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Table of Contents

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Physicochemical Analysis of Lake Chitu: The Origin of *Arthrospira Plantesis*

[1]Yiglet Mebrat, & [2]Damitew Etisa

Abstract

Chitu is a unique poly-extreme soda lake with high alkalinity and salinity that supports Arthrospira plantesis inhabitation. In this study, the physical parameters, chemical analysis, and some heavy metal contents in Lake Chitu were determined using flam and hydride AAS. The physicochemical analysis showed higher variability in anion and cation concentration in the three transactional areas of the lake. The physical parameters of the lake showed no difference and the chemical analysis indicated that pH, carbonate, sulphate, and fluoride concentration were higher in the anthropogenic part of the lake. This shows that human/animal interference and thermal spring water play a role. Of the three transactional areas of the lake, samples from the flooded area of the lake showed the highest alkalinity and bicarbonate concentration, while samples from the protected area showed the lowest alkalinity. The mercury and arsenic contamination was highest in the protected and anthropogenic parts of the lake respectively. The present study strongly suggest that Lake Chitu, the unique habitat for arthrospira plantesis with possible use in diverse applications, which should be further investigated by seasonal sampling.

Keywords: *alkalinity, spirulina platensis, soda lake, anions and cations*

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1. Introduction

Water is the most precious natural resource, could not be replaced by any other known natural or man-made compound (Dar & Singh, 2020). It is an essential component for the survival of life on earth, which contains minerals, important for humans as well as for world and aquatic life (Raji *et al*., 2015). Lake is an indispensable element of the natural environment that defines both landscape and its ecological functioning, source of significant elements of the world's biological diversity (Pant *et al*., 2017) and has important social/economic benefits as a result of tourism/recreation and culturally/aesthetically important for the nearby communities (Dirican, 2015). Thus, water quality analysis is important to protect the natural ecosystem (Patil *et al*., 2012).

Natural water contains different types of impurities which are introduced into the aquatic system by different ways, such as weathering of rocks and leaching of soils, dissolution of aerosol particles from the atmosphere and from several human activities (mining, processing, and the use of metal-based materials) (Sharma *et al*., 2015). Water must be tested with different physicochemical parameters, before it is used for drinking, domestic, agricultural or industrial purposes, which helps to maintain a healthy ecosystem and biological diversity (Pant *et al*., 2017). It is difficult to understand the biological phenomenon fully because the chemistry of water reveals much about the metabolism of the ecosystem and explains the general hydro-biological relationship (Sharma *et al*., 2015). But the selection of physicochemical parameters depends on the purpose of using that water/objectives of the study and what extent we need its quality and purity which helps to get an exact idea about the quality of water (Dirican, 2015). Physical characteristics whereas chemical properties of the lake water highly govern the aquatic life and determine the trophic status of the water body. Abiotic factors are usually the governing forces of the environment and influence the wellbeing, distribution of organisms and functioning of the ecosystem (Pant *et al*., 2017).

In Ethiopia, Lake Chitu is a soda lake having extremely high primary productivity and algal biomass associated with the superabundance of *Arthrospira* and supporting the huge flocks of the Lesser Flamingos (Ogato *et al*., 2015). Basically, unlike terrestrial crops which grown on soil, *Spirulina* grows in water containing various minerals and free from substances inhibiting nutrient uptake (Sukumaran *et al*., 2014). Hence, water with proper

nutrient supplementation enhances nutrient uptake, promoting microalgal growth and intracellular substance accumulation. *Spirulina* is capable of growing in high alkalinity with the presence of carbonate, bicarbonates and inorganic nitrogen (Devanathan *et al.*, 2019). *S. plantesis* is reported to grow over a wide range of salinity. Lake Chitu is a creator lake situated in the central refit valley, highly salty, surrounded by hot springs flow into the lake with high $CaCO_3$ containing types of soil. The high salinity and alkalinity with temperature makes Chitu Lake the preference habitats of *Spirulina plantesis* which is the main food source for huge flocks of the lesser flamingo (*Phoeniconias minor*) (Tadesse *et al*., 2014; Ogato *et al*., 2015). In view of the environmental preference in which natural populations of *S. plantesis* occur in line with the multi functionalities of the species, absence of research works on the physicochemical analysis of Chitu Lake, the need to study the physicochemical characteristics of Chitu Lake to determine the correlation with *S. platensis* growth as well as its component bicarbonate, sulphate, phosphate and heavy metals.

2. Material and Methods

2.1. Description of the Study Area

Lake Chitu was selected based on the availability of *Spirulina.* Lake Chitu is a volcanic explosion crater lake which is located 287 km South of Addis Ababa in West Arsi zone which is situated at 25 km from Shashamane town with **latitude 07^0 24' 26''N, longitude of 038^0 25' 33''E** with an altitude of 1540 meters above sea level. The lake covers an area of 0.8 km^2 and a maximum depth of 21 meters.

2.2. Sample Collection

The 99 water samples were collected in clean glass stoppered sampling bottles from three transactional areas of the lake represented as flooded area, anthropogenic and protected area (33 samples from each). The water sample was immediately brought to the laboratory to analyse the required parameters. pH, temperature, EC and TDS were taken from the lake at the time of sample collection.

2.3. Laboratory analysis

pH. pH is considered as an important factor for the growth of *spirulina*, it is the measurement of the acidity and alkalinity of the water and was measured by pH meter (HANNA instruments, Italy) at the time of sample collection.

***Electrical Conductivity (EC), Total dissolved solids (TDS) and Temperature*.** The EC, TDS and T^0 of Chitu Lake were measured at the time of sample collection by EC/TDS tester (Model AD31, Europe).

Ammonia (NH_3-N). Ammonia was determined by nessler's method by the principles of the reaction free ammonia or ammonium ions with nessler's reagent to form a reddish-brown complex and the absorbance of the complex was measured at 420nm which is proportional to the ammonia nitrogen content (Wang *et al*., 2019).

