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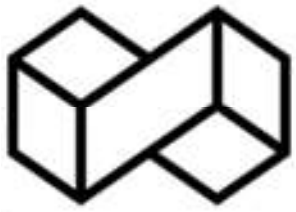

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1. To encourage and publish knowledge and useful opinions in any field of study
2. To support academicians and teachers in creating work beneficial to the academic community
3. To stimulate and support education at the university level

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Editorial Note

The Interdisciplinary Research Review (IRR) was established with academic cooperation by The Royal Society of Thailand Committee of Interdisciplinary Research and Development, Rajabhat University (Western Group), and Rajamangala University of Technology Rattanakosin. This Issue, Volume 19 Number 6 (November – December 2024). This issue contains of four interesting articles in multidisciplinary fields: (1) Challenges experienced by home-based palliative caregivers of the elderly with Alzheimer's disease (AD): a review, (2) Microalgae: Sustainable Cell Factories for Functional Foods and Ingredients , (3) Utilization of Filipino Sign Language-Sight Words Intervention (FSL-SWI) to Increase the Literacy Skills of Deaf and Hard-of-Hearing (DHH) Pupils , (4) Phronetic Leadership Contextualized in Higher Education:The Case of Ifugao State University, Philippines.

The Editorial Board of the IRR encourages anyone to submit articles for evaluation and review. The processes of submission, review and publication of articles are described on the journal's website, https://www.tci-thaijo.org/index.php/jtir. The Editorial Board and Committees of the IRR sincerely thank all peer reviewers who have sacrificed their time to help us produce a better journal, and also wish to thank all teachers, researchers and other academicians for submitting their valuable research to this journal. Finally, we thank readers of our journal who help to spread the knowledge and benefits gained to others. With your feedback and suggestions, we will strive to improve the quality and relevance of the IRR.

Yongyudh Vajaradul
Editor
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Challenges experienced by home-based palliative caregivers of the elderly with Alzheimer's disease (AD): a review

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Abstract

As the world's population ages due to increasing longevity, many elderly people are affected by many diseases, and Alzheimer's disease (AD) is another disease susceptible more to the ageing population. AD is a kind of degeneration in the brain, and the elderly with AD suffer a progressive functional and cognitive decline. It is the most common cause of dementia, which causes challenges to the elderly patient as well as family caregivers. Home-based palliative care for AD provides care and support, especially to terminally ill patients, surrounded by their family caregivers. This article aims to describe: 1. introduction to Alzheimer's disease; 2. importance of home-based palliative care for the elderly; and 3. Challenges experienced by home-based palliative caregivers of the elderly with Alzheimer's disease. The study used a rapid reviewing method to collect relevant data, information, and contents related to the objectives from various electronic source search engines, searched by typing keywords such as Alzheimer's disease, goals, and challenges of palliative care of the elderly at home by family caregivers, and the relevant contents were analyzed. The result found major challenges experienced by family caregivers, including stress, fatigue, anxiety, sleep deprivation, expenditure burden, and less time for self-care and social responsibility. The findings of this article provide a better understanding of Alzheimer's disease, the importance of palliative care at home for elderly people with AD, and the challenges encountered in providing care, which can be useful to academicians, family caregivers, AD patients, policymakers, and medical professionals to improve the quality of life of both patients and caregivers through integration of applicable intervention measures in health care planning and policy making.

Keywords: Alzheimer's disease, home-based palliative care, challenges of family caregivers, elderly with AD

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1. Background

The world's ageing population, 60 years and older in the world, is an increasing trend, which is estimated to increase from 14 percent in 2022 to 26 percent by 2050 [1] due to changes in life expectancy. As the population ages, many elderlies are affected by many diseases, and Alzheimer's disease (AD) is another disease susceptible more to the ageing population. According to the World Alzheimer´s Report worldwide, approximately 47.0 million people in the global population suffer from the disease [2], and this proportion may triple by 2050, which will be a burden to healthcare

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providers [3] as the elderly with AD suffer a progressive functional and cognitive decline and gradually lose decision-making and value-expression abilities [4]. Alzheimer's disease is a kind of degeneration in the brain that starts slowly years before the symptoms appear and destroys memory and thinking skills, leading to changes in behavior and personality and affecting the skills to perform daily life activities. It takes years to notice the symptoms of brain disorders due to AD, such as memory loss, personality change, and language problems. Symptoms start showing when neurons or nerve cells of the brain, having functions for cognition, memory, thinking, learning, reasoning, walking, and swallowing, are affected, which gradually spread to other parts of the brain as the disease progresses. Over time, the person who is affected by AD has become disorganized with increased anxiety, lost abilities to perform daily normal tasks, manage money, move, communicate, or walk, and thus remains in bed, which requires all day and night care from a caregiver [5]. An elderly AD patient is said to be affected by dementia if the patient shows symptoms of failing to recognize the environment and familiar faces of people, lost memory, unsteadiness in getting up, and changes in behavior and communication. AD is the most common cause of dementia among elderly people [6]. Most ageing people usually suffer from chronic multi-morbidities, weakness, and cognitive decline, so AD is another disease that causes challenges to elderly patients as well as family caregivers. Age is the contributing factor of AD, but people less than 60 years old can also develop the disease. There is a growing challenge for the elderly with AD because, as the disease advances, it needs the utmost care and support from family or others, and no medicine has been discovered by medical science to cure it to date. Consequently, it causes lots of stress and challenges to the affected elderly, healthcare professionals, and family members, and this causes the need to adopt a palliative care approach [7].

According to the World Health Organization [8], palliative care aims to improve the quality of life of patients suffering from chronic life-threatening illnesses like AD. Home-based palliative care brings benefits to the patient and family as its main objective is to lessen the pain and suffering of the patient through communication with health care staff and provides psychosocial support to the patient and family caregivers to ease the burden, symptoms, fear, and worries and to be prepared for the pending outcome. Home-based palliative care is provided by family caregivers in consultation and advice of trained medical staff and professionals and has many positive contributions. Firstly, it saves the increasing financial cost of long-term inpatient hospitalization fees for illnesses such as AD. Many families find it hard to pay for long-term care in hospitals in the absence of financial protection to meet the cost of treatment and care. So family caregivers have an important role in providing palliative care at home. Thirdly, palliative care reduces the workload of congested hospitals or hospitals with inadequate healthcare staff in rural areas. However, efficient home-based palliative caregivers need training and advice from medical personnel or staff to learn the basics of palliative care [9].

The study used a rapid reviewing method to collect relevant data, information, and

contents during 2000–2023, related to the objectives from various electronic source search engines, searched by typing keywords such as Alzheimer's disease, goals, strategies, and challenges of palliative care of the elderly at home by family caregivers, and the relevant contents were analyzed. The article is organized into sections: Background; Introduction to Alzheimer's disease; Importance of home-based palliative care for elderly with Alzheimer's disease; Challenges experienced by home-based palliative family caregivers of elderly with Alzheimer's disease; and lastly, Discussion, Conclusion, and Recommendations.

This article aims to describe the following:

1. Introduction to Alzheimer's disease
2. Importance of home-based palliative care for the elderly
3. Challenges experienced by home-based palliative caregivers of the elderly with Alzheimer's disease.

2. Introduction to Alzheimer's disease

Alzheimer's disease (AD), derived from the name of the German scientist 'Alois Alzheimer', is a slowly progressive neurodegenerative brain disorder associated with loss of memory, reasoning, thinking skills, and disability [10]. AD is the most common cause of dementia among elderly people and one of the greatest challenges in health care of the twenty-first century. It has been estimated that about 47 million people in the world are affected by dementia, and the yearly increase is about 10.00 million [11]. Medical researchers found "tau-proteins built up" as the main cause of brain damage in the ageing brain leading to dementia [6]. Common symptoms of dementia include a decline in thinking, remembering, reasoning, judgment, and behavior. AD is characterized by damage in the brain causing plaques that result in the loss of nerve cells or neurons and their connections [12]. Ageing elderly people 65 years and above are more at risk of dementia due to AD, commonly characterized by symptoms such as an inability to recognize familiar surroundings and people, selection of the right word for daily communication, or performing a normal daily life activity. It is estimated that one-third of the ageing elderly, 85 years and above, may be affected by AD [13] since age is the main factor for dementia among the elderly [7]. Also, several factors cause functional changes or degeneration in the ageing brain, such as chronic inflammation, damage in the human anatomy, blood vessels, high blood pressure, exposure to pollutants, diabetes, heart disease, stroke, genetic factors, head injuries, and environmental factors that affect neurons and other brain cells [14].

AD is challenging as there is no cure for the disease and the patient loses abilities in reasoning, communication, thinking, and performing daily activities such as taking a bath, eating, going to the toilet on their own, and getting up from bed. The affected patient has to be monitored and provided supportive care by family caregivers all day and night if not hospitalized. The cost of staying in the hospital for a prolonged period is very expensive and unaffordable in the absence of health care insurance, which only a few have the privilege to possess, especially in developing rural communities. So, home-based palliative care provided by family caregivers will help to solve double issues. One, it reduces

the workload of a congested hospital or hospital with inadequate health care staff in rural areas, and two, it provides support and end-of-life care for elderly AD, as the main treatment for AD is to provide affection, care, and support to have a better quality of life to AD patients in a congenial home environment surrounded by closed family members. In home-based palliative care of elderlies with AD, family caregivers have to take on the role of nurses in hospitals all around the clock. For effective care and management of symptoms, they have to be aware of the progressive nature of the disease and collaborate with medical staff in the hospital or clinic to have proper guidance for imparting palliative care to their loved ones and to increase the well-being of AD patients [15]. In this regard, caregivers need to be aware that AD patients with advanced dementia need to provide support and care with various restrictions, including mobility, pain, difficulty eating, anxiety, and sleeping disorders. Along with these include symptom management such as disorganized behavior, agitation, loss of appetite, excessive weight loss due to refusal to eat food, problems in swallowing and drinking, etc. [16]. As the disease progresses to an advanced stage, the patient shows problems in body functions, including incontinence, difficulties in walking or performing daily activities, symptoms of indifference, changes in behaviors, asking the same question repetitively, asking meaningless questions and answers, confusion, depression, and nervousness, ultimately leading the patient to be fully dependent on the family caregivers.

3. Importance of home-based palliative care for the elderly with Alzheimer's disease (AD)

The global ageing population of 60 years and older is increasing rapidly and is expected to increase by double digits in 50 years, from 11.00 percent in 2000 to 22.00 percent in 2050 [17] due to the impact of medical science, which increases longevity. However, this increase in life expectancy is associated with various kinds of comorbidities, disabilities, and diseases, and Alzheimer's disease (AD) has gained prominence recently and is the main cause of dementia among the ageing population. The proportion of AD in the world has increased by 117.0 percent in 26 years (1990-2016), and this proportion of AD is estimated to increase in large numbers due to the population ageing by 95.4 million from 2019 (57.4 million) to 2050 (152.8 million) [18]. According to the report, cases of AD increased in large numbers—20.2 million in 1990 and 40.8 million in 2016 [19]. Consequently, these changes in the ageing population due to changes in life expectancy and increases in cases of AD among ageing elderlies lead to increasing demand for palliative care. In recent decades, there has been an increasing number of elderly people suffering from various deadly diseases such as cancer, heart disease, chronic multi-morbidities, and Alzheimer's disease, leading to the increasing need for end-of-life palliative care. This is quite in contrast to the past decades, as most elderly people suffered mainly from acute infections. The term 'palliative care' refers to the alleviation of the patient's symptoms, intending to improve the well-being of patients and their families while facing various kinds of

deadly diseases [20, 21]. Providing palliative care at home to terminally sick elderly is important, as elderly people deserve dignity, comfort, and affection together with the family during the final stage of life [22]. Palliative care (PC) aims to improve the quality of life of both patient and family by adopting appropriate measures, such as detecting and preventing the disease at an early stage, assessing the stage of the disease, managing the treatment plan, and relieving pain and suffering. In other words, the adoption of home-based palliative care will help to increase the quality of life of AD patients, taking into consideration five dimensions (physical, social, spiritual, and economic) [23]. This has been confirmed from reports of previous studies, which stated that patients who received home-based palliative care at home surrounded and observed by their family caregivers and loved ones had a lower burden from symptoms and health care costs, achieved better care, and died a dignified and peaceful death [24, 25]. Most family caregivers prefer to provide home-based palliative care to terminally ill elderly people, as most patients do not get adequate healthcare coverage and support. However, the quality of home-based PCs depends on the family caregivers.

For home-based palliative care, family caregivers need to learn how to impart and manage palliative care at home effectively by having consultation and guidance from a palliative care-trained team of doctors, nurses, or health care specialists to assist the patient in controlling sleeping disorders, anxiety, and other common symptoms of AD. The family caregivers should organize the daily routine of care to be given to the patient from morning till bedtime. The bedroom environment of the patient should be quiet, calm, and not very bright so that the patient can rest without getting disturbed since the main goal of palliative care is to relieve suffering and pain [7]. Family caregivers can soothe pain and other symptoms by taking advice from the palliative care team in the hospital or clinic, through medication, spiritual, and social support, as palliative care aims to provide comfort care for terminally ill patients, unlike medical care that aims to cure the disease. Through palliative care, the lifespan can be extended and should be given simultaneously with other medical treatments, care, and options [26]. This implies that the approach of palliative care is interdisciplinary, integrates physical science, psychosocial, and practical dimensions, focusing on symptoms treatment instead of the disease, relieving suffering and pain, and increasing comfort to terminally ill patients before leaving their near and dear ones forever [27, 28].

