTEXT IN BIOPHYSICS

MARIO P. OBRERO
MARIQUIT M. OBRERO
GRACE A. GARCIA
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This study was conducted to develop a worktext in Biophysics for college students. Specifically, it aimed to a) determine the availability and adequacy of instructional materials in Biophysics, b) describe the worktext; c) evaluate the worktext in terms of objectives, format, content, organization, language, and usability; and d) determine the readability of the worktext. The study used the research and development (R&D) design and the descriptive method of research. The respondents of the survey were nine Physics faculty members and a university librarian. Six experts in Physics and Biology served as evaluators of the worktext. A survey checklist and the evaluation questionnaire, adopted from Salavaria (2014) were utilized. The development of the worktext was guided by the first three stages (Analysis, Design, and Development) of the ADDIE Model of Instructional Design. The data were analyzed using the mean.

Results of the study revealed that 1) there is a need to develop worktexts and other instructional materials in Biophysics, 2) the worktext was described as substantial, clear, simple to understand, stimulating, and loaded with activities, 3) worktext was evaluated as excellent overall and in all criteria; 4) in terms of its readability, the worktext is suitable for college students; and 5)

the worktext is highly valid as an instructional material in Biophysics. The worktext is recommended for utilization in the university. The effect of using it on the achievement of students may be measured. Similar studies may be conducted to develop worktexts in other courses using the ADDIE Model.

Keywords: *physics education, instructional material, ADDIE Model* (1 hr)

P26. PROBLEM-BASED APPROACH IN TEACHING TORQUE TO PHILIPPINE SCIENCE HIGH SCHOOL WESTERN VISAYAS CAMPUS GRADE 9 STUDENTS

ATTY. WILLIAM A. LARIDE

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The presentation is about how torque is introduced and taught, in a learner centered method, to Grade 9 scholars of Philippine Science High School Western Visayas Campus using Problem-based Approach.

Incorporated in the presentation are some interesting classroom demonstrations to help illustrate conceptual applications of torque. The presentation also elaboratessimple and complextorque problems with applications in real-world activities that are used in the problem-based approach of teaching in order to stimulate students thinking and problem-solving abilities during the teaching and learning process.

Common torque misconceptions are also discussed with suggested remediation activities in order to help the students build the correct torque concepts. (1 hr)

P27. PPS GOLDEN ANNIVERSARY (50TH): A WALK THROUGH THE YEARS

HOPE M. BANDAL, PHD

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This tells the story of the Philippine Physics Society (PPS) from its birth in 1974 to today. It traces the trajectory that the PPS has taken, the challenges encountered and the eventual triumphs - from a group of less than 10 young physics graduates from the University of San Carlos to thousands of members now spread all over Luzon, Visayas, and Mindanao. (2 hr)

P28. DEVELOPMENT OF A TEACHING-LEARNING SEQUENCE ON TENSION FORCE USING BRIDGING ANALOGIES

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This study aimed to develop a teaching-learning sequence (TLS) on tension force using bridging analogies (Camp & Clement, 2010) and investigate its effect on students' conceptions to promote conceptual understanding. This is so since traditional methods of physics teaching do not usually consider students' debilitating alternative conceptions; thus, failing to engender conceptual change. A Type-3 developmental concurrent-nested mixed methods research design was used in which the target alternative conceptions on tension force were based from the literature, and the quantitative data set provided a supportive role to the qualitative data. The quantitative data included a conceptual inventory in determining students' initial and final conceptions. The qualitative data gathered from focus group discussions, journal entries, activity sheets, and voting sheets helped in describing students' conceptual changes. The study involved an intact heterogenous General Physics 1 class of Grade 12 students (n=42). The results revealed that there were correct and incorrect conceptions before and after the implementation, and that the bridging cases were successful in promoting conceptual change. The study also affirmed the resistance of alternative conceptions which harbor among students.

Keywords: *teaching-learning sequence, tension force, bridging analogies, conceptual change, alternative conceptions, Physics* (1hr)

P29. PHYSICS IN ENVIRONMENTAL PRESERVATION: UTILIZING ELECTRORESISTIVITY DATA IN DETERMINING WATER-HOLDING CAPACITY AND VULNERABILITY OF SUBSURFACE MATERIALS

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Physics takes a very big role in understanding characteristics of subsurface materials. Using an electro-resistivity meter and IP2WIN software, we can produce Vertical Electrical Sounding (VES) sections of ground locations which determine different subsurface layers and their true average resistivity values. Using standard values for resistivities, we can decipher which rock or soil strata have water-bearing capacities or aquifer potential. Given enough data points, we can make underground sections of water-bearing rocks with the aid of Geographic Information System software (GIS). The correctness of the sections is enhanced by corroborating data, such as borehole and well inventory data. This study aims to show that physics data can be used along with environmental data, such as rainfall, infiltration, soil type, and geology as a tool in environmental

preservation. In an Environmental Impact Assessment study done in UP-Mindanao Campus, Davao City, GIS-processed electro-resistivity and supporting data showed that 40% of the campus has high contaminant vulnerability for surficial aquifers and 10% moderate vulnerability for bedrock aquifers. Physics and environmental data, thus, can be used to make specific recommendations in creating better environmental settings, such as efficient urban planning, effluent sewage establishment, and pesticide disposal.