Alkalinity ($CaCO_3$) test. The alkalinity of the water sample was measured due to the ability of the water sample to neutralize acids by titrating the water sample with sulphuric acid of known values of pH, volume and concentration. Based on stoichiometry of the reaction and the number of moles of sulphuric acid needed to reach the reaction point, the concentration of alkalinity in water was calculated by the equation below.

$$Alkalinity, {}^{Mg}/_{L}\, CaCO_3 = \frac{(V_a x\ N_a)E_{wt}}{V_s}$$

Where: V_a- Volume of acid used
N_a-normality of acid
E_{wt}-equivalent weight of CaCO3

***Carbonate (CO_3^{2-}) and Bicarbonate (HCO_3^-) estimation*.** The presence of carbonate (CO_3^{2-}) and bicarbonates (HCO_3^-) influences the hardness and alkalinity of water. The concentration was measured by titration with standardized hydrochloric acid using methyl orange as indicator to be turned yellow below pH 4.0 mentioned by Sharma *et al*., (2015). At this pH, the carbonic acid decomposes to give carbon dioxide and water.

Nitrate (NO_3-N) and Nitrite (NO_2-N) Test. NO_3-N was estimated by Cadmium reduction method in principles of reduction of nitrate to nitrite when the sample allowed to pass through a column containing amalgamated cadmium filings. Nitrate has been calculated from the standard curve by plotting absorbance of standards against NO_3-N concentration (Balance, 1996). Nitrite, that originally present plus that reduced from nitrate, was then determined.

Nitrite (NO_2-N) concentration has been estimated in accordance with the principles reactions of nitrite with sulphanilamide in strong acid medium and the resulting diazo

compound is coupled with N-(1-naphthyl)-ethylenediamine dihydrochloride to form an intensely red colored azo-compound (Balance, 1996). The absorbance of the dye at 540 nm is proportional to the concentration of nitrite present.

Silica (SiO_2) test. Silica concentration was estimated based on the formation of heteropoly acids when ammonium molybdate reacts with silica and phosphate approximately at a pH of 1.2 (Balance, 1996). Thus, addition of oxalic acid destroys any molybdophosphoric acid but not the molybdosilicic acid and the yellow molybdosilicic acid is reduced by amino-naphthol-sulphonic acid to heteropoly blue, finally, the concentration of Silica was measured at 815 nm. Silica was calculated as:

$$[Silica] = \frac{SiO_2\ from\ graph\ (mg)}{(L)\ of sample}$$

Fluoride (F^-) estimation: Estimation of fluoride concentrations was performed by modifying Reshetnyak *et al*. (2019) methods of direct potentiometry to determine fluoride ion activity using fluoride ion–selective electrode. A standard silver chloride electrode was used as a reference electrode. To determine fluoride concentration in water sample, the method of standard addition was applied and water samples were diluted in total ionic strength adjustment buffer (TISAB), which sets constant ionic strength during measurement and which also pre-complexes interfering ions.

Phosphate (PO_4^{3-}-P) test. Phosphate concentration was tested by Ascorbic acid/Molybdate blue method implemented by Habibah *et al*. (2018) based on the reaction between orthophosphate and ammonium molybdate in the aqueous acidic condition, followed by its reduction by ascorbic acid reducing agent. In the reaction result, molybdenum blue complex absorbance was measured at 800-900 nm range and the color intensity of the molybdenum blue complex were proportionally with the phosphate content in the water sample.

Heavy Metal test. The concentration of Chromium (Cr), Mercury (Hg) and Arsenic (As) were tested by Atomic Absorption Spectrophotometer (AAS) methods (novAA-400P, Germany). Chromium (Cr) was tested by Flame AAS, whereas Mercury (Hg) and Arsenic (As) were tested by Hydride AAS.

3. Result and Discussion

3.1. Physical Parameters

Some physical tests were performed on the three-transactional area of Chitu Lake, stated on **Table 1**. The colors of the lake in protected area were slightly green due to the micro algae biomass dominated by *Spirulina.* Whereas, the anthropogenic and flooding areas were highly turbid and turbid brown respectively because of human and animal interferences and soil erosion in the mean order. The anthropogenic part of the lake was highly affected by human activities such as washing clothes with soaps/detergents, bathing and showering. More so, animal interference (drinking as well as disposing their feces and urine into the lake) which were disseminated into the other part of the lake via waves and concentration gradient after the anthropogenic part of the lake. Flocks of flamingos were staking in the lake has a great role in the lake's color and odor. There was no difference in the temperature and the electro-conductivity of the lake in the three transactional areas. But there was a high TDS concentration in the protected area as compared with the other area. This were due to

Table 1

The physical parameters of Chitu Lake

Parameters	Anthropogenic area	Protected area	Flooding area
Color	Highly turbid	Turbid slightly green	Turbid brown
T^0	23	23	22.94±0.11
EC	399	399	399
TDS	200	228.75±0.46	221.63±13.35

3.2. Chemical analysis of Chitu Lake

Chitu lake is an alkaline lake, "soda lakes" that has saline waters with carbonate species ($HCO^{3-} + CO3^{2-}$) as the dominant ions and typically exceed a pH of 9. This is in consistence with the scientific report on the extreme physical and chemical conditions of "soda lakes" with combination of sodium and carbonates results in alkaline conditions (Boros & Kolpakova, 2018). The highest pH value was recorded on anthropogenic area as compared with the rest transactional areas were due to high animal and human interference. The animal feces, urine, and the dust on the animal legs may play a role in the pH value. In addition, the human wash their cloth, showing by using soaps and detergents and swimming activities leads to a high pH value in the area. But there was no significant pH difference in the

protected and flooding area. pH is controlled in part by the concentration of Ca^{+} and $CO3^{2-}$ (Bowman & Sachs, 2008), these ions were shown to be present in low concentrations in protected area as compared with the rest transactional part of the lake. Reports indicated that the well mixed and turbid part of the soda lake was highly alkaline which is similar to the result on Chitu Lake (Boros & Kolpakova, 2018). The Lake Chitu at the anthropogenic area was well mixed and turbid due to the human and animal interference, which plays a role in high alkalinity of the area. The same concept was reported by Bowman and Sachs (2008) to indicate the highly alkaline lakes containing a high concentration of carbonate.