4. Challenges experienced by home-based palliative family caregivers of the elderly with Alzheimer's disease

There have been many studies that reported experiences faced by healthcare staff and professionals in imparting home-based care services for terminally ill elderly people [29, 30], but on searching about challenges and obstacles met by family caregivers for taking care of terminally ill AD patients at home, there are only a few research reports relating to it in the available literature. The present article aims to fill the knowledge gap to increase the efficiency of home-based palliative care for elderly people with AD. Taking care of an elderly person with AD is more challenging than other ageing

elderly people who are sick with other common diseases because AD causes disorganization in the behavior, personality, and reasoning skills of elderly people. Since the brain of an AD patient is damaged, there is a deterioration of the patient's cognitive function, resulting in judgment, orientation, and the ability to understand and communicate effectively. Managing these changes is a common challenge for family caregivers. As the disease progresses, the elderly suffer from many symptoms and need all day and night care from family caregivers who suffer from emotional stress, depression, health, and financial impact [31]. The following provides some challenges and interventions for the caregiving of AD patients obtained from the literature review.

Table 1. Challenges for caregiving of AD patients obtained from literature review

References	Challenges and interventions
Yazdanmanesh et al. [31]	Investigated the challenges faced by family caregivers of elderlies with AD with aims to lessen the problems of caregivers and to improve the knowledge and quality of caregiving with minimal impact on the well-being of caregivers as well as care recipients.
Brodaty & Donkin [32]	Family caregivers have to play many challenging roles in the palliative care of elderly patients with AD. The well-being of the care receiver depends on the quality of the care provided by the care provider. A family caregiver has to meet many burdens, including health, psychological (stress, depression, social isolation), and financial burdens in addition to family, occupation, and other social responsibilities.
Hosseini et al. [33]	This study explored the family caregivers' experiences of AD patients in Iran. The result showed five dimensions of challenges such as commitment, control, challenge, communication, and culture.
Supaporn et al. [34]	Investigated the challenges that Thai family caregivers experienced while imparting home-based palliative care to terminally ill elderly patients. Results found five categories of challenges, such as (1) caregivers' burden in bathing, turning positions, feeding, and managing waste; health, economic, and anxiety impact the caregivers; (2) problems how to manage symptoms; (3) diagnosis of the disease; (4) not prepared for death; and (5) taking decisions regarding place and procedure of treatment.
Ashrafizadeh et al. [35]	This study explained family caregivers' experiences in providing palliative care to elderlies with AD in Iran. The obtained result revealed various challenges related to the caregiving burden, strain, and the associated stage affecting the patient with the disease. Finally, the study suggested health planners identify and incorporate challenges, pain, and burden experienced by family caregivers in policy planning and adopt appropriate strategies for interventions of palliative care of elderly patients with AD.
Liao et al.[36]	It is commonly observed that most family caregivers experience fatigue and physical and mental stress due to the long-term care of patients with AD. So this study investigated family caregivers' health-related quality of life to explore those factors. The result revealed that the quality of life of family caregivers was highly affected, and the responsible factors include the nature of AD symptoms, long-term care, reduced cognitive function, and the stage of the disease. Suggested to relieve this family caregivers' burden in making health policy and planning for interventions.
Eisenmann et al.[37]	Studied challenges and distress as burdens in the management of symptoms, complications, and place of treatment. The result of the study revealed that family caregivers need support with the

References	Challenges and interventions
	provision of proxy decision-making and collaboration with healthcare officials in every stage of the disease from the beginning to the end stage of home-based palliative care at home for better management and well-being of both AD's patient and family caregivers.
Lindeza et al.[38]	AD caregivers experienced negative feelings such as fear, sadness, social isolation, and concerns about the future impacting their emotional and social aspects. The result provides holistic insights into caregiving experiences with suggestions to solve the negativity through intervention for better care of AD patients without affecting the quality of life of home-based palliative caregivers.
Kawaharada et al. [39]	This study confirmed family caregivers' challenges in feeding patients with AD and the decision of food selection, as many AD patients have disorders in eating behaviors and appetite changes, and due to these changes in eating habits, difficulties in swallowing and consuming lots of time in preparing soft, wholesome food for AD's patients and feeding them. After taking lots of time to prepare the food, caregivers have emotional fatigue if the patient hardly eats or refuses to eat the meal.
Sandberg et al.[40]	This study revealed that more than 60% of elderly with dementia need a caregiver's help in bathing. Family caregivers have to help the patient in the bathroom or clean the body if very weak with wipers and sanitary requirements for maintaining proper hygiene of elderlies with AD, which causes lots of physical effort and stress to the family caregivers.
Grabher [41]	This study reported that family caregivers often have emotional feelings, including sadness, discouragement, loneliness, anger, fatigue, depression, and stress along with many challenges of job and family responsibilities. Family caregivers have stress as they have to balance caregiving with other demands, have to take double or multiple responsibilities such as adjustment of work schedule, going late to work, leaving early, or taking time off, and difficulty in full-time concentration to important office work, besides taking care of families as well as the ailing patient with AD.
Mars et al.[42]	This is a study about African-American caregivers' experiences of palliative care. The result indicated some challenges faced by informal family caregivers, such as inadequate support from healthcare staff and a lack of knowledge and guidance on palliative care. The study suggested that family caregivers should be provided information and training through knowledge sharing, collaboration, and support from a professional healthcare team.
Sinha et al. [43]	This study compared the caregiving burden of elderly patients with AD and other psychiatric elderly patients in India. The result revealed that taking care of dementia elderlies is more challenging than elderlies with other diseases and therefore suggested lessening the burden through the government. policies, training, guidance, and other innovative interventions.
Lethin et al. [44]	This study revealed that in the absence of family support, taking full-time care of an elderly person with AD has many impacts on the caregivers, as they have to perform multiple roles besides caregiving for their beloved elderly, such as job, family, and society. These caregivers were socially isolated, as they hardly had time to join social gatherings or activities. Finally, the study pointed out the importance of collaboration with formal agencies of formal care to impart better care according to the condition of the patient and the stage of the disease.
Meyer et al. [45]	This study aimed to improve dementia care and lessen the family caregiving burden in Vietnam through the adoption of intervention measures such as organization of training, awareness programs, publicity, education, and communication with formal professionals and staff. The study revealed that sociocultural values, beliefs, norms, and expectations influence the quality of care provided to the patients and the caregiving experiences of the family caregivers.

References	Challenges and interventions
Park et al.[46]	This research used community data to explore factors that increased the caregiving burden for family caregivers of AD patients. The result revealed factors such as the stage of dementia, the behavioral problem of the patient, the physical health status of the family caregivers, the number of family caregivers, and the length of caregiving (time).
Xiao et al.[47]	This article aimed to compare facilitators and obstacles associated with caregivers of dementia patients in Australia and China by analyzing the subjective as well as objective experiences of those caregivers. The target goal of the study was to improve the available dementia care strategies and management. The result of the study found challenges experienced by caregivers of the family such as less time for personal care, neglect of caregivers' other responsibilities, difficulties in performing multiple roles of caregiving, family responsibility, employment, parental responsibility, and social participation.
Richardson et al.[48]	This research reviewed recent literature on caregivers' experiences in taking care of a relative with AD and dementia. The result revealed problems associated with managing behavioral and other disorderly symptoms of dementia. The result concluded with the need to adopt psychosocial intervention measures to solve the problem of caregivers and, at the same time, improve the quality of care for the well-being of both patient and family caregivers.
Tasci et al. [49]	This study was conducted to investigate the family caregivers' experiences and challenges in taking care of patients with AD in Turkey. The result revealed challenges such as too much demand for the caregiver's role and time. Due to the need for intense care of a family member with AD at home, the caregiver faced difficulties in finding time for relaxation, professional, family, and social life.
Chan [50]	This research was conducted by reviewing the literature of published works during 1990–2010 on the issue of challenges of home-based caregiving for the elderly with AD. The result revealed various forms of challenges, including physical, emotional, work (employment), and family responsibilities. The result suggested the requirement of systematically planned intervention measures through training and education to lessen the caregiving burden to family caregivers.
Valera et al. [51]	This article described major challenges experienced by family caregivers in taking care of relatives with AD. Some notable challenges listed were: intense anxiety, stress, and sleep deprivation as most caregivers need to remain awake at night to monitor the advanced-stage patient.
Hudson et al. [52]	The study reported that since the main goal of palliative care is to provide all kinds of support to terminally ill patients all day and night, the family caregiver has to remain vigilant and look after the needs and welfare of the patient, and this causes many negative impacts to the caregivers, such as neglect of self-care, health deterioration, and less time to interact with friends, families, and social life.
Pahlavanzadeh et al.[53]	The study results revealed the benefits of the family education program to relieve, lessen, and solve problems of caregiving to family members of AD patients to decrease the burden. Recommended to develop and evaluate such programs in scientific research for policy implications.
Takai et al.[54]	The study examined challenges experienced by family caregivers of dementia patients. Examples of challenges were burnout, depression, emotional and physical stress, and retarded quality of life. The result of the study suggested more research and interventions in family care to solve the problem and improve the quality of life of both patients and caregivers.

References	Challenges and interventions
Papastavrou et al. [55]	As taking care of an elderly person with AD has many challenges, including physical, emotional, financial, and social problems, this study investigated the burden of caring for a family member with dementia and the impact on the mental health of the caregivers. The study concluded with the essential strategies that should be used to solve stress and other problems of caregivers.
Serrano-Aguilar et al. [56]	This research aimed to assess informal family caregivers' experiences of taking care of family members with AD by analyzing the impact on the health-related quality of life of caregivers. The study was conducted in Spain and the result reported that a high proportion of family caregivers (83.3%) experienced a high level of burden.
Mahoney et al. [57]	This study analyzed a sample of AD family caregivers who suffer from anxiety, stress, and depression and then compared it with those who did not suffer from stress or anxiety. The result revealed that one-fourth of family caregivers of patients with AD have anxiety, while 10 percent have depression.
Schulz & Martire [58]	This study reported on the challenges and physical and psychological impact of palliative caregiving to elderly patients with AD at home and concluded with a suggestion to adopt intervention measures to lessen family caregivers' burden and, at the same time, improve the quality of life of patients and caregivers.
Choo et al. [59]	The study selected factors such as socio-demographic, social support, and coping to investigate whether these variables have any association with the caregiving burden experiences of families having a dementia patient at home. The result showed the need to improve social support and coping skills to lessen the burden on family caregivers of relatives with AD.
Farcnik & Persyko [60]	This study was conducted by reviewing available literature on the complexities of caregiver's burden, ways of measurement of the challenges, characteristics of the caregivers, symptoms shown by patients, and type of intervention measures to reduce those challenges. The study suggested the importance of intervention measures both pharmacologically and psychosocially.
Connell et al.[61]	This paper aimed to examine the impact of caregiving to a dementia relative at home from two dimensions, physical and psychological. It also examined the magnitude and intensity of these impacts and finally discussed many approaches for inventions to solve and minimize caregiving challenges.
Leong et al. [62]	This article reported on the challenges of home-based dementia palliative care at home. The study recommended interventions needed to improve the health and well-being of family caregivers. Some of these intervention needs include (1) finding a replacement caregiver when the caregiver is absent or busy with other work; (2) availability of a telephone number for consultation and assistance; (3) finding some free time for rest; (4) finding means and support to cope with extreme stress; and (5) finding means for solving impacts on health, emotion, social, and family.
Clyburn, et al.[63]	The study reported the importance of effective management of symptoms and disturbing behavior of highly impaired dementia elderly based at home by family caregivers through consultation with the health care team, social support, and improvement of coping skills.