Keywords: *Physics data, Environmental Impact Assessment, Geographic Information System, Vulnerability, electroresistivity* (1 hr)

P30. THE EFFECT OF REACT STRATEGY ON SENIOR HIGH SCHOOL STUDENTS' CONCEPTUAL UNDERSTANDING OF NEWTON'S LAWS OF MOTION

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This study aimed to investigate the effect of the REACT (Relating, Experiencing, Applying, Cooperating, Transfering) strategy in facilitating conceptual understanding of Newton's Laws of Motion among senior high Physical Science students with different scientific reasoning levels. The students' scientific reasoning levels were identified using Lawson's Classroom Test of Scientific Reasoning (LCTSR). Students were pretested with the 11-item Force Concept Inventory (FCI) to identify students' pretest mean scores and initial conceptions. During the implementation of the REACT strategy, the changes in the students' conceptual understanding were identified using their answers from the activity sheets and focus group discussions. After the implementation, students were post-tested to identify students' post-test mean scores and final conceptions. The results show that there were significant learning gains after the implementation. The study shows that REACT strategy is effective in improving students with concrete operational reasoning and transitional reasoning conceptual understanding of Newton's Laws of Motion. Based on the findings, it is recommended that educators incorporate the REACT strategy in teaching science.

Keywords: *REACT strategy, conceptual understanding, scientific reasoning, Newton's Laws of Motion* (1 hr)

P31.USING SIMULATION-BASED LEARNING IN EXPLORING ENERGY FORMS, CHANGES, AND SYSTEMS

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In the context of energy systems and transformations, simulations offer visual representations that elucidate the complex systems of energy. This engaging lecture explores the immersive experience of using simulation-based learning in teaching energy forms, changes, and systems through a PhET simulation called Energy Forms and Changes. These are hard to replicate in a classroom setting since these experiments are impractical and may be dangerous for the students. In this session, we will explore the significance of incorporating simulation-based approaches to physics education to help students fully grasp and deepen their understanding of the concepts. Through aligning simulation-based learning with the learning objectives, students can explore on their own, manipulate the variables, observe the cause-and-effect relationships, and analyze data which develops their problem-solving skills. This lecture promotes the use of simulation-based learning as a transformative approach towards a transformative science education. (1 hr)

P32. THE ART OF TEACHING PHYSICS: ADAPTING METHODS FOR NON-STEM STUDENTS

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This presentation explores the efficacy of creative teaching methodologies tailored to non-STEM learners, aiming to foster understanding and appreciation of fundamental physics concepts. Through a variety of interactive teaching methods, this session presents interventions designed to bridge the gap between traditional physics instruction and diverse cognitive backgrounds of non-STEM students. Drawing from our experiences, we will share findings highlighting increased student engagement, confidence, and enthusiasm for physics. This lecture underscores the importance of adjusting teaching methods to accommodate the diverse needs of learners found in non-STEM disciplines. Creating an inclusive and engaging learning environment enables teachers to instill an appreciation for the significance of physics among all students, irrespective of their academic backgrounds. (1hr)

P33. DEVELOPMENT OF ELECTRONICS LAB CIRCUIT TRAINER (ELCT) FOR CLASSROOM INSTRUCTION

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This paper presents the design, development, and implementation of an electronics lab circuit trainer tailored for classroom instruction, aimed at consolidating experimentation in electricity and electronics into a comprehensive toolkit. The system encompasses essential components such as digital input/output, signal generator, power supply variations, and measurement instruments, facilitating a wide range of experiments including series and parallel circuits, time-dependent circuits, logic gates, and function generator operations. (1hr)

P34. DEVELOPMENT OF A DIGITAL CALORIMETER FOR CLASSROOM INSTRUCTION

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The development of a digital calorimeter for classroom instruction focuses on designing and implementing a user-friendly digital calorimeter system that will be used to understand concepts of thermodynamics. It is to address the limitation of traditional calorimeters that often lack accessibility, precision, and real-time data visualization, hindering effective teaching and learning of thermodynamics concepts.

The digital calorimeter integrates advanced sensor technology and motor application enabling real-time measurement and analysis of heat transfer processes. The system offers precise monitoring and data logging capabilities to measure temperature digitally. The device also allows students to interactively explore concepts such as specific heat capacity, heat transfer, and calorimetry experiments with less heat exchange with the system and environment, thus minimizing errors.

Through collaborative development and continuous refinement of the device, this innovative tool promises to aid classroom instruction and inspire the next generation of scientists and engineers to innovate and develop similar devices that will be used to facilitate the teaching and learning process. (1hr)

P35. CATCH THE RULER: AN EXPERIMENTAL SET-UP ON LINEAR FITTING OF DATA

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The presentation, intended primarily for high school physics teachers, focuses on techniques for plotting slopes and intercepts using the "eye-ball method" and linear regression formula. However, it is also relevant for college physics educators seeking to enhance their teaching methods. While not exhaustive, it covers essential materials for experiment setup, procedures, and the integration of technology, such as electronic spreadsheets, to streamline collaborative work assessment. Structured around the 5E learning cycle - Engage, Explore, Explain, Elaborate, and Evaluate - the presentation offers a condensed yet impactful approach within the time constraints typically faced by educators at both the high school and college levels. (1hr).