Table 2

The chemical parameters of Chitu Lake

Parameters	Anthropogenic area	Protected area	Flooding area	WHO allowable Conc.
pH (M±SD)	9.99±0.06	9.86±0.05	9.87±0.13	
Carbonate (CO_3^{-2}) (mg/L)	32558.40	29376.00	31824.00	-------
Bicarbonate (HCO_3^{-}) (mg/L)	2239.92	Null	5226.48	-------
Alkalinity ($CaCO_3$) (mg/L)	56100.0	47736.0	57324.0	-------
Ammonia (NH_3-N) (mg/L)	1.12	1.12	1.12	-------
Sulphate (SO^{-2}_4) (mg/L)	67.03	60.72	60.24	400.0
Nitrate (NO_3-N) (mg/L)	9.9	10.1	7.8	10.0
Nitrite (NO_2-N) (mg/L)	0.8	0.79	0.83	3.0
Fluoride (F^{-}) (mg/L)	450	380.0	300.0	1.5
Phosphate (PO_4^{3-}-P) (mg/L)	0.1	0.1	0.1	-------
Silica (SiO_2) (mg/L)	ND	ND	ND	-------

The null bicarbonate (HCO_3^{-}) concentration in the protected area is expected to be due to grass coverage on the area, acacia coverage, macrophyts density which decreases the iterance of bicarbonate in to the lake and aggregates of *Spirulina* mass in the area may leads high bicarbonate consumption by the cyanobacteria as a carbon source. In addition, the sample was taken from the surface of the water, so the bicarbonate may be sediment under the water. This is corresponding with Keskinkan *et al*. (2012) report on the crucial role of cyanobacteria in carbonate precipitation within oceans, lakes, springs, caves, and soils. Farther more, the bicarbonate may be below the detection capacity of the machine.

Ammonia (NH_3-N) concentration was consistent in the three-transactional areas of the lake, this may be due to the absence of outflow. On the other hand, Chitu Lake may accumulate nutrients and organic matter in addition to salts, which maintain via internal

cycling the active biological production. This idea is analogous with Clarisse *et al.* (2019) reports on the decomposition and associated ammonification of nutrient rich organic matter to be the principal source of NH_3 in soda lakes. In addition, the report includes the breakdown of plankton, droppings of flamingos and other water birds and miscellaneous organic material carried in animals or hot springs (plant residues, and waste of mammals and humans) (Clarisse *et al.*, 2019). All these factors were a critical feature of Lake Chitu which plays the same role as reported. In addition, via their feeding and excreting, Flamingos play an important role in nitrogen cycle of the Chitu Lake. *A. platensis* growth depends on nutrient availability, especially the nitrogen source, although nitrates and ammonium salts are commonly used. The cyanbacterium *Spirulina platensis* is capable of utilizing ammonia as a sole source of nitrogen even at pH 10 and above, since the entry of ammonia into *Spirulina* cells is primarily driven by the pH gradient (Belkin & Boussiba, 1991). Reports indicated that, the fed-batch addition of ammonia-based nitrogen sources was shown to prevent any inhibiting effect effectively on *A.plantesis* cultivation (Rodrigues *et al*., 2011).

Soda lakes are characterized by elevated pH and dominance of sodium and carbonate species in the cation and anion dissolved solutes, and key to the occurrence of conservative cations over conservative anions like SO_4^{2-} (Deocampo & Renaut, 2016) and Sulphate (SO^{-2}_4) is the dominant anions (Sorokin *et al*., 2011). The Sulphate (SO^{-2}_4) concentration was higher in the anthropogenic part of the lake as compared with the other parts of the lake; there was no significant difference between the protected and flooded area of the lake. But the Sulphate (SO^{-2}_4) concentration of Chitu Lake was under the WHO recommendation level. The result corresponds with the report of Foti *et al.* (2007), on the sulfur cycle which is one of the most active element cycles in soda lakes. One of the explanations for sulfur cycle is the high-energy efficiency of dissimilatory conversions of inorganic sulfur compounds, both oxidative (driven by chemo-litho-autotrophic halo-alkaliphilic sulfur-oxidizing bacteria (SOB), unique for soda lakes) and reductive, sufficient to cope with costly life at double extreme conditions (Sorokin *et al*., 2011). Although, the relatively low sulphate (SO^{-2}_4) concentration in the lake expected to be the high-energy efficiency of microorganisms and *A. planthesis*. This idea is supported by the report on the importance of sulphate on the growth performance and biochemical status *Spirulina platensis*. In addition, the microscopic analysis of *Spirulina platensis* revealed that the number of whorls and filaments are influenced by

sulphate salts concentration (Pierre *et al*., 2021). In this regard, the relatively higher concentration of sulphate (SO^{-2}_4) in the anthropogenic area could be due to the flow of spring water towards the lake and the low concentration in the remaining parts were expected to be due to *Spirulina platensis* mass observed at the time of sample collection.