Since most developing countries have insufficient AD care homes, the family takes the responsibility for caring for the elderly patients with AD. In traditional families, it is a familial responsibility to take care of each other, and young people are disciplined in the socialization process to be responsible for taking care of elderly

or sick parents. So, in traditional society, it is customary for youngsters to take care of their elderly parents when they are helpless and bedridden, and due to this norm, most elderly patients with AD stay at home and are provided all necessary care by family caregivers. However, taking care of an elderly person with AD is more challenging than taking care of other elderly people who suffer from other diseases. This is because, in the advanced stage of AD with advanced dementia, the patient displays various types of complicated symptoms. So, family caregivers need to monitor the patient 24 hours per day, and this causes challenges that have an impact on the family caregiver, including physical, psychological, emotional, social, and financial problems. Palliative care aims to solve the various disorders and symptom management by an efficient family caregiver through systematic planning and consultation with health care providers so that the elderly patient with AD can have a relaxed environment surrounded by loved family members till the patient breathes his/her last. Understanding the caregivers' challenges is important as the finding will lead to an effective intervention for health care planners and family caregivers for elderly AD patients at home with due consideration that consideration of care issues and management is influenced by the available culture and society, which varies from one society to another. AD is a product of neurological and physiological changes in the brain that are not spontaneous but pass through long-term changes in brain function. Common symptoms include retardation in memory, thinking, and reasoning skills. The disease commonly affects mostly the elderly, and if affected in the advanced stage, it makes the elderly patients dependent, bedridden, and need to be monitored and cared for all around the clock by the patient's family and caregivers [64]. However, since a person with AD lost the ability to perform personal care and tasks, they are dependent on the family caregivers for everyday routine personal care such as getting up from bed, brushing teeth, sitting and getting up from a chair, eating breakfast, going to the bathroom, and getting dressed up. Having an AD patient at home increases the caregiving burden of the family to family caregivers, as caregivers have to assist the patient in getting up from the bed, bathing, feeding, getting to and fro from the toilet, etc. In the absence of a family caregiver, the elderly patient needs to be monitored and assisted by another caregiver, family member, or other. Traditionally, the family system is joint, and there is close bonding and interdependence among members, so palliative family caregiving was not so difficult. However, with the disintegration of the joint family into a nuclear one due to urbanization, modernization, population control, declining household income, and lifestyle changes, there are changes in supportive families, and many helpless parents live alone or without adequate support from family members. Also, those families who took care of their elderly parents with AD do not have the knowledge and training to manage the symptoms of AD at home. In addition, these caregivers have multiple roles besides caring for the elderly, so these caregivers have to adapt and need to be trained through education and collaboration with healthcare staff to improve their caregiving abilities and competence [65].

From the above review of literature, many studies have reported challenges experienced by family caregivers, including physical health, psychological state of mind, and expenditure burden. Having an AD patient at home causes changes in the lives of family caregivers in many ways, such as insufficient time, impact on emotional feelings, having limited time for social life or gatherings, along with continuous stress physically and mentally. These changes can be factors that have an impact on their physical health and mental state of mind. This has been supported by previous studies [49–52] that reported family caregivers to have suffered from stress, anxiety, and insomnia, which affected their health and quality of life.

5. Discussion, Conclusion, and Recommendations

As the ageing population is increasing worldwide, dementia due to Alzheimer's disease (AD) commonly affects the ageing elderly. This disease is a progressive neurodegenerative disease of the brain. Symptoms can be commonly felt by forgetfulness and behavioral changes due to deterioration of memory, learning, speaking, reasoning, and communication skills, finally leading AD elderly patients to be dependent on family caregivers. In most developing countries and traditional societies, it is customary obligatory for grown-up children to take care of their elderly parents, as parents have devoted themselves to bringing up and looking after their children. Due to this customary norm, elderly parents, when they become sick with any disease, including AD, adult children, and their families take care of the dependent elderly. There is so much stress and strain on the family members of AD, as family caregivers play a major role in caring for the elderly patient in every stage of the disease. For instance, most AD patients sleep excessively during the daytime while at night they remain awake, and this causes disruption in the sleeping hours of the family caregiver and affects their health, having fewer sleeping hours at night. So, providing caregiving to an elderly AD patient is not an easy task, as caregivers need to monitor the patient all around the clock, consequently affecting the normal life of the caregiver in terms of their health, emotions, and family life [47]. Home-based palliative care provides care and support, especially to terminally ill patients, surrounded by their family caregivers. The main aim of home-based palliative care is to provide the sick elderly with the maximum level of care, comfort, and love till death. However, palliative care in developing countries is still at a nascent stage with inadequate facilities for geriatric care of elderly people with AD. Currently, utilization of home-based palliative family caregiving is essential to provide support and care for elderly patients with AD. Due to this important role of caregiving to dependent home-based AD patients, it is considered necessary to study the challenges of caring for dementia patients caused by AD, with a target to improve the health and well-being of both the dependent elderly patient as well as the family caregiver. Public health policymakers need to adopt interventions that can reduce the challenges to family caregivers and improve the role of caregiving. This will help to improve the role of caregivers without affecting their health and thus will improve the well-being of both patients and caregivers [42, 44]. Even though home-based caregiving affects the health, family,

job, and social life of caregivers, it has many positive contributions. Firstly, it increases the patients' happiness, reduces loneliness, and improves well-being surrounded by their loved ones and close family members. Secondly, it saves the cost of hospitalization. As the care of AD patients is for a prolonged period and 24-hour care is similar to caring for a patient in ICU, the financial cost of hospitalization fees is huge, which is quite difficult to manage in the absence of health care support and insurance, especially for poor and middle-income families. Thirdly, it reduces the burden on the health care system. Due to these positive aspects, the WHO has encouraged healthcare systems to promote home-based palliative care. However, it is important to have collaboration and support from healthcare medical professionals and family caregivers to provide better reliable decision-making and guidance in everyday care, symptom management, and other critical care situations. Many studies from the above literature review reported challenges experienced by family caregivers while taking care of the elderly with AD. Some of the notable challenges include the emotional state, financial expenditure, negative health impact due to mental stress, physical fatigue, inadequate sleeping hours and social life, work stress for not being able to concentrate on office work, duties, going to the office late and returning home early by skipping office working hours, etc., as found in previous studies [32, 51]. Many family caregivers suffer from social isolation, deprivation of social and financial support, inadequate time for leisure or family life, and disruption of family relationships. All these factors can be a pioneer in impacting caregivers' and patients' well-being [41, 52]. Below are listed some main challenges as obtained from the above literature review:

- Depression, anxiety, and impact on the health of health caregivers physically as well as mentally
- Reduced earnings and finances due to negligence on the job
- More expenditure for patients with AD
- Need support, proxy decision-making, and guidance from expert health care professionals in symptom management, pain, and other needs when demanded of the patient,
- Fatigue and deterioration in social and family relations due to stress and insufficient time.

The findings of this article provide a better understanding of Alzheimer's disease, the importance of palliative care at home for elderly people with AD, and the challenges encountered in providing care. Understanding the disease symptoms and challenges experienced by caregivers can pave the way for solutions to palliative care teams with comprehensive care for AD elderly patients, as well as improving the health and well-being of both patients and family caregivers. In the end, it can be concluded that the knowledge obtained from this article can be useful to academicians, family caregivers, AD patients, policymakers, and medical professionals to solve the challenges of palliative care at home and to provide better care, symptom management, and pain management with minimal negative effect on the caregivers of elderlies with AD

through education, government support, and rehabilitation. Some recommendations for improvement are given below:

- Provide integrated palliative care in collaboration with healthcare providers to manage symptoms, have awareness of the signs of approaching death, and plan care [37].
- Make home-based palliative care fully functional needs development with the availability of all facilities for elderly care.
- Collaborate with public health organizations to improve the effectiveness of palliative care of the elderly at home through education, training programs, and research works [42, 44].
- Collaborate with family caregivers, medical staff, the community medicine palliative care team, and other health care professionals to manage the complex care needs of people with AD and solve any hurdles for family caregivers [42].
- Given the importance of reducing caregivers' burden and improving patients' well-being with AD, various aspects should be studied, including challenges encountered and factors causing the problem, through research studies, and then integrate applicable intervention measures in health care planning and policymaking of palliative care.

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Microalgae: Sustainable Cell Factories for Functional Foods and Ingredients

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Abstract

Microalgae are unicellular photosynthetic organisms that offer a sustainable solution for producing bioactive compounds essential for human health. Due to their biochemical versatility and minimal resource requirements, they serve as an efficient cell factory for synthesizing functional ingredients like proteins, omega-3 fatty acids, carbohydrates, vitamins, and antioxidants. This review highlights recent advancements in microalgal biotechnology, emphasizing their potential to meet the rising demand for diverse and nutritionally enriched foods. The adaptability and capacity of microalgae for genetic and metabolic engineering enable the production of targeted compounds, paving the way for tailored functional food and ingredient development. To achieve full-scale industrial implementation, it is imperative to address challenges including scaling up cultivation processes, optimizing metabolic pathways, and maintaining stable gene expression. The integration of systems biology with bioprocess engineering principles offers significant potential for improving productivity, advancing sustainability, and enhancing economic feasibility. As global dietary preferences evolve towards plant-based options, microalgae emerge as key players in reshaping the food and ingredient industries towards more environmentally conscious practices.

Keywords: Cell Factory, Functional Foods and Ingredients, Microalgae

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1. Introduction

Microalgae, a diverse group of unicellular photosynthetic organisms, have emerged as a promising frontier in the realm of sustainable biotechnology. Their microscopic size and ability to harness solar energy through photosynthesis make them efficient producers of a wide range of bioactive compounds essential for human health [1-2]. Microalgae are classified into various species such as *Chlamydomonas* sp., *Chlorella* sp., *Arthrospira (Spirulina)* sp., *Haematococcus* sp., etc., which are light-driven cell factories that synthesize bioactive compounds from primary metabolites such as lipids, proteins, and carbohydrates and secondary metabolites such as pigments, carotenoids, vitamins, and minerals at various their growth stages [3-4]. This biochemical versatility endows microalgae with considerable utility as valuable reservoirs for sustainably synthesizing functional ingredients, offering an environmentally conscientious alternative to conventional sources with a substantially diminished ecological footprint [5].

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The global population, set to reach 9.7 billion by 2050 according to the United Nations, propels a correlated surge in food demand [6-7]. Transformative shifts in dietary patterns, notably in emerging economies, manifest an inclination toward diverse, economically valuable foods. This trend aligns with a preference for nutritionally enriched diets and the growing popularity of functional foods, offering health benefits beyond basic nutrition [8]. The increasing consumer awareness of health and wellness has led to a notable shift in behavior, fostering a demand for food products that offer more than basic nutritional value. This demographic transformation substantively fuels the market for a variety of food products. The intricate interplay between demographic shifts, dietary preferences, and the demand for innovative food products underscores the multifaceted evolution of global food [6].

As consumers increasingly lean towards natural, plant-based options, microalgae offer a promising way to produce functional ingredients like omega-3 fatty acids, antioxidants, and protein-rich biomass or plant-based protein [4-5, 8]. This inherent versatility positions microalgae as dynamic cellular entities with the capacity to adapt to and address the evolving requirements of the food and nutraceutical sectors [6-8]. The latent potential of microalgae, as sustainable and adaptable cell factories, stands as a pivotal force capable of reshaping the paradigm of food and ingredient production. In contrast to conventional crops, microalgae necessitate minimal land and water resources, presenting an environmentally friendly alternative [5]. Notably, microalgae possess a distinctive capability to sequester carbon dioxide through photosynthesis [2-6]. Leveraging this trait, microalgae cultivation can be seamlessly integrated into carbon capture strategies, thereby mitigating greenhouse gas emissions [9]. Furthermore, microalgae contribute significantly to environmental remediation by extracting nutrients from wastewater. This dual functionality aligns seamlessly with the tenets of a circular economy and sustainable resource management. Consequently, these efficiencies culminate in a more sustainable production process characterized by diminished inputs and a mitigated environmental impact [10-11].

This review aimed to present the recent advancements in microalgal biotechnology, emphasizing their potential as cell factories for the production of bioactive compounds, which are utilized as functional food and ingredients essential for human health.

2. Biochemical Composition of Microalgae

The biochemical composition of microalgae is a harmonious blend of proteins, lipids, carbohydrates, pigments, vitamins, minerals, antioxidants, and other bioactive compounds. The diversity in nutritional content among different microalgae species presents a vast array of options for developing functional foods and ingredients [12].

2.1. Proteins

Microalgae contain a protein content that varies from 30-80 mass percent, and their protein production can exceed that of conventional land crops by more than 10 times [13]. Microalgal proteins possess a well-balanced amino acid profile, meeting the nutritional guidelines established by the WHO, FAO, and UNU for human and animal dietary requirements. Their capacity to provide essential amino acids in ample quantities designates these proteins as high-quality sources [14]. Certain microalgae as listed in Table 1, including *Haematococcus* sp. [14], *Chlorella* sp., *Dunaliela* sp. [15], *Nannochloropsis* sp. [16], and *Spirulina* sp. [17] are recognized as valuable protein sources due to their favorable amino acid composition such as alanine, arginine, glutamic acid, isoleucine, leucine, lysine, phenylalanine, threonine, and valine.