P36. AN IMPROVISED AIR TABLE THAT DEMONSTRATES TWO-DIMENSIONAL COLLISION

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This study aimed to construct and test an improvised air table that would show collisions in a nearly frictionless surface.

As part of the testing of the improvised apparatus, the following masses of discs were used: 6.7 grams and 7.47 grams. This study determined if there are significant differences on the total momentum as well as the total kinetic energy of the discs before and after collision. Different cases were considered: in the first case, one disc is moving towards the other stationary disc; and in the second, both discs are moving towards each other. By the aid of a digital camera and a computer software, Logger Pro, the initial and final velocities of the discs were determined. By comparing the differences before and after the collision, the total momentum and total energy was tested statistically using t-test at 0.01 level of significance.

Results showed that the improvised apparatus is effective in demonstrating the equality of the total momentum and total energy of the discs before and after collision. Furthermore, the apparatus performed well in demonstrating the kinematics of bodies undergoing two-dimensional collision.

It was recommended that the improvised air table be used for classroom instruction, particularly in demonstrating two-dimensional collision. (1hr)

P37. DIURNAL CYCLE OF PRECIPITATION AMOUNT AND DURATION OVER CAGAYAN VALLEY, PHILIPPINES

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Understanding the diurnal behavior of precipitation will aid in the understanding not only of the mechanisms involved in rain formation but also the mechanism of the local climate. It is also a crucial aspect for disaster risk reduction, hazard mitigation, water resource management, and policy making. This study aimed to examine the climatology of precipitation with higher spatial and temporal scale along Cagayan Valley, Philippines using hourly automated weather station data and Advanced Research – Weather Research and Forecasting model simulations from July 2013 to June 2017. Specifically, it aimed to describe the characteristics of the amplitude and phase of the diurnal and semidiurnal cycles of precipitation; and explain and elucidate the physical mechanisms involved in the diurnal and semidiurnal cycles.

Strong diurnal cycle signals are observed along the mountainous areas in Cordillera and Caraballo, while weaker signals are observed along the coasts and small islands of Batanes. Afternoon to evening (14 – 22 LST) precipitation predominates along the valley throughout the year, with relatively higher amplitudes during the April-May-June season and lower amplitudes during the October-November-December (OND) season. Furthermore, early morning (23 – 10 LST) precipitation predominates between the eastern Cordillera Mountain Range and western Caraballo during the January-February-March (JFM) season, and northern coastal areas during the JFM and OND seasons. These characteristics suggest a strong implication of diurnal rainfall to the hydrological cycle and agriculture. The phase of the diurnal cycle is closely related to the duration of precipitation. The afternoon to evening maxima were more prevailing in the short-term precipitation events lasting 1-3 hours, while the early morning maxima were more prevailing in the long-term precipitation events which persisted for more than three hours. Spatial analysis of wind vectors suggests that mesoscale weather systems such as the sea breeze mechanism, mountain-valley breeze, and propagating mesoscale convective systems, have a greater effect on the diurnal cycle observed, particularly during the AMJ season. (1hr)

P38. SENSITIVITY ANALYSIS OF PM10 POLLUTANTS TO VARIOUS GAS-PHASE CHEMISTRY AND AEROSOL MECHANISMS USING THE WEATHER RESEARCH AND FORECASTING MODEL COUPLED WITH CHEMISTRY (WRF-CHEM) IN ILOCOS NORTE

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WRF-Chem is an air quality modeling system commonly used worldwide for simulating air pollution. It combines the Weather Research and Forecasting (WRF) model with a chemistry component to simulate the complex interactions between meteorology and atmospheric chemistry. This study evaluated the performance of the WRF-Chem model in simulating PM10 concentrations from various gas-phase chemistry and aerosol mechanisms. One-way analysis of variance, root mean square error, and bias were used for model verification. In addition to the sensitivity analysis, the spatial distribution of PM10 concentration, including the diurnal variability from model outputs were examined and compared.

Results show that the three model outputs simulated higher PM10 concentrations in Batac and Laoag and the surrounding municipalities. Moreover, the three simulations detected higher concentration during midnight to early morning and lower during daytime. This diurnal variability is attributed to the height of the planetary boundary layer – higher during daytime leading to dilution and dispersion of particulate matter and resulting to lower PM10 concentration, and lower during the evening to early morning leading to more stable atmosphere, thus particulate matters are suspended near the ground, resulting to higher PM10 concentration. Model evaluation show that the WRF-Chem performed better using the RADM2-MADE/SORGAM gas-phase chemistry and aerosol mechanism. However, bias analysis reveal that the model underestimated the observed PM10 concentration.