Nitrate and Nitrite. The nitrogen fixing and denitrification activities of *Spirulina spp*. and some *Halomonas spp* respectively, have already been noted. Nitrate (NO_3-N) concentration is higher in protected area as compared with the anthropogenic areas as shown in **table 2**. Organic nitrogen sources from feather degradation may also be important in Lake Chitu as keratin-degrading microbes and their effective degradation of keratin from the feathers of flamingos was reported for the same lake (Sitotaw, 2014). It has been reported that, in productive lakes such as Lake Chitu, over 90% of the total nitrogen is in the algal biomass and this is regenerated during decomposition of the organic materials (Ogato *et al*., 2015). But the lowest nitrate concentration was recorded in flooding area of the lake. The high rates of denitrification by the abundant populations of some bacteria (e.g., *Halomonas spp*.) in soda lakes together with the favorably high tropical temperature are believed to contribute considerably to the low nitrogen levels in such lakes (Ogato *et al*., 2015). A relatively low nitrite concentration was observed in the protected area of the lake, this is an indication with nitrite reductase active within a very broad salinity range (Shapovalova *et al*., 2008). The lowest nitrate and a relatively highest accumulation of nitrite were observed in the flooded area of the lake. This suggested that, the presence of active populations of denitrifying and nitrate-utilizing bacteria, including heterotrophic haloalkaliphilic *Halomonas spp*. and chemolithoautotrophic (Yu & Gijs, 2005). In addition, high level of nitrite accumulation during anaerobic growth with nitrate at high salt suggested that the nitrite reduction step was a bottleneck in the denitrification process (Shapovalova *et al*., 2008).

The Rift Valley is one of few active rifts on the Earth's land area Fluoride is naturally found in volcanic rocks (Tekle-Haimanot *et al*., 2006). An abundance of thermal springs indicates the ongoing volcanic activity in the area and often high in elements such as florid (Reimann *et al*., 2003). It is obvious that the Rift Valley is the region in Ethiopia that is most affected by the fluoride problem. Thus, the present study is supported by the evidence due to high concentration of florid (F^-) (450 mg/L) (**table. 2**) in the anthropogenic area of lake Chitu as compared with the other transactional areas of the lake due to the abundance of thermal

springs in the anthropogenic area. In addition, there was high hot spring in flow towards the lake in the protected area, as a result, increased florid concentration were recorded in the protected area of the lake. There was no thermal spring water in the flooded area of the lake, as a result of a relatively decreased concentration of florid (300 mg/L) were reported (**table 2**). In general, the florid concentration of Chitu lake were higher than the WHO recommendation, as a result the communities facing dental fluorosis. This report is supported by Reimann *et al*. (2003) on the use of drinking water from drilled wells in the Rift Valley, Ethiopia, dental and skeletal fluorosis has become a serious medical problem (Reimann *et al*., 2003).

Phosphate (PO_4^{3-}P). Phosphate is central to the origin of life because it is a key component of nucleotides, phospholipids, and metabolites such as adenosine triphosphate used in cellular replication, compartmentalization, and energy transfer, respectively (Tonera & Catling, 2019). But the phosphate level in Lake Chitu was consistent within the three transactional areas of the lake (0.1 mg/L), which was relatively lower as shown in table 2. Such concentration of phosphate may be mainly from the predominant phosphatic mineral-rich rocks and released to anoxic water column (Ogato *et al*., 2015). Lower phosphate concentration may be due to high-rate consumption of phosphate by *Artherospira,* other micro algae and macrophyta. The present result was supported by Sofiyah and Suryawan (2021) reports on the convenience of phosphate compounds for microalgae cell growth, energy transformation, photosynthesis, and for the formation of chlorophyll. On the other hand, phosphate used as a buffer to catalyze acid/base and nucleophilic reactions and acts as a pH and chemical buffer, which may lead to a low phosphate concentration in the lake (Powner *et al.,* 2009). Furthermore, a major issue for prebiotic chemistry is that phosphate combines with Ca^{2+} down to micromolar levels to form apatite-group minerals [e.g., $Ca_5(PO_4)_3(OH,F,Cl)$] or with Fe^{3+} and Al^{3+} in acidic solutions to form Fe/Al phosphates which may cause low phosphate concentration (Tonera & Catling, 2019).

Silica (SiO_2): The Silica (SiO_2) in Chitu Lake was not detected, this is probably due to the occurrence of some processes within the lake causing low SiO_2 concentrations. The present observations are in consistence with the result of Ogato *et al.* (2015) studies made on the same lake and other soda lakes of the Ethiopian rift valley. Several studies made on tropical African lakes (e.g., Gebre-Mariam, 2002) reported the association of SiO_2 depletion

with the abundance of diatoms. Organic matter accumulation in the sediment, which inhibits dissolution rates of silicic acid from diatom frustules, may have contributed to the low SiO_2 in this lake.

3.3. Heavy metal contents of Chitu Lake

Chromium (Cr^{+6}) concentration in Chitu lake was not determined as shown in **table 3**. This may be due to the absence of anthropogenic contamination of the lake with potential Chromium source industrial wastes. On the other hand, the Cr^{+6} concentration may be below the detection levels of our laboratory equipment. Furthermore, bio-reduction of Cr^{6+} to Cr^{3+} by Cr^{6+} by bioremediation process, since it is an effective way of combating Cr^{6+} (Ibrahim *et al*., 2011).

Table 3

Selected Heavy Metal content of Chitu Lake

Parameters	Anthropogenic area	Protected area	Flooding area	WHO allowable Conc.
Cr^{+6} (mg/L)	ND	ND	ND	0.05
Hg (µg/L)	0.2	0.32	0.23	0.006
As (µg/L)	11.47	11.25	11.09	0.01

Inorganic arsenic is the most abundant arsenic species in nature and is commonly found in different environments (Valdés *et al*., 2014). The anthropogenic area of the lake was the highly affected in Arsenic concentration, this is mainly caused by various anthropogenic activities such as excessive use of arsenic in pesticides, herbicides, wood preservatives and medicinal products, which is consistent with Dey *et al*. (2016) report. There was no significance difference in Arsenic concentration both in the protected and flooded part of the lake. These might be due to some microorganisms which can cope with arsenic toxicity by using different ways such as taken into the cell by aqua-glycero-porins play an important role in the arsenic geocycle (Omeroglu *et al*., 2022).