Table 1 The composition of amino acids in proteins present in different types of microalgae species

Amino acid	Amino acid content (g/100g protein)				
	H. pluvialis	*C. vulgaris*	*D. salina*	*N. oceanica*	*S. platensis*
Alanine	11.14 ± 1.44	10.82 ± 0.32	10.99 ± 0.32	2.95 ± 0.12	6.07 ± 0.20
Arginine	5.63 ± 0.37	7.33 ± 0.21	8.16 ± 0.24	2.60 ± 0.01	4.85 ± 0.12
Aspartic acid	1.42 ± 0.04	8.54 ± 0.25	9.56 ± 0.28	4.93 ± 0.02	7.24 ± 0.11
Cysteine	0.44 ± 0.02	1.47 ± 0.04	1.63 ± 0.04	0.26 ± 0.05	1.12 ± 0.02
Glutamic acid	8.96 ± 0.88	10.28 ± 0.30	12.41 ± 0.37	4.78 ± 0.03	9.04 ± 0.01
Glycine	9.60 ± 0.67	7.14 ± 0.21	8.71 ± 0.26	2.65 ± 0.01	3.94 ± 0.27
Histidine	1.85 ± 0.06	1.52 ± 0.04	1.73 ± 0.05	0.77 ± 0.01	8.06 ± 0.37
Isoleucine	1.85 ± 0.03	3.36 ± 0.10	4.09 ± 0.12	1.88 ± 0.03	4.66 ± 0.41
Leucine	8.13 ± 0.37	8.41 ± 0.25	9.58 ± 0.28	3.20 ± 0.04	6.13 ± 0.23
Lysine	8.70 ± 0.36	5.35 ± 0.16	5.99 ± 0.17	2.67 ± 0.01	6.84 ± 0.19
Methionine	1.79 ± 0.06	2.52 ± 0.07	2.79 ± 0.08	0.98 ± 0.01	1.91 ± 0.37
Phenylalanine	5.44 ± 0.26	6.17 ± 0.18	6.98 ± 0.20	2.27 ± 0.23	5.34 ± 0.30
Proline	5.50 ± 0.24	5.08 ± 0.15	5.23 ± 0.15	2.21 ± 0.02	1.65 ± 0.31
Serine	6.85 ± 0.56	4.34 ± 0.13	4.81 ± 0.14	1.60 ± 0.01	3.32 ± 0.62
Threonine	5.18 ± 0.47	5.46 ± 0.16	5.16 ± 0.15	2.23 ± 0.01	3.44 ± 0.23
Tryptophan	0.64 ± 0.03	0.21 ± 0.01	0.18 ± 0.01	n.d.	n.d.
Tyrosine	2.75 ± 0.14	4.34 ± 0.13	4.86 ± 0.14	1.32 ± 0.03	4.18 ± 0.11
Valine	2.94 ± 0.15	6.89 ± 0.20	7.23 ± 0.21	2.50 ± 0.01	6.41 ± 0.14
Ref.	[14]	[15]	[15]	[16]	[17]

2.2. Lipids and Fatty Acids

The capability of microalgae to convert carbon into valuable compounds makes them attractive for sustainable lipid production. The predominant components of most lipids derived from microalgae are glycerol and polyunsaturated fatty acids (PUFAs), featuring chains containing twelve or more carbon atoms. Microalgae contain various types of omega-3 fatty acids, primarily comprising long-chain fatty acids (LCFAs) and very long-chain fatty acids (VLCFAs) with carbon atom counts ranging from 16 to 22. Among these, α-linolenic acid (ALA, C18:3), eicosapentaenoic acid (EPA, C20:5), and docosahexaenoic acid (DHA, C22:6) exhibit the highest omega-3 fatty acid levels, collectively constituting over 13% of the total fatty acid [18-20]. Table 2 provides

information on microalgae species along with their omega-3 fatty acid contents. Interestingly, the current cost-effectiveness of producing algal PUFAs has outpaced that of biofuel production. As a result, a significant number of producers have redirected their attention to PUFA production for food, nutraceutical, and commodity oils [21].

Table 2 Lipid and free omega-3 fatty acid contents found in different microalgae.

Microalgae species	Lipid content (%w/w)	Omega-3 contents (% total fatty acid)			Ref
		ALA (C18:3)	EPA (C20:5)	DHA (C22:6)	
Chlorella sp.	28.00-53.00	13.20	1.30	n.d.	[22]
Dunaliella salina	6.00-25.00	38.4	0.05	5.12	[22]
Botryococcus braunii	9.55-26.00	11.20	2.23	3.88	[23]
Isochrysis sp.	22.00-34.10	6.30	0.90	15.00	[24]
Rhodomonas sp.	9.50-20.50	22.00	12.60	4.70	[24]
Nanochloropsis sp.	21.30-37.80	n.d.	30.80	n.d.	[24]

2.3. Carbohydrates

An essential group of macronutrient substances presented in the hydrophilic portion of microalgae biomass includes different categories of carbohydrates, with a particular focus on polysaccharides [12]. Microalgal cells contain a substantial proportion of polysaccharides, which can be categorized into three groups: structural cell wall polysaccharides (CWPS), reserve polysaccharides (RPS; such as α- and β-glucans), and extracellular polysaccharides (EPS). The diversity in microalgal cell wall structures leads to variations in the composition and configuration of CWPS, encompassing β-glucans, β-mannans, α-rhamnans, β-galactofuranans, and various heteropolysaccharides. Fibrillar components like cellulose or chitin contribute to microalgal cell wall formation. Branched starches and β-glucans are the prevailing RPS [25]. Specific genera of eukaryotic green and red microalgae, such as *Chlorella* sp*., Porphyridium* sp., *Rhodella* sp., *Botryococcus* sp., and *Dunaliellas* sp., alongside prokaryotic microalgae like *Nostoc* sp. and *Spirulina* sp., are recognized for producing substantial amounts of polysaccharides. Extracellularly released EPS forms protective layers to endure adverse environmental conditions, exhibiting cohesion and adhesion. Notably, these microalgal polysaccharides demonstrate diverse biological activities, including immunomodulation, antitumor, antibacterial, and antioxidant effects. Additionally, researchers have been examining microalgae polysaccharides and their derivatives, such as dietary fibers, as a promising prebiotic source for the development of functional foods and being utilized in medicinal applications [26].

Overview of microalgae species, their carbohydrate types, and applications in functional foods based on findings from various research studies were listed in the table 3. Microalgae carbohydrates are primarily composed of polysaccharides, starch, glycogen-like compounds, and exopolysaccharides. For instance, *Chlorella vulgaris* contains polysaccharides and dietary

fibers, which are beneficial for digestive health and act as prebiotics, promoting the growth of beneficial gut bacteria [27]. On the other hand, *Spirulina platensis* is rich in glycogen-like polysaccharides, which are particularly valuable in developing low-glycemic foods, such as gluten-free baked goods, for individuals with dietary restrictions [28]. Furthermore, *Porphyridium cruentum* produces sulfated polysaccharides, known for their potent antioxidant and immune-boosting properties, making them suitable for functional beverages designed to enhance immune health [29]. The starch and exopolysaccharides from *Dunaliella salina* serve as natural thickeners and gelling agents in food applications such as sauces, soups, and functional food gels [30]. Similarly, *Nannochloropsis gaditana* provides fiber-enriched ingredients for snacks and nutritional bars that promote digestive health [31]. In addition, the complex carbohydrates and astaxanthin-linked polysaccharides in *Haematococcus pluvialis* are of interest for antioxidant-rich dietary supplements and energy drinks [32]. Meanwhile, *Tetraselmis suecica* contributes mannans and galactans, which are used as stabilizers and emulsifiers in plant-based dairy alternatives, such as vegan yogurts [33].

Table 3 Microalgae-derived carbohydrates and their applications in functional foods.

Microalgae Species	Type of Carbohydrates	Applications in Functional Foods	Ref
Chlorella vulgaris	Polysaccharides, dietary fiber	Prebiotic supplements for gut health; low-calorie food additives	[27]
Spirulina platensis	Glycogen-like polysaccharides	Low-glycemic index ingredients; gluten-free baked goods	[28]
Porphyridium cruentum	Sulfated polysaccharides	Antioxidant-rich functional beverages; immune-boosting supplements	[29]
Dunaliella salina	Starch, exopolysaccharides	Natural thickeners in sauces and soups; functional food gels	[30]
Nannochloropsis gaditana	Cell wall polysaccharides	Fiber-enriched snacks; nutritional bars targeting digestive health	[31]
Haematococcus pluvialis	Complex carbohydrates, astaxanthin-linked polysaccharides	Antioxidant-rich dietary supplements; energy drinks	[32]
Tetraselmis suecica	Mannans, galactans	Stabilizers in dairy alternatives; emulsifiers in plant-based yogurts	[33]

2.4. Pigments, Vitamins, Minerals and Antioxidants

Microalgae exhibit a vibrant spectrum of pigments, including chlorophylls, carotenoids, and phycobiliproteins. Chlorophyll imparting the green color associated with various microalgae species such as *Chlorella* sp., *Chlamydomonas* sp. and *Nannochloropsis* sp. are frequently employed in commercial production [3]. Carotenoids, such as astaxanthin found in *Haematococcus* sp. and β-carotene found in *Dunaliella* sp., contribute to red, orange, and yellow hues. These pigments not only serve as natural colorants in food but also possess antioxidant properties, enhancing the stability of functional products. Microalgae are rich sources of vitamins, including B-complex vitamins (B1, B2, B3, B6, B12) and vitamin E [12]. *Spirulina* sp., for example, is recognized for its high vitamin B12 content, making it a valuable option for plant-based diets that may lack this crucial nutrient. *Chlorella* sp. is another microalga rich in vitamins, particularly vitamin C and vitamin K, as well as minerals such as magnesium and zinc. Additionally, *Dunaliella salina* stands out for its beta-carotene content, contributing to its role as a potent antioxidant [3]. *H. pluvialis* is rich in astaxanthin, comprising 4–5% of its dry weight exhibiting various health benefits including antioxidative,anticancer, antidiabetic, and anti-inflammatory effects [4-5].

3. Advancements in Microalgal Cell Factory

Microalgae boast a remarkable metabolic complexity allowing for the production of an array of unique algae-specific compounds. Consequently, they have become heralded as versatile multiproduct cell factories. Generally, microalgae thrive on minimal resources such as light, CO_2, water, and minerals, essential for their growth through photosynthesis. However, they can also utilize additional nutrients to expedite their growth as demonstrated in Figure 1. Notably, their biochemical composition is highly adjustable through manipulating cultivation conditions, offering significant control over their output [34]. Traditionally, microalgae were cultivated in basic open ponds; however, recent advancements in research and technology have resulted in a wide range of efficient bioreactor designs optimized for high productivity [1]. In studies focusing on photobioreactors, researchers have investigated the cultivation of microalgae such as *Chlorella vulgaris* and *Nannochloropsis* sp [35]. These species are suitable for cultivation in controlled environments provided by photobioreactors, where factors such as light intensity, temperature, and nutrient availability can be precisely regulated. By fine-tuning these parameters, researchers have achieved higher biomass yields and enhanced production of functional ingredients such as omega-3 fatty acids and antioxidants [23].

Microalgae possess diverse metabolites that can be harnessed to create various compounds. Application of genetic and metabolic engineering methodologies becomes feasible to augment the synthesis of targeted compounds, modify extant biochemical products, or even introduce entirely novel metabolic pathways [34]. Genetic engineering holds promise for high-productivity strains, targeting fermentable carbohydrates or fatty acids. Strategies involve enhancing photosynthesis, modifying enzymes for lipid production, and identifying limiting steps [2]. Research in this area has yielded encouraging results across different enzymes and microalgae species, identifying potential target genes and organisms for further investigation [9]. Recent advancements in transformation methods have facilitated genetic manipulation in

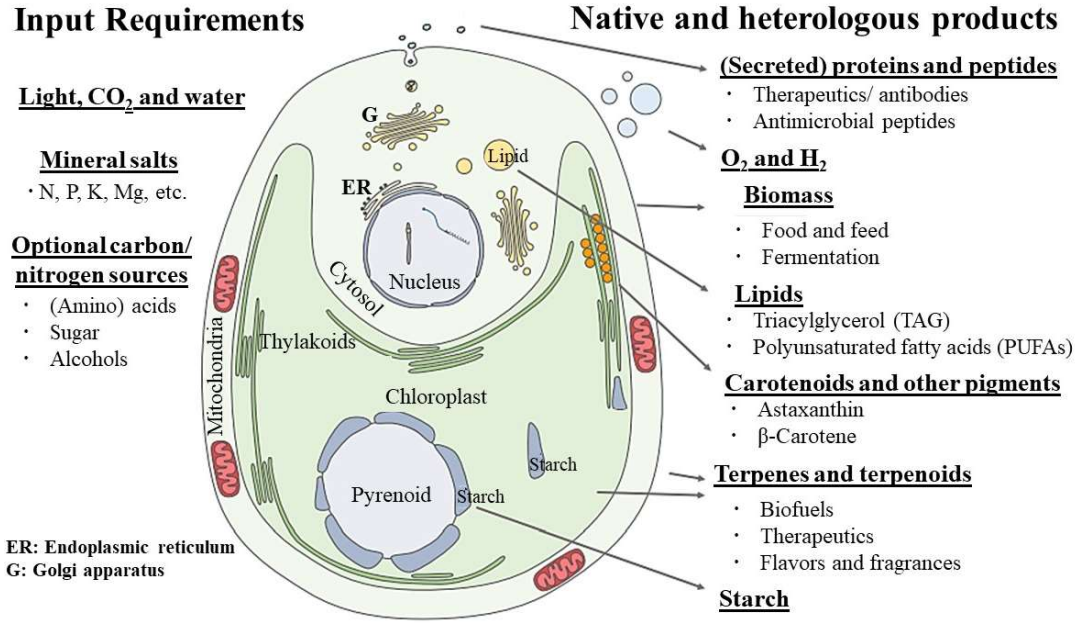

Figure 1 The cell structure of microalgae and diversity of microalgal cell factory products (Adapted from Einhaus, Baier & Kruse [34]).

various microalgal species, including lipid-producing ones like *C. reinhardtii*, *P. tricornutum*, and *Nannochloropsis* sp. Various techniques such as nanoparticle bombardment, glass bead agitation, bacterial conjugation, agrobacterium transformation, and electroporation enable the introduction of genetic material into the cell nucleus, primarily to manipulate gene expression [18]. Another promising approach is manipulating transcription factors, which can regulate multiple metabolic pathways simultaneously, offering the potential for comprehensive intervention. By redesigning enzymes in the carotenoid pathway and systematically screening for bottlenecks of *C. reinhardtii*, significant advancements have been made in enhancing astaxanthin production. A combined strategy involving the expression of β-carotene ketolase, phytoene synthase, and β-carotene hydroxylase, astaxanthin production levels have been substantially increased, offering promising prospects for industrial biotechnology [36]. Redirecting metabolic flux through the manipulation of enzyme activities and substrate availability in metabolic pathways leads to the production of target compounds. The development of the genome-scale model integrates 837 genes, 887 reactions, and 801 metabolites (iMS837) for *Synechococcus elongatus* PCC7942, representing a significant advancement in understanding and utilizing this cyanobacterium as a microbial cell factory. The iMS837 enhances comprehension of vital metabolic pathways such as fatty acid biosynthesis, oxidative phosphorylation, photosynthesis, and transport. Computational analysis with the iMS837 model identified novel targets like *fab*F enzyme overexpression, augmenting omega-3 fatty acid production [37].