This study emphasizes the role of numerical models such as the WRF-Chem model in simulating the atmosphere for weather and air quality monitoring. Evaluating the performance of the model is an essential step towards analyzing and better forecasting the atmosphere. Thus, it is recommended to use WRF-Chem model, with integration of the RADM2-MADE/SORGAM gas-phase chemistry and aerosol mechanism, for simulating and forecasting air quality. This will lead to proper management of policy related measures to maintain good air quality or mitigate from increasing levels of air pollution associated with industrialization. (1hr)

P39. STEP_POWERUP: REDESIGNING PIEZOELECTRIC ENERGY HARVESTING TILES FOR SUSTAINABLE ENERGY GENERATION WITH THE USE OF SPRING ACTUATORS AND ARDUINO UNO MONITORING

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State-of-the-art prototypes of piezoelectric energy harvester (PEH) tile designs have attempted various design improvements and recommendations to improve the efficacy of capturing the ambient biomechanical energy generated by human motion. However, most existing PEH tile prototypes lack actual human testing involving weight thresholds of the produced potential difference on each footstep while simultaneously having an intelligent monitoring technology integration. Thus, the researchers designed a working PEH tile prototype fused with Arduino Uno technology that employs the feature enhancements of piezoelectric nanogenerators (PENGs) proposed by experts and existing studies. The prototype design comprises the bottom plates (wiring connection housing), middle plates (16 PENGs), and top plate tile. Upon constructing the PEH prototype, specific design considerations were found to be feasible, such as using piezoelectric transducers (PZT) PENGs, hybrid series-parallel connections, together with the support mechanisms (lifting caps, four springs, and four sponge modules), and finally, external positioning of the monitoring system. The researchers found it could generate an average peak voltage of 22.6 V when stepped by a calculated mass average of 54.1 kg per person. In general, the results from this prototype indicate that continuous application of innovations in real life could foster opportunities for future researchers and engineers to explore the possibilities of these sustainable alternative sources of energy designs further.

Keywords: *Piezoelectricity, transducers, energy harvesters, Arduino Uno* (1hr)

P40. KINEMATICS OF PUBLIC HEALTH NURSES WITH DIFFERENT WORK EXPERIENCES IN A LOCAL HOSPITAL

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The level of expertise, type of nursing unit, nurses' age, and unit experience are considered as factors that affect the distance traversed by nurses. The distance and speed that nurses cover throughout their shifts can be an indicator of how heavy one's workload is. Nurses with little to no experience are more likely to take the greatest number of steps and distance compared to long serving nurses. Thus, this investigation aimed to determine the differences between the motion of Registered Nurse I and Registered Nurse III within one-day shift. To assess the mean distance and mean speed of the data obtained, the data were evaluated using the Wilcoxon Rank-Sum non parametric statistical technique. Registered Nurse I covered an average distance of 1410 m at a mean speed of 176.25m/h, while Registered Nurse III covered an average distance 750 m with a mean speed of 93.75m/h. The results showed that the distance and the speed travelled by nurses with less working experience were significantly longer and greater, respectively, than those with more working experience in one shift. This study used a smart band to record the motion, including distance travelled and speed, allowing for an objective assessment of the physical activity levels of nurses working a single shift. These findings indicate that nurses' motion, such as the speed and distance travelled, is most directly affected and depends accordingly on the nurses' work experience. This calls for the creation of tailored support initiatives that meet the specific nursing experience levels' needs. (1hr)

P41. OCULAR MOVEMENT OF COMMON VISION DEFECTS USING AN ONLINE-BASED WEBCAM EYE TRACKING APPLICATION

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Eye gaze tracking has been widely used in medical research for it reveals variations in the visual ability of individuals with various medical conditions. However, despite studies on eye gaze in vision-affecting disorders, there is a lack of comparative analysis among common eye defects using visible light, as many rely on infrared imaging methods. Hence, this investigation focused

on using an open source software-based visible-imaging gaze tracker to identify potential variances in the eye gaze of various prevalent eye conditions, such as astigmatism, nearsightedness (myopia), and farsightedness (hyperopia). After conducting the gaze tracking procedure, results showed that while gaze trajectories vary between the groups, a myopic individual demonstrated a close resemblance to an individual with normal vision. On the other hand, the hyperopia group exhibited frequent fixations on the lower quadrants of the screen, while the astigmatism group exhibited inconsistencies on fixation patterns. The analysis revealed distinct fixation patterns and gaze paths among individuals with different visual impairments compared to those with normal vision. Gaze pattern variations among myopic, hyperopic, and astigmatism-affected eyes when compared to normal-visioned eyes may be due to the eyes' proximity to the screen, habitual tilting of head, and their difficulty in visual acuity and object detection. Therefore, common eye conditions like astigmatism, myopia, and hyperopia can have an impact on how a person gazes, leading to deviations from gaze patterns of the normal-visioned eye. (1hr)