As shown in **table 3**, the concentration of Mercury was highest in protected area of the lake, and lowest in anthropogenic area. This is because the mercury might be released to ecosystems by both natural and anthropogenic processes, which is consistence with report of Windisch *et al*. (2022). Anthropogenic processes with the highest contribution to global Hg

release include disposal of batteries and energy-efficient lamps (Xu *et al*., 2015), mining and mine wastes, fossil fuel combustion (mainly coal) (Zhu *et al*., 2018), leather tannery (Tasca *et al*., 2019) and other industrial activities, including the manufacturing of chlor-alkali and caustic soda using Hg-cell. But in the case of Chitu Lake, some of these reasons are not the main cause of increased mercury concentration, rather disposal of batteries and energy-efficient lamps might be the reason. Moreover, due to the Hg cycle through the air, water, and soil, re-emissions of Hg from Hg-contaminated areas, including natural and anthropogenic sources of the past, are also significant drivers of the total Hg releases, especially to the atmosphere (Windisch *et al*., 2022). Local factors such as the presence of hot springs around lakes are also thought to account for high Hg concentrations in the waters of Ethiopian Rift Valley soda lakes (Ermias Deribe *et al*., 2014).

The lowest Hg concentration in the anthropogenic part of the lake was expected to be due to the relatively high pH, alkalinity and sulphate concentration. This is consistent with Windisch *et al*. (2022) reports on the potential factors on Hg bioavailability. Water bodies in close proximity to one another can experience major differences of Hg content in biota depending on their physicochemical properties (salinity, alkalinity, pH, sulfur species and chloride concentrations) and biological activities have been identified to influence Hg cycling significantly by directly influencing availability of Hg– even if they receive similar atmospheric loads of the metal (Windisch *et al*., 2022).

4. Conclusion

This study showed that the water physicochemical nature of lake Chitu in line with the availability of micro-nutrients (carbonate, bicarbonate, nitrate, sulphate and phosphate) were the highly effective and supportive habitat for *Arthrospira plantesis*. The presence of high concentration of florid is visualized by the decayed tooth in the community, which suggested that stalk holders should take measures to access clean water for the societies. This study also demonstrated that the presence of heavy metals such as Mercury and Arsenic. The result indicated that Arsenic concentration in the anthropogenic area was the big concern, since the community and the animal were highly situated on the area. Additionally, the study was conducted by taking a water sample at a time, seasonal and explicit studies are needed to

successfully exploit the full properties of the Chitu Lake including Silicate and heavy metal contamination in the lake.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Spatial Error Model to Analyze Morbidity Rate in Indonesia

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Abstract

Morbidity is a diseased state or symptom in which a person is unable to do daily activities. The morbidity rates can differ by person and place. This paper aims to investigate factors affecting morbidity rates in each province in Indonesia. Using applied spatial error model (SEM), this study analyzed the spatial effect on factors being investigated. It demonstrated that SEM is well-applied on Indonesian morbidity rates data. The results show that in 2020, provinces on Java Island and some provinces on Sulawesi Island have health problems that need to be addressed because they are in the high and moderately high morbidity categories. The value of the Moran Index is positive, indicating a similarity in the percentage of morbidity rates in adjacent provinces. The morbidity rates in most of provinces in Indonesia are affected by the duration averages of school attendance, health insurance, and population density. The coefficient of determination (R^2) of the SEM model of 77.60% can be said to be a fairly good model.

Keywords: *morbidity, spatial error model, school attendance, health insurance, provincial minimum wage system*

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1. Introduction

The level of public health can be described by morbidity, mortality, and nutritional status (Ministry of Health RI, 2010). According to Tulchinsky and Varavikova (2014), morbidity (measure of disease occurrence) can be measured based on the number of people with disease, period and duration of illness, frequency of deaths, disease, disability, and risk factors related to health outcomes. On the other hand, mortality or death rate is the measure of death frequency over a given period (Nolte & McKee, 2012) while nutritional status refer to the physiological state of the population in reference to nutrient intake (Food Agric Organ, 2007). One of many indicators to assess successful development in public health is the level of morbidity rates in the communities. The lower the morbidity, the healthier the people are.

Morbidity rate is the number of certain disease incidences that is formulated as the number of people suffering from disease per 1000 people exposed to the disease (Kardjati et al., 1985; Singh-Manoux et al., 2008). The morbidity rate is more important to tackle than mortality rate, because high morbidity rate can also trigger high mortality rate. Morbidity rate can be used to measure the health condition in general, to assess how successful the programs of disease eradication, sanitation of environment, and to understand the people knowledge on health services.

Based on research conducted by health experts (Okoroiwu, 2020; Moise, 2018; Wunsch & Gourbin, 2018; Zylke & Bauchner, 2020; Amini et al., 2021; Chang et al., 2022), morbidity is caused by neonatal respiratory distress syndrome, tuberculosis and diarrhea. In most cases, asthma, tuberculosis and diarrhea diseases have a negative impact on the patient's life, causing children to often miss school, limiting personal and family activities and decreasing work productivity. The higher the morbidity rate, the worse the level of public health. The morbidity rate can reflect the real state of health because it has a close relationship with environmental factors such as poverty, malnutrition, infectious diseases, housing, proper drinking water, environmental hygiene and health services (Kardjati, et.all. 1985; Krieger & Higgins, 2002; Boyles et al., 2021; Jian et al., 2017; Kumari et al., 2023).