4. Challenges and Future Directions

While the potential of microalgae as cell factories for functional foods and ingredients is promising, several challenges must be addressed to realize their full commercial and industrial potential. Scaling up microalgal cultivation to industrial levels while

maintaining high productivity and purity remains a significant challenge. Optimization of culture conditions is crucial for maximizing biomass and metabolite production [24]. Altering metabolic pathways to enhance the production of desired compounds poses challenges in balancing target compound synthesis with cellular growth and viability. Additionally, ensuring stable gene expression and minimizing metabolic burden is critical for successful metabolic engineering efforts [36]. Continued efforts in strain selection and genetic manipulation are needed to develop high-yielding microalgal strains with enhanced productivity and adaptability [2]. Advanced bioreactor designs and process control strategies should be developed to optimize cultivation while minimizing resource consumption and environmental impact [35]. Integration of systems biology and/or synthetic biology approaches with bioprocess and metabolic engineering can provide insights into microalgal metabolism and facilitate optimized strain and cultivation process design [1, 9]. Implementation of biorefinery concepts for integrated production of multiple value-added products can enhance overall process economics and sustainability.

5. Conclusion

Microalgae represent a promising frontier in sustainable biotechnology, offering diverse bioactive compounds crucial for human health. Their adaptability, coupled with genetic and metabolic engineering capabilities, positions them as versatile cell factories addressing evolving industry demands. Microalgae provide functional ingredients like proteins, omega-3 fatty acids, carbohydrates, vitamins, and antioxidants, enhancing nutrition and product stability. Advancements in cultivation, genetic manipulation, and metabolic engineering have bolstered their productivity and specificity. By optimizing conditions and leveraging their metabolic complexity, microalgae can revolutionize functional food and ingredient production sustainably.

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Utilization of Filipino Sign Language-Sight Words Intervention (FSL-SWI) to Increase the Literacy Skills of Deaf and Hard-of-Hearing (DHH) Pupils

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Abstract

Having a vast repertoire of sight words that they are familiar with from previous literature will assist young readers in recognizing words by sight or memory. Due to their unique learning characteristics, Deaf and hard-of-hearing (DHH) students may find reading challenging. Given their inclination for visual learning, sign language serves as their primary means of communication. The majority of Filipino DHH students struggle to comprehend Filipino-written terminology. Results from the Phil-IRI screening tests conducted on pupils in grades 4, 5, and 6 show that they fall under the frustration level. The main goal of this study is to use an intervention known as Filipino Sign Language-Sight Words Intervention (FSL-SWI) to alleviate the difficulties DHH learners face in learning Filipino-written words. The intervention involved using multimedia teaching materials that are accessible on all Android and iOS devices. A mixed-methods technique was employed in the study to gather both quantitative and qualitative data. Pre- and post-tests were administered to 89 students in grades 4, 5, and 6 who participated as student participants to collect quantitative data. The significant increase in mean percentage scores seen in the pre-and post-test findings suggests that the use of FSL-SWI is a potent and successful multimedia learning intervention that can assist DHH learners in expanding their vocabulary in Filipino. The post-test results indicated that following the intervention, the learners reached an independent reading level, showing proficiency in using sign language to function independently and comprehend information effectively. On the other hand, survey forms and focus group interviews with selected stakeholders were utilized to gather qualitative data. The focus group interview generated three themes for this study: Filipino sign language variation, sign language training for parents/guardians, and easy access to multimedia. All stakeholders rated the FSL-SWI positively overall. Based on feedback and evaluation, FSL-SWI is strongly recommended as an intervention to help students in grades 4, 5, and 6 expand their Filipino vocabulary.

Keywords: sight words, deaf and hard-of-hearing education, Filipino Sign Language, multimedia

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1. Introduction

Reading is undeniably one of the most essential life skills acquired by young children. Primary school students are typically anticipated to read fundamental texts by the commencement of second grade. Sight words, or high-frequency words, are commonly found in texts and can enhance learning. The capacity to acquire an extensive vocabulary of sight words will enable young readers to recognize terms they are familiar with or have previously encountered through memory or visual recognition [1]. Children acquiring reading

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skills are taught to enhance their phonics proficiency, phonemic awareness, and capacity to comprehend written language and sight words to become competent readers. [2]. Sight word recognition facilitates effortless reading [3], allowing readers to avoid pausing to decipher unknown words, thereby maintaining focus and enhancing comprehension of the material [1].

Deaf and hard-of-hearing (DHH) learners have distinct learning traits that may exacerbate their challenges with reading. Sign language serves as their principal means of communication owing to their preference for visual learning. The literacy development of these youngsters is markedly inferior to that of their hearing counterparts of the same age. [4]. There are two broad components to the reading challenges faced by DHH students - the challenge of accessing phonology, and the challenge of recognizing the differences between the structure of a written language and the structure of a signed language [5]. It is observed that children who use spoken language and who have hearing loss lag their peers with normal hearing in terms of the development of phonological awareness, which is related to the development of literacy [6]. In addition, children with hearing loss are more likely to experience a delay in vocabulary development than those with normal hearing. This is due to the fact that their receptive and expressive lexicons are smaller, and their word learning abilities are altered [7]. Based on the findings of two studies, there is some preliminary evidence that individuals with hearing loss may have a relative advantage in the acquisition of print knowledge [8]. However, these studies primarily focused on alphabet knowledge, as opposed to a more comprehensive understanding of print. It was argued by Werfel [6], and Lund [7] that this conclusion was contrary to reality. Concerning alphabet knowledge, preschoolers with hearing loss demonstrated comparable or occasionally superior performance to their peers with normal hearing. In comparison to their peers, children with hearing impairments exhibited substantially lower conceptual print knowledge scores. Therefore, it can be contended that conceptual print knowledge is one of the domains in which children with hearing loss exhibit a sizeable deficit [6].

Madronio's [9] research demonstrates the critical role of accessibility, layout, and content in the development of educational interventions that target the enhancement of the written vocabulary of DHH learners in Filipino. To determine whether children at certain grade levels can read texts at an age-appropriate level, the Philippine Informal Reading Inventory (Phil-IRI) is used as a tool by the Philippine Department of Education to assess their reading abilities [10] and to aid in identifying the interventions needed by learners. Nevertheless, it is crucial to recognize that the Phil-IRI manual [11] is tailored to the needs of regular and hearing learners. The school year 2022-2023 is the pilot year of the Philippine School for the Deaf (PSD) to utilize Phil-IRI in Filipino Language.

The Phil-IRI screening test results for students in grades 4, 5, and 6 indicate that they are at the Frustration Level. As a result, the majority of the students scored below 14 and required reading intervention in Filipino.

Figure 1 shows the grade 4 performance level in the Phil-IRI screening test results for the 2022–2023 academic year. Section Narra, Mahogany, and Yakal got mean percentage scores of 32.2%, 28.15%, and 15%, respectively, with a total average performance of 25.1% that falls under the frustration category of reading.

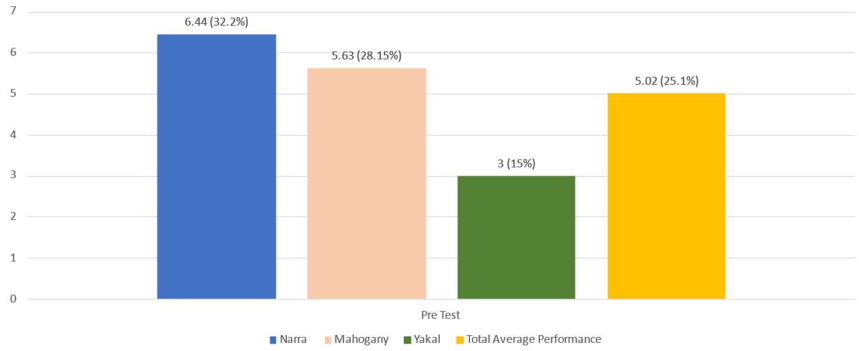

Figure 1. Grade 4 Phil-IRI Screening Test Results (School Year 2022-2023)

Figure 2 presents the results of the screening tests for learners in grade 5. They also consist of three (3) sections, Jupiter, Earth, and Venus, with mean percentage scores of 28.35%, 16.1 %, and 24.45%, respectively.

The total average performance of this grade level is 22.95%, which also falls under the frustration level of reading.

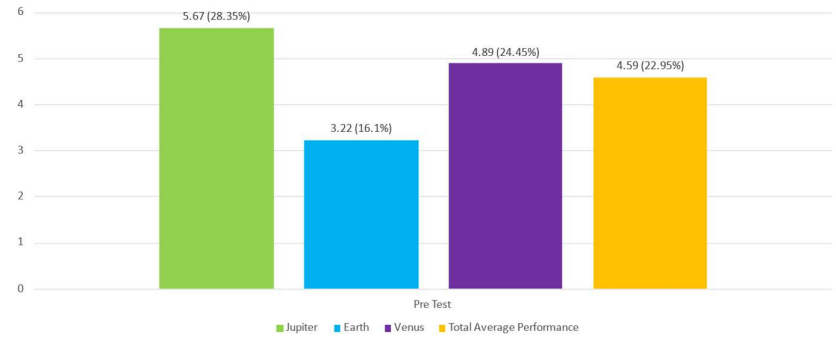

Figure 2. Grade 5 Phil-IRI Screening Test Results (School Year 2022-2023)

The grade 6 performance level on the Phil-IRI screening test for that same academic year is summarized in Figure 3. Like the previous grade levels, it's also composed of 3 sections, Star, Meteor, and Asteroid. MPS of these sections were 20.2%, 18.2%, and 17.25%, respectively with a total average performance of 18.55% which also falls under the frustration category of reading.

The aforementioned data demonstrates that the written Filipino language is unfamiliar to the majority of Filipino DHH learners. The primary objective of this study is to provide an effective intervention that will enhance the literacy levels of DHH students in Filipino vocabulary. Specifically, the study aims to utilize the Filipino Sign Language Sight Words Intervention (FSL-SWI) through multimedia presentations to increase their vocabulary in Filipino words. Table 1, the Table of Abbreviations was developed to guarantee clarity and facilitate understanding of this work. It will serve as a quick reference tool for readers.

Figure 3. Grade 6 Phil-IRI Screening Test Results (School Year 2022-2023)

Table 1. *Table of Abbreviation*

FSL-SWI	Filipino Sign Language Sight Words Intervention
Phil-IRI	Philippine Informal Reading Inventory
DHH	Deaf and Hard-of-Hearing
DepEd	Department of Education
MPS	Mean Percentage Score

1.1 Conceptual Framework

Given that the Phil-IRI was intended for regular and hearing learners, and the screening tests of grades 4, 5, and 6 were classified as "frustrated," the special education teachers at the Philippine School for the Deaf (PSD) who instruct the Filipino subject must identify an appropriate intervention to resolve these literacy obstacles. Through the use of the Filipino Sign Language Sight Word Intervention (FSL-SWI), students engage in an active learning process that helps them to mimic the sign language they observe in multimedia presentations and comprehend the meaning of the word. Figure 4 shows the conceptual framework of the study. The execution of sign language, words, and images are the intervention's primary characteristics. The word's definition is illustrated in the image. The learner's vocabulary in Filipino is anticipated to be enhanced by the written text.