P42. PARTNERING LEARNERS IN INSTRUCTION THROUGH ENHANCED ENGAGEMENT IN PHYSICS. IN AN OPEN AND DIFFERENTIATED INQUIRY

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The conduct of the laboratory is indispensable in Physics instruction since it scaffolds the learner's understanding of the Physics concepts by showing how physics phenomena work. A laboratory is utilized in various intentions to unfold before the learner's eyes the wonders of Physics. The laboratory activities motivate learners, provide avenue to confirm hypotheses, and consequently the results of the investigation. However, the pandemic only highlighted the perennial issues associated with the holding of laboratory classes. Issues include the lack of equipment, access to the laboratory rooms during blended or remote setup, time and safety constraints, lack of resources, and teacher comfort level in implementing an authentic inquiry, among others. The attempt to partner with learners in instruction through enhanced engagement in Physics laboratory presents exemplary outputs. The learner-centered approach enabled investigators the freedom to design their inquiry with due consideration on their limitations. The investigators were able to utilize whatever is accessible and efficient for them to accomplish the laboratory requirements. The learners acquired insights on how to address these issues and strategize to perform the inquiry independently. The strategies and insights are helpful to educators in crafting their laboratory activities in a challenging environment. (1 hr)

P43. LOW-COST EXPERIMENTAL DEMONSTRATION OF BRACHISTOCHRONE PRINCIPLE FOR SENIOR HIGH SCHOOL STUDENTS

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This demostration presents a low-cost experimental setup designed to demonstrate the brachistochrone principle to senior high school students. The brachistochrone problem, a classic in physics and calculus, challenges the notion of shortest paths by exploring the path of fastest descent under gravity. The setup consists of a wooden frame or cardboard structure with a flexible pipe that can be shaped into various curves: a.) straight path, b.) circle, c.) ellipse, and d.) cycloid. Using a toy car, small marble, and big marble, and cellphone timers and camera in recording time and motion, students test and compare the travel times along these paths, learning fundamental principles of Newtonian mechanics, calculus of variations, and the impact of curved space on motion. Accompanied by a worksheet, this hands-on experience enhances students' understanding of optimization, geometry, and physics concepts in a practical and engaging manner. (1hr)

P44. DEVELOPING THE RAT 3000: AN ELECTRONIC MOUSE TRAP DEVICE

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The RAT (Rodent Alarm-Trap) 3000 is designed as an improvement of the latest models of mousetrap technology. Current designs utilize LED light as an indicator of a successful capture of a pest inside the instrument, but the researchers have designed a similar design with an addition of sound alarms. The integration of the circuitry of water-level indicator was utilized by the researchers to immediately alert the owner that a rodent has been trapped inside the system. This innovation can be done using the materials that we see at home. For instance, old bucket and scrap wood serves as cover for the RAT 3000. Simply physics concepts apply with this kind of prototype with perfect combination of basic electronics and fluid mechanics which the weight of the rodent will be main force to activate the prototype. Since sound is the second-most sensitive sense of human beings, alarming the owners about a successful entrapment of rats would be more immediate eliminating the risks of possible diseases brought by the diffusion of fluids from rats when threatened. In general, the result of this prototype leads applications in terms of trap in terms of innovation, also let the science and technology may be accessible for all people so that we obtain

sustainability to contribute solutions for 17 Sustainable Development Goals of United Nation in terms of Physics. (1 hr)

P45. EXPLORING THE POTENTIAL AND IMPLICATION OF CHATGPT IN SENIOR HIGH SCHOOL PHYSICS EDUCATION

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This research paper investigates the capabilities of ChatGPT in solving physics problems. While ChatGPT has versions specialized for mathematical equations, its application to physics problems necessitates a deeper exploration due to the interplay of linguistic and mathematical elements. Employing a sequential explanatory design, the study evaluates the accuracy of solutions generated by ChatGPT for standard physics problems sourced from textbooks, with a specific focus on mechanics topics and explores its implications in physics instruction. The findings reveal that ChatGPT exhibits a 'high level' of accuracy across most topics; however, it demonstrates weaknesses in certain areas. Consequently, the findings underscore the pedagogical advantages of leveraging ChatGPT in physics education while emphasizing the importance of interventions to foster creativity, particularly aiming to elevate physics instruction to the highest levels of learning.

Keywords: *ChatGPT, Physics, Physics Education* (1 hr)

P46. MOBILITY OF NURSES ASSIGNED TO DIFFERENT HOSPITAL WARDS

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Busyness among nurses entails significant motion fueled by time constraints in fulfilling caregiving duties, influencing their energy and work quality. This phenomenon is marked by a persistent sense of pressure and motion, often impacting the quality of nursing-patient care. Nurses' motion plays a crucial role in the quality and efficiency of their service, with variations observed across different specializations such as Emergency Room and Intensive Care Units compared to