Based on data from Bangdan Pusat Statistik (BPS), the percentage of Indonesia's morbidity rate from 2017 was 14.31%, decreased to 13.19% in 2018 but experienced an increase again in 2019 to 15.38%. According to Soleman (2020), every five children in preterm birth in neonatal phase carried co-morbid factors that increase morbidity rate. The study of Hussain et al. (2015) found that one-third of the Indonesian adult population have multimorbidity. Aside from women being particularly affected, the study showed high prevalence of multimorbidity among younger individuals. Based on these data, the government must take steps to deal with it so that the morbidity rate does not increase in the following years.

Morbidity rate differ by geographical area and country. It depends on life quality of the people within the area. The factors affecting morbidity rate also differ by geographical area. Accordingly, the method to analyze such a situation should incorporate spatial term in its model. One of the models that can tackle this condition is a spatial regression model. The spatial effect can show the clustering effects on adjacent areas. By this method, the spatial effects can be seen and be applied to analyze the morbidity rate in Indonesia using dataset obtained in 2020.

2. Literature review

2.1. Spatial Regression Models

According to Rey et al. (2020), regression and prediction examines how spatial structure analyze data. Through spatial structure, regression models generate explicitly spatial data. If the model systematically mispredicts, a better model can be developed. For example, mapping classification or prediction error can help errors in data clusters. Hence, "*regardless of whether or not the true process is explicitly geographic*, *additional information about the spatial relationships between observations can make predictions better*" (Rey et al., 2020).

Spatial Dependence Test. According to Anselin (1988), the tests to be used to investigate the spatial dependence in the error term of a model are Moran's *I* and Lagrange Multiplier (LM). Moran's index is a kind of correlation to investigate the relationship among adjacent observations. Under null hypothesis the observations are assumed to have no spatial correlation (H_0: $I = 0$). The test statistic used is as follows.

$$Z_{hitung} = \frac{I - E(I)}{\sqrt{\text{var}(I)}} \quad (1)$$

with $E(I) = I_0 = -\frac{1}{n-1}$, $\text{var}(I) = \frac{n(n^2 - 3n + 3)S_1 - nS_2 + 2S_0{}^2)}{(n-1)(n-2)(n-3)S_0{}^2}$

Accordingly, Moran's index (Moran's *I*) can be calculated as:

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n}\mathbf{W}_{ij}^{*}(y_i - \bar{y})(y_j - \bar{y})}{S_0\sum_{i=1}^{n}(y_i - \bar{y})^2}$$

(2)

With $S_0 = \sum_{i=1}^{n}\sum_{j=1}^{n}\mathbf{W}_{ij}^{*}$, $S_1 = \frac{1}{2}\sum_{i\neq j}^{n}(\mathbf{W}_{ij}^{*} + \mathbf{W}_{ij}^{*})^2$ $S_2 = \sum_{i=1}^{n}(\mathbf{W}_{ij}^{*} + \mathbf{W}_{ij}^{*})^2$

Where:

y_i	: *i*-th observation (*i*= 1, 2, … , *n)*
y_j	: *j*-th observation (*j*= 1, 2, ... ,*n)*
$\bar{y}$	: general mean of observations
$\mathbf{W}_{ij}^{*}$	: spatial weight matrix
n	: number of areas
I	: value of Moran's *I*
$E(I)$	: mean value of *I*
$\text{var}(I)$	: variance of *I*

Reject H_0 if the value of calculated Z greater than tabulated $Z_{\alpha/2}$.

Spatial Heterogeneity Test. To test the effect of spatial heterogeneity, it can be done by applying Breusch-Pagantest (BP test). The hypotheses are:

H_0 : No heterogeneity among areas

H_1 : Heterogeneity exists among areas

The formula for Breusch-Pagan test is:

$$BP = \frac{1}{2}\mathbf{f}^T\mathbf{Z}(\mathbf{Z}^T\mathbf{Z})^{-1}\mathbf{Z}^T\mathbf{f} \tag{3}$$

with:

$$f_i = \left(\frac{e_i^2}{\sigma^2} - 1\right)$$

Where e_i^2 is errorof *i*-th observation and $\boldsymbol{Z}$ is a matrix of independent variables of size *n* x (*k* + 1). Reject H_0 if the value of $BP > \chi^2_{(\alpha,k)}$.

Lagrange Multiplier (LM) Test. LM test is applied to determine the existence of spatial effect in the model. The procedures of LM test are as follows.

a) ***Lagrange Multiplier Lag***

The hypotheses are:

$H_0 : \rho = 0$ (no spatial-lag dependency)

$H_1 : \rho \neq 0$ (spatial-lag dependency exists)

Test-statistic:

$$LM_{lag} = \frac{(\boldsymbol{\varepsilon}^T\mathbf{W}\mathbf{y})^2}{s^2((\mathbf{W}\mathbf{X}\boldsymbol{\beta})^T\mathbf{M}(\mathbf{W}\mathbf{X}\boldsymbol{\beta}) + \mathbf{T}s^2)} \tag{4}$$

with

$$\mathbf{M} = \mathbf{I} - \mathbf{X}(\mathbf{X}^T\mathbf{X})^{-1}\mathbf{X}^T, \quad \mathbf{T} = tr[(\mathbf{W}^T + \mathbf{W})\mathbf{W}], \quad s^2 = \frac{\boldsymbol{\varepsilon}^T\boldsymbol{\varepsilon}}{n}$$

Decision criterion, reject H0 if $LM_{lag} > \chi^2_{(1,\alpha)}$ or *p-value* < α.

b) ***Lagrange Multiplier Error***

The hypotheses are:

$H_0 : \lambda = 0$ (no spatial-error dependency)

$H_1 : \lambda \neq 0$ (spatial-error dependency exists)

Test-statistic:

$$LM_{error} = \frac{(\boldsymbol{\varepsilon}^T\mathbf{W}\boldsymbol{\varepsilon}/s^2)^2}{\mathbf{T}} \tag{5}$$

Decision criterion, reject H0 if $LM_{error} > \chi^2_{(1,\alpha)}$ or *p-value* < α.