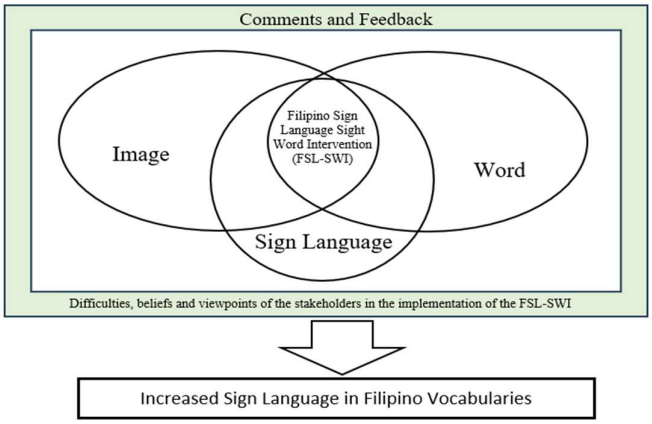

Figure 4. The Conceptual Framework of the Study

The text is manually read through the use of sign language. Enclosed within a box, the FSL-SWI displays the comments, suggestions, and input from the chosen stakeholders. The goal of the study is to assist DHH students in expanding their Filipino language vocabulary.

2. Research Questions

2.1 What was the DHH learners' level of Filipino vocabulary in grades 4, 5, and 6 prior to using FSL-SWI?

2.2 What is the Filipino vocabulary level of DHH learners in grades 4, 5, and 6 after utilizing the FSL-SWI?

2.3 What are the difficulties, beliefs, and viewpoints of the stakeholders in the implementation of FSL-SWI?

HYPOTHESIS (H_0)

Filipino Sign Language Sight Words Intervention (FSL-SWI) does not increase the DHH learners' Filipino vocabulary.

3. Methodology

Figure 5 displays the visual diagram of the methodology process utilized in this study. A quantitative and qualitative data collection process was used in the design [12]. Participants' pre-and post-test results were analysed using quantitative research methods. Surveys and semi-structured interviews were utilized in the qualitative section to gather perspectives, ideas, and opinions from some selected stakeholders.

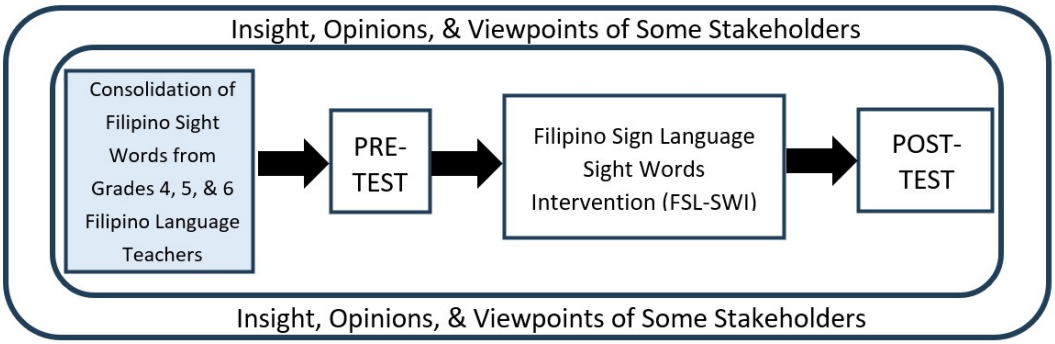

Figure 5. Visual Diagram of the Methodology Process

3.1 Population and samples. The participants of the study were pupils from grades 4, 5, and 6 enrolled in the pioneer government-owned sign language institution that offers basic education in the Philippines, for the school year 2022-2023. The gender breakdown of participants is displayed in Table 2. 51 or 57% were males and 38 or 43% were females.

Table 2. *Distribution Participants According to Gender*

Gender	Grade 4	Grade 5	Grade 6	Frequency	Percentage
Male	12	18	21	51	57%
Female	14	13	11	38	43%
Total	26	31	32	89	100%

The predominance of male participants is evident in this research study. For the academic year 2022–2023, the participation percentage is 100%, which reflects the whole PSD upper-grade population.

Purposive sampling method was utilized in selecting stakeholders to evaluate the FSL-SWI. They are in line with the Department of Education's (DepEd) efforts to increase the literacy of DHH learners. Further, their willingness to participate was strongly demonstrated during the voluntary selection procedure. They represent the various stakeholders which include

learners, parents, teachers, the hard-of-hearing, and the Deaf community.

Table 3 summarizes the profile of the stakeholder participants who participated in the interview and focus group discussion. It presents their age, profession, and hearing ability/loss.

Table 3. *Profile of the Participants in the Evaluation of the FSL-SWI Intervention*

Participants	Age	Gender	Profession	Hearing Ability/Loss
A	13	Male	Pupil	Profound
B	15	Female	Pupil	Severe
C	36	Female	Parent	Regular Hearing
D	41	Male	Parent	Profound
E	33	Female	Deaf teacher	Profound
F	58	Female	Teacher	Regular Hearing
G	36	Female	Teacher	Hard-of-Hearing

3.2 Research Instrument

The FSL-SWI Vocabulary Form, a 50-item list including columns for Filipino vocabulary, a pre-test, a post-test, and a remarks column, was the validated evaluation tool used in the study to gather quantitative data. The instrument used in this study was validated by master teachers, and a Deaf teacher using a five-point Instrument Rating Scale. The validators gave a rating of 4, an Agree Interpretation, which suggests that the research instrument is valid and recommended to gather relevant data for the study. Most of the items were taken from the stories in the Phil-IRI manual. Some vocabularies were carefully selected by the Filipino teachers themselves.

Sign language is executed twice. The Filipino vocabulary is presented first, then fingerspelling, another manual sign language, images, and another manual sign language. Figure 6 shows the sample multimedia of the Filipino Sign Language Sight Words Intervention.

Figure 6. Sample Multimedia of FSL-SWI

Each slide presentation contains Filipino-written words, an image, and manual sign language. The study adopted the "Reading Level Proficiency Rubric" of the Philippine Informal Reading Inventory (Phil-IRI) to measure and describe the level of the vocabulary of the pupils [11]. Scores of the participants were recorded in the Level of

Vocabulary Competency Form to ascertain the extent of their Filipino vocabulary proficiency. It has a scale rated as follows: 0-15, Frustration Reading Level, which means that the learner finds the FSL-SWI so difficult that they cannot successfully respond to them [13]; 16-35, Instructional Reading Level, which means that the learner profits the most from teacher-directed instruction in Filipino vocabularies; and 36-50, at the Independent Reading Level, students can read and comprehend nearly flawlessly on their own using manual sign language.

To evaluate the intervention's overall impression and applicability in terms of content, layout, and accessibility features, qualitative data were gathered for this study using the FSL-SWI Feedback Form. It is a five-point Likert scale, and the answers are indicated by ticking the box next to the number that represents the assessors' answers. The following ratings were given to the criteria on the aforementioned scale: 5-Strongly Agree, 4-Agree, 3-Neutral, 2-Disagree, and 1-Strongly Disagree. The weighted means were interpreted using the same arbitrary scale. Additionally, it has a comments section where stakeholders can provide specific feedback and suggestions. In order to ascertain the obstacles, viewpoints, and opinions of the stakeholders about the FSL-SWI, focus group interviews were also held.

3.3 Data Analysis

The collected data was examined using the subsequent statistical instruments:

3.3.1 Mean. When the data were divided into groups before and after the FSL-SWI, the mean was used to determine the scores of the DHH students in grades 4, 5, and 6.

3.3.2 Paired Sample T-Test. The outcomes or mean scores from the pre-and post-test were compared using the Paired Sample T-Test.

3.3.3 Thematic Analysis. The focus group interviews yielded specific themes that were identified through the application of thematic analysis.

4. Results and Discussion

The following findings from a study on increasing the vocabulary of DHH learners in grades 4, 5, and 6 with FSL-SWI intervention are reported in accordance with the previously stated research goals:

4.1 To ascertain the difference between the learners' levels of Filipino vocabulary in grades 4, 5, and 6 before and after completing the intervention program, data were painstakingly recorded, tabulated, and assessed using a paired sample t-test. To make it simple to identify variations, the data is provided in tabular form. The pre-and post-test findings of the 89 participants in the researcher's 50-item test, administered both before and after the use of the FSL-SWI, are displayed in Table 4.

The grade 4 pupils acquired an MPS of 10 in their pre-test and 83.23 for their post-test result. Learners of grade 5 scored 8 MPS on their pre-test and 80 MPS on the post-test. The grade 6 pupils got 14 and 82 MPS in their pre and post-test, respectively.

Table 4. *Mean Percentage Scores (MPS) of Pre-Test and Post-Test*

Grade Level	No. of Items	No. of Pupils	PRE-TEST MPS	POST-TEST MPS	Difference
4	50	26	10	83.23	73.23
5	50	31	8	80	72
6	50	32	14	82	68

Table 4 makes it abundantly evident that, following the use of the FSL-SWI, participants' MPS of the pre-test increased significantly, with differences of 73.23 (grade 4), 72 (grade 5), and 68 (grade 6). This is a noteworthy indication that using FSL-SWI is a powerful and successful learning material intervention to help DHH learners expand their vocabulary in Filipino. The total level of Filipino vocabulary attained by the students in the upper grades is displayed in Table 5.

Table 5. *Level of Filipino Vocabulary*

Grade Level	AVERAGE PRETEST RESULTS	*Proficiency Scale	AVERAGE POST-TEST RESULTS	*Proficiency Scale
4	5.31	Frustration Reading Level	44.88	Independent Reading Level
5	4.90	Frustration Reading Level	42.64	Independent Reading Level
6	4.66	Frustration Reading Level	41.71	Independent Reading Level

** The Reading Level Proficiency Rubric of Phil-IRI served as the basis for the Proficiency Scale.*

The literacy levels of all students in the upper grades who participated in the pre-test were below the frustration threshold. This suggests that the learners were unable to adequately respond to the Filipino vocabulary prior to the implementation of the FSL-SWI, as they found it to be exceedingly difficult. The average post-test scores, which are in the independent reading level, showed that the FSL-SWI had a good influence. Grade 4 obtained the highest post-test result, 44.88, followed by Grade 5 at 42.64 and Grade 6 at 41.71. This implies that after the intervention, upper-grade learners can function independently and have strong comprehension when using sign language. It was also noted that the learners sign along with the multimedia intervention's content, which is similar to reading the words aloud. The intervention program called Filipino Sign Language- Sight Word Intervention (FSL-SWI) is a very effective intervention in improving the Filipino vocabulary of DHH learners.

4.2 The t-test's outcome for identifying a significant difference between the pre-and post-test findings is displayed in Table 6.

Table 6. *T-Test Result on Finding the Significant Difference in the Means of the Grades 4, 5, and 6 Pupils Before and After the Utilization of the FSL-SWI*

Variables Compared	DF	MPS	Computed t-value	Critical t - value	Decision	Impression @ 0.05 Level
Grade 4						
Pre-Test (X_1)	25	10.61	33.93	1.70	Reject H_o	Significant
Post-Test (X_2)		89.77				
Grade 5						
Pre-Test (X_1)	30	9.81	30.56	1.69	Reject H_o	Significant
Post-Test(X_2)		85.29				
Grade 6						
Pre-Test (X_1)	31	9.31	24.64	1.69	Reject H_o	Significant
Post-Test(X_2)		83.43				

The researchers rejected the null hypothesis, which is significant at the 0.05 level, based on the data collected from the grade 4 students, which yielded a computed t-value of 33.93 and a critical level of 1.70. The researchers rejected the null hypothesis, which is significant at the 0.05 level, based on the grade 5 participants' computed t-value of 30.56 and critical t-value of 1.69. With the learners' grade 6 data, the researchers rejected the null hypothesis, which is significant at the 0.05 level, with a computed t-value of 24.64 and a critical t-value of 1.69. The impressive increase in the mean following the use of FSL-SWI suggests that there was a very notable improvement in the Filipino vocabulary of students in grades 4, 5, and 6.

4.3 The difficulties, beliefs, and viewpoints of the FSL-SWI stakeholders are listed in Table 7. It received a score of 4.59 and was interpreted as strongly

agreeable. This clearly indicates that FSL-SWI should be utilized as an intervention to assist students in grades 4, 5, and 6 in expanding their Filipino vocabulary.

Table 7. *FSL-SWI Feedback and Evaluation Form*

Criteria	**Stakeholders**				**WM**	**INT**
	1	**2**	**3**	**4**		
The contents of FSL-SWI are …						
1. accurate and are based on the Most Essential Learning Competency (MELC) Self Learning Modules of DepEd	4	4	4	5	4.25	Agree
2. current and are based on the Most Essential Learning Competency (MELC) Self Learning Modules of DepEd	4	4	4	5	4.25	Agree
3. suited for the deaf and hard-of-hearing (DHH) learners	5	5	5	5	5	Strongly Agree
4. level appropriate to the grades 4, 5, and 6 DHH learners	4	5	5	4	4.5	Strongly Agree
The layout …						
5. makes it easy for the DHH learners to process graphics, text and sign language	3	5	4	5	4.25	Agree
6. of the FSL-SWI intervention is consistent	4	4	5	5	4.5	Strongly Agree
7. is clear and logical	4	5	4	5	4.5	Strongly Agree
8. words and subtitles are clearly visible	5	5	5	5	5	Strongly Agree
Accessibility…						
9. The FSL-SWI intervention accommodates the unique learning style of DHH pupils	4	5	4	5	4.5	Strongly Agree
10. The FSL-SWI intervention can be utilized by the DHH learners without much help from the teacher.	4	5	5	5	4.75	Strongly Agree
11. The FSL-SWI intervention can be accessed in any type of computer	5	5	5	5	5	Strongly Agree
Total:					**4.59**	**Strongly Agree**

Legend: WM – Weighted Mean; INT – Interpretation

The focus group interview produced three themes that were found in this study. These are:

4.3.1 Filipino Sign Language Variation. The selected stakeholders emphasized the need to be familiar with the various varieties of Filipino Sign Language. It is worth noting that the Deaf community does not have a universal sign language to bind its members [14]. Madronio [15] explained that sign variation is unavoidable in the Philippines due to its geographical peculiarities. As a result, variety occurs naturally in both spoken and sign languages, which is an important aspect of any linguistic study. Sign languages, like spoken languages, vary significantly according to sociolinguistic context. This variability can be influenced by factors such as region, age, gender, education, family history, social status, ethnicity, registration, and language [16]. Some vocabularies (*anak*, *baboy*, *lagi*, *wala*) included in the FSL-SWI need to include sign variations in FSL for early awareness of the individual who utilizes the intervention.