General Wards. Studies, including Time and Motion Studies and the use of various tracking devices like radiofrequency identification and pedometers, have explored nurses' activity levels, but detailed motion patterns and the impact of workload and specialization remain underexplored areas. Additionally, some employed procedures, like the Time and Motion method, and applications used may not be conducive, as they often require manual recording of tasks by nurses. Thus, this study utilized the Pacer app to investigate the mobility of nurses in the Emergency Room and General Ward, streamlining data collection by accurately recording individual distances traveled. The General Ward nurse covered a total distance of 2807 meters (4657 steps), while the Emergency Room nurse traveled 2578 meters (4504 steps). Moreover, the average speed for the General Ward nurse over the 8-hour shift was 0.10 m/s, slightly higher than the Emergency Room nurse's average speed of 0.09 m/s. During the 8-hour shift, the General Ward nurse covered a greater total distance and maintained a faster average speed compared to the Emergency Room nurse. This suggests that the nurses assigned to different wards play a role in influencing their motion patterns during their day-shift. A single shift, however, does not fully represent the motion pattern of nurses over longer periods of time, thus highlighting the need for comprehensive analysis across multiple shifts. (1hr)

P47. THE DEVELOPMENT OF AN ELECTROMAGNETISM LEARNING KIT TO INCREASE STUDENT AWARENESS AND APPRECIATION OF ELECTROMAGNETS

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Electromagnetic induction remains to be one of the more challenging concepts to teach students due to its abstract nature and the complex vocabulary involved. To address this challenge of providing a hands-on learning experience on electromagnetism, Project Tanarau of PSHSWVC Physics and IS Unit developed an electromagnetism learning kit which makes use of home-based and improvised demonstrations.

The learning kit consists mainly of batteries (A, AA, D), copper wires, paper clips, neodymium magnets, bar magnets, nails, various configurations of copper wire, iron filings, compass, steel needle, and a prepared motor set-up, as well as workbook for students and a teaching guide for teachers. The kit will enable the students to perform various experiments, such as simple electric motors, magnetic plotting, homopolar motors, wireless power transmission, and do-it-yourself compass, all anchored in the learning competencies stated in the DeEd Science curriculum and PSHS curriculum.

This presentation will showcase some of the experiments in the learning kit. (2 hr)

P48. WIND PROFILE OF ILOCOS NORTE WIND FARM INDUSTRY

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Wind farms depend on wind, with wind variability driving the fluctuation of their over-all power generation. The Ilocos Norte Wind Farm Industry is one of the main producers of wind power. It is located on the northwest part of Luzon on the seashore of the Bangui Bay where the wind speed is strong. But since the country is located on the tropics, the wind speed varies with season, monsoon and other climate oscillations. This study aims to determine factors that contribute to the variations of wind speed and power production. Specifically, the study determined the relationship between wind speed and different climate driver indices (East Asian Summer Monsoon (EASM), Western North Pacific Summer Monsoon (WNPSM) and El Nino Southern Oscillation (ENSO)). Results show that different climate drivers are significantly correlated with the wind speed and consequently with the power production of the industry. This means that, as the climate driver indices mentioned changes, the wind speed and power production also varies. The results of the study can be used for the effective management of power production and distribution in Ilocos Norte. (1hr)

P49. INCORPORATING PALM KERNEL SHELLS AS A SUSTAINABLE ADDITIVE IN CONCRETE HOLLOW BLOCKS (CHB)

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The production of concrete materials causes harm to the environment, and this poses a need to seek sustainable materials. Palm oil production creates significant waste, such as palm kernel shells, which can harm the environment if not disposed of properly. So, instead of throwing or burning it, these shells can be a suitable aggregate for making concrete. This study aimed to utilize palm oil kernel shells as an additive in concrete hollow blocks (CHB) as a sustainable material for producing CHB at 25%, 50%, 75%, and 100% in the ratio of sand and gravel. This study utilized a quantitative approach with an experimental research design. The study tested compressive strength and bulk density to assess the overall physical properties of the developed palm oil kernel concrete hollow blocks. Testing the compressive strength of the 25%, 50%, 75%, and 100% CHB resulted in 29.8 Psi, 29.0 Psi, 21.7 Psi, and 27.1 Psi, respectively. These values are above the minimum compressive strength standard for lightweight hollow blocks prescribed by the DPWH.

Moreover, the bulk density results of the 25%, 50%, 75%, and 100% CHB are 2072.07 kg/m3, 1701.7 kg/m3, 1371.37 kg/m3, and 1401.4 kg/m3, respectively. Furthermore, the one-way ANOVA results show a p-value of 0.724 (p-value<0.05) for compressive strength, which means no significant difference, and a p-value of 0.000 for bulk density (p-value>0.05), which means there is a significant difference. This means that regardless of concentrations, the palm kernel CHBs were equally able to withstand loads before failure. However, the 25% CHB is more robust regarding bulk density than the other concentrations. Based on the results of this study, it is recommended that palm oil kernel shells be utilized as a viable and sustainable additive for hollow concrete blocks.