2.2. Spatial Regression

Spatial regression is a regression in which it incorporates spatial effect which is represented in the spatial weight matrix based on areal adjacency.

Spatial Model. Model for spatial regression according to Anselin is as follows:

$$\mathbf{y} = \rho\mathbf{W}\mathbf{y} + \mathbf{X}\boldsymbol{\beta} + \mathbf{u} \quad (6)$$

$$\mathbf{u} = \lambda\mathbf{W}\mathbf{u} + \boldsymbol{\varepsilon} \quad (7)$$

Substituting equation (6) to (7) becomes

$$\mathbf{y} = \rho\mathbf{W}\mathbf{y} + \mathbf{X}\boldsymbol{\beta} + \lambda\mathbf{W}\mathbf{u} + \boldsymbol{\varepsilon}, \quad \boldsymbol{\varepsilon} \sim \mathbf{N}(\mathbf{0}, \boldsymbol{\sigma}^2\mathbf{I}) \quad (8)$$

Where,

- $\mathbf{Y}$: vector for response variable (*nx1)*
- $\mathbf{X}$: matrix for predictor variables (*nx(k+1))*
- $\boldsymbol{\beta}$: coefficient vector of regression parameters
- ρ : spatial lag coefficient parameter of dependent variable
- λ : spatial lag coefficient parameter on errors
- $\mathbf{u}$: vector for error terms on Y (n x 1)
- n : number of observations or locations
- $\mathbf{I}$: identity matrix (n x n)
- $\boldsymbol{\varepsilon}$: vector for error term in equation U which has normal distribution with mean zero and variance $\sigma^2 I$ of size n x 1

Spatial regression with area approximation consists of some models i.e., Spatial Error Model(SEM). General model for SEM can be seen as follows:

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \lambda\mathbf{W}\mathbf{u} + \boldsymbol{\varepsilon}, \quad \boldsymbol{\varepsilon} \sim \mathbf{N}(\mathbf{0}, \boldsymbol{\sigma}^2\mathbf{I}) \quad (9)$$

Where $\lambda\mathbf{W}\mathbf{u}$ shows spatial on spatially dependent error(ε).

Parameter estimation is obtained by maximizing the logarithm or using maximum likelihood method. Parameter estimation of SEM as the following equation:

$$\hat{\boldsymbol{\beta}} = (\mathbf{X}^T(\mathbf{I} - \lambda\mathbf{W})^T(\mathbf{I} - \lambda\mathbf{W})\mathbf{X})^{-1}(\mathbf{X}^T(\mathbf{I} - \lambda\mathbf{W})^T(\mathbf{I} - \lambda\mathbf{W})\mathbf{y}) \quad (10)$$

2.3. Parameter Significance of Spatial Regression

Model Fitness Test. To test the fitness of SAR model, the following procedure is employed:

$H_0 : \rho = \beta_k = 0$

$H_1 : \rho \neq 0$ (at least there is a $\beta_k \neq 0$ for $k = 1, 2, ..., p$)

Test statistic used is:

$$F_{hitung} = \frac{JKR / k}{JKG / (n-k-1)} = \frac{R^2 / k}{(1-R^2) / (n-k-1)}$$

(11)

Where:

k : number of predictor variables

R^2 : coefficient of determination

Decision criterion: reject H_0 if $F_{calculated} > F_{(\alpha,k,n-k-1)}$.

Partial Test. The Hypothesis for partial test is as follows: (Anselin,2003)

$H_0 : \theta = 0$ (Parameter is unsignificant)

$H_1 : \theta \neq 0$ (Parameter is significant)

Test statistic for parameter significance is:

$$Z_{hitung} = \frac{\hat{\theta}}{s.b_{(\hat{\theta})}} \quad (12)$$

Where $s.b_{(\hat{\theta})}$ be *asymptotic standard error*, and θ be the parameter of spatial regression (namely β, λ and ρ). If $Z_{hitung} \geq Z_{\alpha/2}$ or *p-value*$<\alpha$ (α =0,05), then the decision is to reject H_0, which means the coefficient of regression can be used in the model.

2.4. Selecting the Best Model

The criterion of model selection, which is used in this paper, is AIC criterion. The model is selected when it has the least AIC score. As presented by Hu (2007), the formula to calculate the AIC score is as follows:

$$AIC = -2\log(L(\hat{\theta} \mid y)) + 2\beta \quad (13)$$

Where:

$L(\hat{\theta} \mid y)$: likelihood function of the parameter being estimated.

2.5. Morbidity Rate

Morbidity is the condition of a person who is said to be sick if the health complaints that are felt cause disruption of daily activities, namely not being able to work, take care of the household, and normal activities as usual. According to Hernandez and Kim (2022), morbidity is one of the two commonly measures of epidemiological surveillance which describes the progression of a given health occurrence. Morbidity is usually represented or estimated using prevalence (proportion of population) or incidence (frequency within a population). It can be presented as a ratio or percentage (Mont, 2014).

The following is the morbidity rate formula.

$$\text{AM} = \frac{\text{JPKK}}{\text{JP}} \text{x}100 \quad (14)$$

Description:

AM : morbidity rate

JPKK : number of people who experience health complaints and disruption of activities

JP : total population

According to Choi et al. (2019), morbidity indicators include prevalence, incidence and attack rate. Prevalence measures the proportion of population with specific illness at a specific time period which can be point or period prevalence. Point prevalence measures the number of cases in the population at a point in time while period prevalence estimates the proportion of individuals with a certain condition at any time during a specified time period.