4.3.2 Sign Language Training to Parents/Guardians. Most of the selected stakeholders believe that learning sign language is not only applicable to the enrolled learners in school but also to the parents and guardians. They unanimously agree that intensive sign language training is essential to attain efficient and effective communication with their deaf children. Hence, literature shows that most researchers in the field of sign language education, believe that the Deaf community's expertise and experience are infused into every facet of a successful sign language instruction because they are crucial language and cultural role models [18] [19] [20]. Parents must initially learn sign language, sometimes concurrently with their child, before the child may begin using it. The child's linguistic access will improve in tandem with the parents' fluency. Immediate and positive information on learning sign language and developing social networks is particularly crucial for families and

caregivers, as it greatly impacts the attitudes that these individuals have toward deafness and, in turn, the linguistic strategies that they undertake [21].

4.3.3 Easy Access to Multimedia. FSL-SWI multimedia is straightforward to use for many stakeholder participants. Watching it multiple times helps students remember the manual sign language for a specific Filipino vocabulary. Furthermore, they believe that this type of innovation is critical and can be replicated in other learning domains. This multimedia helps the DHH learners to focus better and to improve their understanding of written vocabulary [22].

5. Summary and Conclusions

Based on the results and discussions drawn from this study, the following are the conclusions and recommendations made by the teacher-researchers:

5.1 Based on the findings of the pre-and post-tests, it was clear that the FSL-SWI was successfully implemented with DHH learners in grades 4, 5, and 6. After using FSL-SWI, the mean significantly increased, indicating that the Filipino vocabulary of students in grades 4, 5, and 6 significantly improved.

5.2 It was also noted that the students signed along with the multimedia intervention's content, which is similar to reading the words aloud. The intervention program called Filipino Sign Language- Sight Word Intervention (FSL-SWI) is a very effective intervention in improving the Filipino vocabulary of DHH learners.

5.3 The FSL-SWI evaluation and feedback from the chosen stakeholders reveals a Strongly Agree rating of 4.59, indicating that FSL-SWI should be utilized as an intervention to help students in grades 4, 5, and 6 expand their Filipino vocabulary.

5.4 The result of the focus group interview reveals the importance of Filipino sign language (FSL) variations, FSL training to parents and/or guardians, and easy access to multimedia as contributing factors in the enhancement of the learners sign language and written vocabularies.

5.5 To help DHH learners expand their vocabulary in the Filipino learning area, it is advised that they utilize the established FSL-SWI intervention as instructional resources.

5.6 The FSL-SWI intervention can potentially be extended to other learning domains to support the development of deaf and hard-of-hearing learners' written vocabulary.

5.7 To overcome the observed shortcomings of this study, more comparable research might be conducted.

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Phronetic Leadership Contextualized in Higher Education: The Case of Ifugao State University, Philippines

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Abstract

Wise, or phronetic leadership (PL), which is embedded in the socialization, externalization, combination, and internalization (SECI) model, contributes greatly to the achievement of organizational goals. This case study contextualized PL at Ifugao State University (IFSU) and aimed to create a PL framework for Administrative Council (ADCO) officials and student leaders. The main participants were the ADCO members of IFSU who traveled from Ifugao to Central Luzon State University (CLSU). The ADCO members of CLSU served as counterparts to the ADCO officials of IFSU for the creation of a university-wide PL framework. For the students' PL framework, the participants consisted of student leaders, advisers, and the Department of Student Services and Development (DSSD) director. Focused group discussions and interviews were undertaken to collect data. The data gathered were analyzed, explained, translated, and processed. As a result, a PL framework for the administrative council members was created. The framework illustrates how the SECI model guides university officials in carrying out their responsibilities. A PL framework for student leaders that describes how the students can successfully apply the SECI model was also crafted. The findings show that PL is applicable in higher education institutions.

Keywords: Phronesis, practical leaders, SECI model, tacit and explicit knowledge

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1. Introduction

The influence of educational leadership is most profound when it directly addresses the learning requirements of students and aligns with desired educational outcomes. Leaders in higher education undertake various roles and responsibilities [1]. Working with others is the very essence of leadership [2]. The servant leadership approach adopted can result in employee satisfaction within academic settings, hence, encouragement from leaders correlates with enhanced performance and increased employee retention [3]. The study and implementation of leadership styles play a significant role in shaping the success of schools. The research concludes that when educational leadership fails, the targets set for the organization will likely fail [4].

The application of indigenous phronetic leadership (PL) was exemplified in the Philippines by Elorde P. Anniban. His practice of PL spearheaded transformative reforms in collaboration with the government of Santa Marcela in the Province of Apayao. A pivotal outcome of this leadership approach was the construction of a dam, stemming from innovative ideas generated during informal discussions with local farmers. These dialogues proved instrumental in addressing issues such as low rice production and poverty within the municipality [5]. Building upon this groundwork in PL, the same researcher extended inquiry to contextualize its application at Ifugao State University (IFSU), a

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government higher education institution in the Philippines.

It is recommended that higher education researchers explore leadership and management in education from the perspective of phronesis [6]. IFSU lacked studies on PL and a guiding PL framework for its implementation when the study was conducted. Recognizing the significance of investigating PL, this research endeavor has the potential to establish this framework and offer further practical implications for IFSU. Moreover, the insights gleaned from this study could be applied across other State Universities and Colleges (SUCs), enhancing leadership practices within the broader educational landscape.

Leaders in higher education are confronted with a diverse array of problems that demand a new breed of leaders who can explore the challenges and envision innovative solutions toward transformative change. Developing leaders is important, but those participating in leadership development programs are usually existing leaders and new candidates. Not all leadership programs include mentoring and coaching to intensify leadership development [7]. Organizations must consider the scenarios where leaders will perform their roles and responsibilities. This will enable them to plan appropriate strategies and techniques for leadership development, evaluation, and promotion [8]. Higher education leaders also face challenges and issues involving the ability to respond to change, strategic leadership, flexibility, creativity, managing resources, and good working relationships [9]. This is similar to Estonia and Finland, where similar concerns were identified among school leaders, such as professional development, curriculum alignment, and community engagement [10].

Phronesis, or practical wisdom, which is drawn from Aristotle's virtue ethics, is vital in leadership. It points out the dual nature of humanity, recognizing that individuals possess both rational and irrational tendencies [11]. The revival of phronesis and moral education has positioned them at the forefront of contemporary educational research [12]. Phronetic Leaders have six abilities [13]: 1. *Wise leaders possess the ability to discern goodness,* signifying that phronetic leaders consistently prioritize actions aligned with ethical principles, moral discernment, and a commitment to excellence while maintaining a visionary outlook. Practicing ethical standards and establishing trust in leadership improves the performance and satisfaction of employees [14]. Leaders must simplify information and enable group members to understand the vision and plans of the organization [15]. Promoting ownership of the vision within the academe is very significant [16]. 2. *Wise leaders can grasp the essence*. This entails practical wisdom that enables leaders to anticipate future scenarios, envision the broader context, and determine strategies to achieve the organizational vision. 3. *Wise leaders cultivate shared contexts.* This is made possible by facilitating opportunities for executives, managers, and colleagues to learn collaboratively, starting from informal interactions in their spaces or "ba." For leaders to better relate with others, it is fundamental for them to realize that leading is a continuous journey that requires self-reflection. They must realize how one's behavior affects others while committing positive change [17]. *4. Wise leaders communicate the essence in a manner where the majority if not all of the stakeholders can understand the message.* They actively engage in conversations with a diverse range of individuals, not just a select few, demonstrating an intense commitment to effective communication. The communication skills of leaders are essential for inspiring employees to find fulfillment in their work while simultaneously driving toward organizational objectives [18]. *5. Wise leaders exercise political power by unifying people and motivating them into action.* They understand not only the conditions but also the thoughts and emotions of others as they exercise political judgment. They are capable of navigating conflicts adeptly and excel in negotiating resolutions that benefit all parties involved. *6. Wise leaders cultivate practical wisdom by empowering and nurturing the development of other leaders.* Distributed phronesis through coaching or mentorship and apprenticeship will empower institutions and communities to maintain responsiveness in all situations. The principles of PL are integrated into the socialization, externalization, combination, and internalization (SECI) model, enhancing organizational learning and adaptability.

There are two types of knowledge: tacit and

explicit [19]. Tacit knowledge encompasses personal experiences and observations that defy quantification due to their context-specific nature. Tacit knowledge is analog, in contrast to explicit knowledge which leans towards digitization and digitalization. However, both tacit and explicit knowledge remain underutilized. Consequently, leaders are strongly urged to maximize the generation and open sharing of ideas, while utilizing all types of knowledge to create environments both healthy and stakeholder-centered [20].

Patterns in creating organizational knowledge through the SECI model [21] have been observed. The initial phase, known as socialization or the "Originating Ba," involves the transfer of tacit knowledge from one individual to another. At this stage, knowledge remains implicit, as individuals engage in observations, learn from mentors and peers, and share their thoughts, experiences, and emotions.

The second phase is known as externalization or the "Interacting Ba," which denotes movement from tacit to explicit knowledge. It comprises choosing people with the requisite knowledge and expertise for a particular program or project team. The formulation of committee members and task forces is necessary in executing plans. Through meetings, dialogues, and interactions, tacit ideas are articulated and transformed into explicit ones.

The third phase is the "Cyber Ba," or the combination phase. Explicit ideas formed in the interacting "Ba" are combined with existing knowledge and skills with the use of information technology.

The fourth phase is internalization, or the "Exercising Ba," which represents the translation of explicit knowledge into tacit knowledge. This stage involves training programs and workshops aimed at continuous self-improvement. The program or project derived from previous stages is put into practice, typically on-site. The four phases must be carried out to achieve successful knowledge creation and conversion within and across the organization. The SECI model is illustrated in Figure 1.

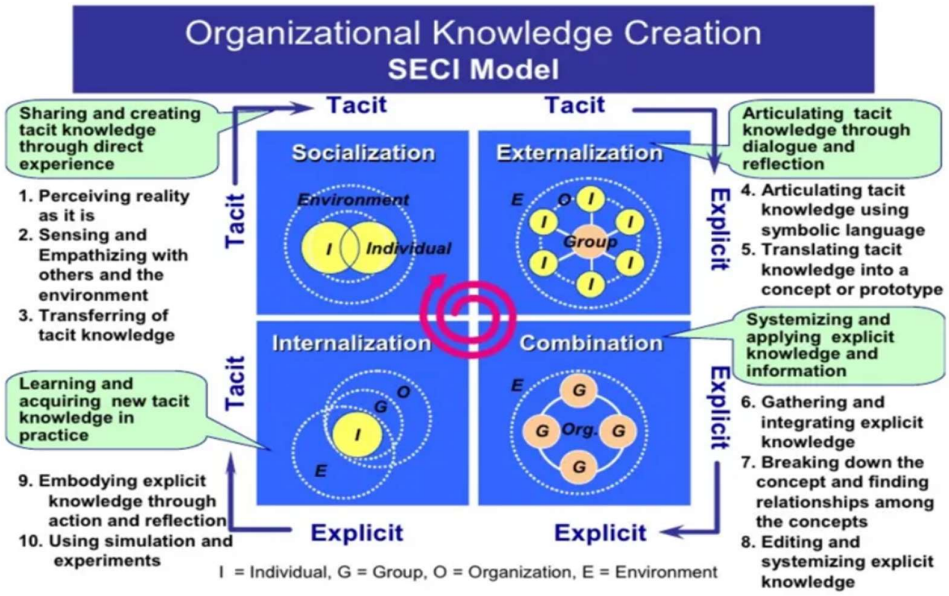

Figure 1. The SECI Model (Nonaka, 2010)

The study aimed at contextualizing PL at IFSU. It specifically sought to create a PL framework for middle and top management, or the Administrative Council (ADCO) leaders of the university and a PL framework for student leaders.

2. Methodology

The research herein comprises a qualitative case study conducted at IFSU. Established in 1920, IFSU is a government university located in Ifugao, Philippines, and is known worldwide. In total, there are six campuses with more than 11, 000 students and 800 employees. The leadership of IFSU is composed of ADCO officials. To implement this effort, IFSU partnered with another SUC, Central Luzon State University (CLSU). A tertiary-level science institution located in Nueva Ecija, CLSU is a shining example of a university dedicated to excellence. The partnership was implemented because the ADCO members of this partner SUC play an enormous role in the co-creation of knowledge and ideas concerning how ADCO officials carry out leadership functions.