Keywords: *bulk density, compressive strength, concrete hollow blocks (CHB), moisture content, palm kernel shell, water absorption*

P50. MECHANICAL PROPERTIES OF COMPRESSED EARTH BRICKS (CEB) STABILIZED WITH CEMENT INCORPORATING PEANUT SHELLS AND HUMAN HAIR WASTE

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Investing in developing more robust, eco-friendly bricks addresses immediate construction needs and aligns with broader sustainability objectives. The primary aim of this study was to analyze the mechanical characteristics of compressed earth bricks (CEB) integrating waste materials such as peanut shells and human hair. To create a sustainable CEB, peanut shells comprising lignin (36.1 wt%), cellulose (44.8 wt%), proteins (5.4 wt%), hemicellulose biopolymers (5.6 wt%), as well as other compounds including minerals were utilized. Additionally, human hair waste, predominantly composed of keratin (95%), was incorporated. Compressed Earth Bricks (CEB) stabilized with cement incorporating peanut shells and human hair waste were produced with a ratio of 60% clay, 15% sand, 15% powdered peanut shell, 8% cement, and 2% human hair waste. This research employed an experimental method using a Research and Development framework. The study tested three (3) bricks for each concentration for the compressive strength, water absorption, and free-fall drop tests to assess the overall mechanical properties of CEB-biowaste. The compressive strength test of CEB-biowaste resulted in 144.68 Psi, 145.22 Psi, and 211.88 Psi, respectively. These values are above the minimum compressive strength standard for CEB prescribed by the DPWH. Moreover, the water absorption test results are 0%, 3.33%, and 0%, respectively, suggesting that CEB-biowaste can resist rainfall.

Furthermore, the free-fall drop test on the CEB-biowaste indicates one breakage and two instances of remaining intact, implying durability. Therefore, based on the study's results, it is recommended that peanut shells and human hair be viable aggregates and be utilized as aggregate and fiber reinforcement for compressed earth bricks.

Keywords: *compressed earth bricks (CEB), compressive strength, free-fall drop test, peanut shell, human hair, water absorption*

P51. DEVELOPMENT OF AN ELECTROLYTIC DAMAGE DETECTION SYSTEM USING ARDUINO UNO

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There are multiple different systems used to detect damage today. The typical systems in use today are strain measurement, acoustic emission, ultrasound, vibration, and Artificial Intelligence. These are used to monitor locations and/or equipment for damage. This research introduces a novel and reliable way to detect damage using the Electrolytic Damage Detector System (EDDS). This system uses electrolytic EDDS cells connected to an Arduino Uno to pinpoint where the damage is located on that system. This paper investigated the performance of the individual EDDS cells under differing molarities and energies applied and compared their performance. Four different molarities were used (2 M, 1 M, 0.5 M, and 0.25 M). A 2 Newton weight was provided for the energy dropped at varying heights (5 cm, 10 cm, 15 cm, and 20 cm). Results revealed that at 0.25 M, 0.5 M, 1 M, and 2 M, the average voltage generated were 1.14 V, 0.95 V, 1.34 V, and 1.74 V (using 0.4 J), respectively. Moreover, the data showed that at 0.1 J, 0.2 J, 0.3 J, and 0.4 J (at 2 M), the average voltage generated were 0.37 V, 1.15 V, 1.40 V, and 1.74 V, respectively. Furthermore, when the voltages generated were compared using varying energies, the p-value was 0.001, meaning there is a significant difference in voltage with different energies. However, when the energies are constant and the molarity varies, the p-value is 0.387, meaning there is no significant difference between the tested molarities. It is concluded that the voltage output of the EDDS-Cell is directly related to the energy input, and the EDDS-Cell molarity can vary without affecting its performance. Based on the study's results, it is recommended that the cells' diameter, length, and material be varied and investigated along with their threshold energy (the maximum energy the cell can take before breaking).

Keywords: *Arduino Uno, Damage Detection System, Electrolytic, Sensor, Voltage*

P52. ENHANCING HIGH SCHOOL STUDENTS' CRITICAL THINKING AND PROBLEM-SOLVING SKILLS IN PHYSICS USING SUPPLEMENTAL GAMES

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In today's dynamic educational environment, incorporating interactive teaching methods such as game-based learning can cultivate essential 21st-century skills among high school students, particularly critical thinking and problem-solving skills. As a discipline, physics explores the universe's fundamental laws and seeks to understand the nature of matter, energy, and their interactions. To understand this, students' proficiency in these skills is crucial as these also have broader applications in various fields, enhancing decision-making and logical reasoning. Focused on addressing the growing need for innovative teaching methods, this study aimed to utilize supplemental games as a teaching strategy to improve student's critical thinking and problem-solving skills in physics. This study used a quasi-experimental pretest-posttest non-equivalent research design. Two different sections were utilized as study participants; one intact class was assigned as the experimental group (n=37) using supplemental games, and the other intact class was designated as the control group (n=38) utilizing traditional learning. The supplemental games employed are the following but not limited to Team Quiz Bee, Pik-Pak-Boom (XY), an oral recitation strategy where the students who stand last will be asked about some questions, GenHuScie Game Ka Na Ba? - a gameshow-inspired questioning about the topic, simulation online educational games, 4-Pics-1-Word, and other games which aim to promote active participation, critical thinking, and problem-solving skills among the students. The critical thinking and problem-solving skills were measured using a reliable open-ended questionnaire with a Cronbach's alpha value of 0.756. They were scored using a validated researcher-made rubric with a Content Validity Index 0.80. Results revealed a significant improvement in students' critical thinking and problem-solving skills under the supplemental games teaching strategy. Moreover, one-way ANCOVA results revealed a significant difference between the experimental and control groups in critical thinking and problem-solving skills with both having a p-value of 0.00. This significant improvement in these skills among students implies that integrating interactive and engaging learning methods, such as supplemental games, can positively impact students' critical thinking and problem-solving skills within the context of physics education. Based on this finding, it is recommended that educators and educational institutions consider integrating supplemental game methods into the high school physics curriculum and in other science subjects that require content mastery and 21st-century skills development.