Focused group discussions (FGD) and interviews were carried out with participants, all of whom responded favorably to letters of invitation. The first group of participants was composed of 79 student leaders, six student leader advisers, and the Director for Student Services and Development. The second group included 62 IFSU school officials and 28 CLSU administrators. Each group had a separate schedule for the FGDs and workshops. The two groups were subdivided into smaller groups during the guided discussions. Stakeholder-driven data were carefully recorded verbatim, manually coded, and read over and over to ensure accuracy. Keywords and phrases were color-coded and categorized. When the themes were identified, comparative analysis and evaluation of the findings were undertaken [22]. Triangulation was utilized to validate the information gathered through the FGDs and interviews. Informed by the data, the preliminary framework was presented to the participants for feedback. This interactive process was crucial as it ensured that the framework resonated with the aspirations of the leaders. The feedback of the participants was thus incorporated. In addition, participants were asked to explain their responses, and they were ultimately shown the output of the finalized discussions and interviews. Thematic analysis was carried out to analyze the data.

3. Results and Discussions

3.1. PL framework for ADCO leaders at IFSU.

The ideas shared by the ADCO officials of both IFSU and CLSU and the researcher during the FGDs and interviews were used to develop a framework following the SECI model (Figure 2).

The PL leadership approach is closely aligned with Nonaka's SECI model where informal discussions take place within designated spaces known as "Ba" [23]. The approaches were founded on practical wisdom rather than the standards of the Quality Assurance Agency (QAA) for Higher Education are more effective in Hull College, England [24].

The researcher, trained and skilled in PL, served as the facilitator in eliciting the experiences, perceptions, opinions, knowledge, and recommendations from the participants. The data derived from the FGDs were enriched through the interviews. Coding was utilized to safeguard the confidentiality of the interviewed ADCO member participants. The first participant was designated ADCO 1 or A1, with each subsequent participant increasing in number.

Socialization

When asked how the ADCO officials observe or describe the socialization phase, A1 responded, “The ADCO and other stakeholders talk together informally in their offices, canteen, while walking or riding together, and anywhere they meet.” Additionally, A2 expressed, “The designated officials also share how they feel, their experiences, and how they handle events and frustrations.” A3 made it clear that “involving others and showing respect for their colleagues must be given careful attention by the ADCO officials.”

Externalization

Regarding externalization, A1 noted, “What was articulated during the informal conversations should not be ignored but presented in meetings for more stakeholders to be involved.” Participant A2 added, “During meetings, ADCO members are encouraged to speak their minds, ask questions to clarify matters, and encourage critical thinking.”

Finally, participant A3 expressed that "the use of data in decision-making is important."

Combination

Participant A1's insight regarding the combination phase is for the ADCO members to "make plans as a team or family." According to Participant A2, while the ADCO works as a group, "they have to think of new ways on how to improve systems and processes." Participant A3 added, "With the rapid changes brought about by technology including artificial intelligence, these disruptions are to be used properly."

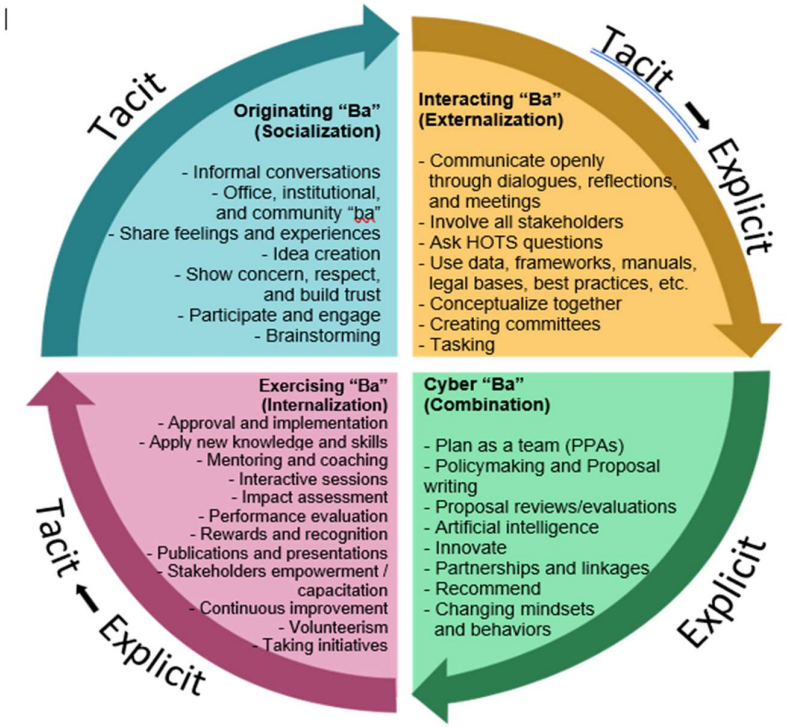

Figure 2. Phronetic Leadership framework for ADCO officials

Internalization

The first ADCO participant explained that the internalization phase is critical. According to A1, "It is imperative that plans be implemented and monitored. Many plans and projects fail because there is a lack of monitoring and evaluation thus this part mustn't be missed." A2 voiced, "Performance assessment is an integral part of any organization or project and those who excel in their performances deserve to be recognized and rewarded." A3 stated, "Human resources or those implementing the plans should be continuously empowered and capacitated. The cycle of empowerment is a nonstop process."

The PL framework for ADCO members presented in Figure 2 was derived from the data gathered. It describes how the SECI Model could be applied by the ADCO in IFSU or even other SUCs if applicable. In the Socialization phase, the ADCO officials interact with their officemates, colleagues, parents, students, industry partners, and other stakeholders in their "ba" spaces. Each participant actively contributes to the conversation, building mutual respect, understanding, openness, and trust among one another.

The insights shared by stakeholders were translated into explicit ideas during the externalization phase through dialogues, reflections, and meetings. The ADCO takes proactive steps on administrative matters and forwards the same recommendations to the Board of Regents (BOR). Regular meetings are conducted, active participation, and task forces and committees are created. Additionally, relevant data, legal foundations, frameworks, and existing information serve as valuable

references for the conceptualization of proposals or programs and projects.

The ADCO and stakeholders collaboratively plan, revise, and use technology and artificial intelligence, craft policies, and guidelines, and recommend them for appropriate action to the BOR. Establishing linkages and partnerships with local and international communities is essential for realizing plans.

In the internalization phase, Plans, Programs, and Activities (PPAs) are implemented, applying newly acquired knowledge and skills. Regular performance evaluations, capacitation, and monitoring and evaluation are conducted. Volunteerism and taking initiative are imperative in serving the stakeholders.

3.2. PL Framework for Student Leaders

Leadership among students is a critical skill for both personal and professional achievements. At both the University of Alabama and Hull College in England, they have practiced PL. The University of Alabama describes PL as ethical leadership [25]. At IFSU, the PL framework for student leaders was formulated based on the data and from the analysis drawn through FGDs and interviews from the student leaders, advisers, and the director of the Department of Student Services and Development (DSSD). Students interviewed were coded as S1, S2, S3, and S4.

Socialization

S1 described this phase as "the time for students to say hello and start communicating their ideas with their friends or classmates." Moreover, S2 feels that socialization enables students to visit school officials as a group. S3 mentions that socialization allows leaders to show respect to one another "Recognizing God's presence through prayers is a good way of starting any conversation, whether informal or formal" (S4). According to the participants they usually share their "ba" sessions in the corridors, canteen, kiosks, churches, or other communal spaces.

Externalization

Information concerning externalization includes S1 feeling the importance of meetings, while dialogues are important for S2, and involving others is important for S3. S4 mentioned, "Consultations with advisers or school officials will help them improve their plans or projects." S3 noted, "It is crucially important to use student manuals or memoranda from authorities as bases of actions and plans." In addition, S1 continued by saying that in the externalization phase, "Working together in teams will be very helpful."

Combination

When the student leaders were asked how they describe the combination phase, S1 expressed that they come together to make plans. S2 exclaimed the importance of "Organizing the plans or activities by indicating them through a calendar." S3 said, "We prepare proposals and package them, and S4 mentioned that they seek funding, or raise funds to finance projects (S4).

Internalization

According to S1, the participant verbalized that "Any plans or projects cannot be implemented without the approval of concerned university officials therefore, we can only implement something provided it is approved." "During the implementation, there will always be coordination between those in charge and other offices" (S2). "If there are enough funds, student organizations can sponsor projects. "It is still necessary to seek the approval of authorities before the implementation of any plan" (S3). "We are students, and I strongly support the spirit of volunteerism because we can always share our time and talents" (S4).

Grounded on the data gathered, the PL framework for student leaders was created. During the socialization phase, student leaders actively engage with various stakeholders resulting in networking, relationship-building, and collaboration. In the "ba" spaces, they engage in open and empathetic discussions, sharing ideas and experiences on diverse topics. Ideas are exchanged during visits, courtesy calls, and interviews. Praying is a fundamental mode of conversation with the Creator and it is also in their spiritual formation activities they deliberate on ideas collectively. Through these interactions, mutual respect and trust are built among students.

The tacit ideas shared by student leaders undergo refinement into explicit concepts through meetings and dialogues with stakeholders. As young leaders, seeking

guidance and advice from advisers, deans, and other stakeholders is imperative. Referring to legal documents or policies and guidelines will likewise improve their decisions and actions. Continuous coordination and working by teams are ways of helping leaders to address conflicts, and improve performance.

Once student leaders have reached a consensus on projects or activities, they start to plan together and decide on their calendar of activities in the combination phase. It is a must for them to demonstrate innovation in developing policies, guidelines, and activity proposals that effectively address student needs. Student leaders are entrusted with managing financial resources allocated to them and sourcing out funds for the benefit of students. Adapting to changes and having a positive mindset as students will help them execute their plans and achieve their end goals.

In the internalization phase, student leaders execute the plans, projects, or proposals they have advocated for. To ensure successful implementation, they must actively monitor and evaluate these initiatives, maintaining ongoing coordination with school officials and relevant authorities. Student leaders may choose to sponsor student or community activities in alignment with their plans. They may also publish their work to disseminate their achievements and integrate volunteerism as a regular activity.

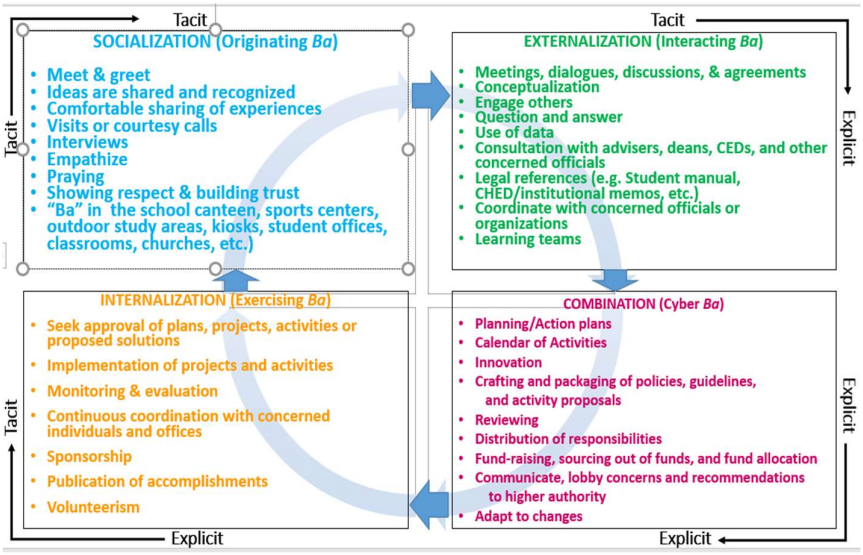

Figure 3. Phronetic Leadership Framework for Student Leaders

4. Conclusion

The application of phronesis in leadership, decision-making, and adherence to ethical standards has significantly contributed to the improvement of educational performance and outcomes. Practical or wise leaders in higher education recognize the significance of tacit and explicit knowledge. Co-creating knowledge begins with valuing and incorporating ideas from various sources, rather than solely relying on the leader's perspective. Combining the insights and vast information from academic and non-academic stakeholders forwards the formation of new organizational knowledge. The PL frameworks for key officials, student leaders, and instruction were developed, through the tacit ideas of the university students, officials, faculty representatives, experts, colleagues, and the researcher.

The practice of PL in higher education benefits both students and employees by instilling sound judgment, upholding ethical standards, mobilizing people to take initiative, translating ideas into action, and encouraging others toward continuous improvement. By cultivating practical wisdom in students, PL

equips them with the skills necessary to excel academically and thrive in their future careers. Likewise, employees are inspired and take initiative in the performance of their responsibilities. All these contribute to the attainment of the organization's vision, mission, goals, and objectives. It is likewise expected that IFSU and other HEIs practicing PL through the SECI model will be exemplars of excellence as they prioritize human-centric approaches and fulfill their mandated functions.

For future research, it is recommended that investigations look into how or to what extent PL is being practiced in organizations in addition to other topics related to PL.

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