Keywords: *4-pics-1-word, critical thinking skills, game-based learning, game ka na ba?, GenHuScie innovative teaching, physics education, pik-pak-boom (XY), problem-solving skills, simulation online educational game, supplemental games, team quiz bee*

P53. PARALLEL PLATE CAPACITOR

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This demonstration will verify the capacitance formula for a parallel plate capacitor. The model improvised parallel plate capacitor used in this demonstration has square plates, 14.2 cm on an edge (A=0.0200 meter2.); one is fixed in place and the other movable. By sliding the movable plate sideways, the effective area A of the plates can vary from maximum to effectively zero meter2. The movable plate may be placed in different grooves in the apparatus, allowing different plate separation, S. The minimum separation is 2.0 mm and this may be increased in steps of 2.0 mm. Some dielectric material will also be used to see its effect on the parallel plate capacitor's capacitance. The capacitance of the plates is measured by using a multimeter. (1hr)

P54. STUDENTS' CONCEPTUAL UNDERSTANDING AND PHYSICS PROBLEM-SOLVING PERFORMANCE USING STATION TEACHING WITH NEWTON'S OLYMPICS

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This quasi-experimental pretest-posttest control group research ascertained the conceptual understanding and physics problem-solving performance of heterogeneously grouped lower sections of fifty-six (56) Junior High School students, Grade eight of national high school during the second quarter of the academic year 2018-2019. This research study utilized a researcher-made Newton's laws of motion conceptual understanding and physics problem-solving tests. All statistical tools were set at 0.05 alpha level of significance.

The conceptual understanding in the pretest and the posttest of the Station Teaching group and Inquiry-based Teaching group was low. However, the problem-solving performance in the pretest and the posttest of both groups was fair. In addition, both groups are comparable in conceptual understanding and problem-solving performance. This showed from the mean gain in conceptual understanding of the Station Teaching group was higher compared to Inquiry-based Teaching group but the mean gain in problem-solving performance of the Inquiry-based Teaching group performed better than the Station Teaching group.

Using the Wilcoxon-Signed Rank test, the study revealed that the difference between the pretest-posttest in conceptual understanding of Station teaching was significantly higher compared

to Inquiry-based Teaching. The difference between pretest-posttest on Physics problem-solving performance in Station Teaching and Inquiry-based Teaching was significant. Using the t-test for independent sample means, the difference in the mean gains on conceptual understanding and Physics problem-solving performance was not significant. It showed that whatever teaching methods in Physics were used, both conceptual understanding and problem-solving performance are improved.

It is recommended that educational policymakers may review the K to 12 program to possibly incorporate teaching approaches like Station Teaching with Newton's Olympics to enhance educational practices, teacher education institutions may employ effective teaching techniques like Station Teaching for diverse types of learners in varied learning conditions and utilize learning experiences in the classrooms to develop learner's skills in discovery learning, problem learning and critical thinking, textbook writers may be provided with opportunities to make instructional materials with an authentic strategy like Station Teaching for the students to work on while curriculum planners may be provided with opportunities to plan and make improvement of the existing K to 12 educational curriculum.

In addition, Department of Education personnel may be afforded with opportunities to help discuss information of understanding new approaches or strategies like Station Teaching during their Learning Action Cell (LAC) sessions and science and pre-service teachers may be enhanced opportunities to attend trainings and seminars on approaches and strategies like Station Teaching for professional development and enhancement to better serve the students.

Keywords: *Station teaching, Newton's Olympics, inquiry-based teaching, conceptual understanding, problem-solving performance* (1 hr)

P55. ACTIVE LEARNING TEACHING SEQUENCE ON THE ENERGY-STORING NATURE OF CAPACITORS: INTERFACING THEORY WITH CONCRETE DEMONSTRATIONS

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This article discusses a teaching sequence for capacitance concepts, particularly the energy-storing nature of capacitors. The active learning approach which may be appropriated for secondary and college introductory physics classes underscores the interface of theoretical derivations and discussions with concrete demonstrations that utilize common laboratory materials and equipment. Students are provided with opportunities to derive and validate mathematical relationships between electrical and physical quantities involved in capacitance, and witness these in actual demonstrations. The teaching sequence also integrates *predict-observe-explain* (POE) strategy to facilitate students' investigation of the effects of the physical dimensions of a parallel-plate

capacitor to its capacitance; and charging voltage to capacitor voltage and stored electric energy. It is also intended for the enhancement of the higher-order thinking skills of students.

Keywords: *capacitance; charging/discharging capacitors; predict-observe-explain (POE); demonstrations; teaching sequence* (1 hr)