Hernandez and Kim (2022) refers incidence to the frequency at which individuals within a specific population develop a given symptom or quality. It could account the number of people with newly developed disease (Choi et al., 2019). Meanwhile, attack rate is the proportion of incident cases of a disease occurring to population exposed to the source of disease.

There are three dimensions that show indicators of morbidity, namely the long and healthy life dimension, the knowledge dimension and the decent life dimension. The longevity and health dimension is measured based on life expectancy and the percentage of population seeking medical treatment at a health worker's practice. The knowledge dimension is measured based on the illiteracy rate and the average years of schooling of the population 15 years and above. While the dimension of a decent life is measured based on the percentage of the population that has access to decent drinking water and the percentage of the poor population.

The Pan American Health Organization (n.d.) enumerates the factors affecting the accuracy of the measurement of morbid events such as data quality, validity of measurement instruments, disease severity, cultural norms, confidentiality and health information system. It is particularly important that the analysis take into consideration the diversity and volume of data. Since data differ by area of a country, it is imperative that the model used identifies the disaggregation of data. Similarly, the probability of errors in the data analysis must be treated with utmost confidence.

2.6. Social Factors

Social factors are factors that are born, grow, and develop in a common life (Salim, 2002). According to Anderson (1995), social factors include education and ethnicity. Increasing education is an effort to prevent morbidity. In a research conducted by Ardhiyanti (2013), the level of education in an area is reflected in the illiteracy rate because it can show the inability of the population in an area to absorb information from various media, communicate orally and in writing. In addition to the illiteracy rate, in 2014 BPS used the average years of schooling as an indicator of education.

According to Institute of Medicine (2001), socioeconomic status is a strong and consistent predictor of morbidity. In fact, most studies showed that lower morbidity rate occurs among socioeconomically advantaged people (Kaplan & Keil, 1993; Syme &

Berkman, 1976; Lantz et al., 1998; Caldwell, 1990; Lantz el al., 2010; Bosworth, 2018; Dhrifi, 2018).

2.7. Environmental and Behavioral Factors

Morbidity reflects the actual state of health because it has a close relationship with environmental factors such as malnutrition, infectious diseases, housing, healthy drinking water, environmental hygiene, and health services (Wulandari, 2017). According to Pan American Health Organization (n.d.), there are environmental factors that are difficult to measure such as exposure to air pollution, exposure to sunlight and exposure to some disease.

3. Methodology

Data used in this research were obtained from Allstats application of BPS (2020). The variables were morbidity rates (Y), average duration of school attendance (X1), proper drinking water availability (X_2), proper sanitation (X_3), health insurance (X_4), population density (X_5), minimum provincial wage (X_6).

The research was conducted based on the following steps.

- Summarizing descriptive statistics of variables
- Analyzing SEM model as follows:
    - Performing spatial effect test and model identification
    - Conducting assumption test of regression for the following SEM model
    - Interpreting model and making conclusion

There are several studies that model mordibitas cases, as follows:

Factors Affecting Morbidity of East Java Residents with Multivariate Geographically Weighted Regression (MGWR) (Hanum, 2013).

Modeling Factors Affecting Morbidity in Central Java Using Spline Truncated Nonparametric Regression (Rosanti, 2020)

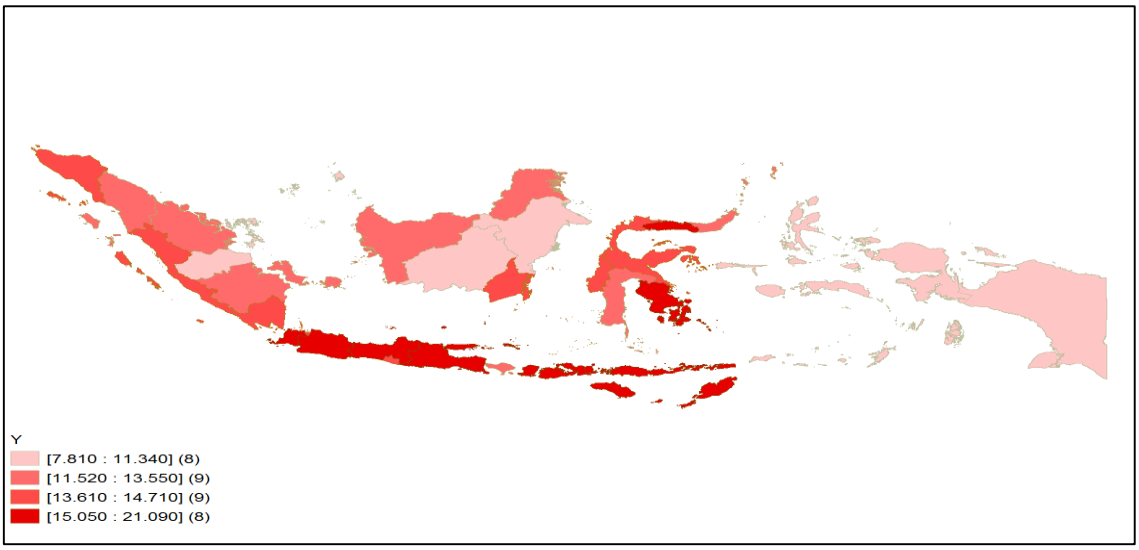
4. Findings and Discussion

4.1. Description of Morbidity Rate

For simplicity in interpreting the spread of morbidity in each province in Indonesia, we do the mapping as seen in Figure 1, where brighter color represents high morbidity rate, while lighter color shows the opposite.

Figure 1

Map of Morbidity Spread in Indonesia 2020



Based on Figure 1, it can be seen that there are 8 provinces to have very high morbidity rates and all these provinces are located in Java. Some 8 other provinces have high morbidity rates. This means that provinces on Java Island and some provinces on Sulawesi Island have health problems that need to be addressed because they are in the high and moderately high morbidity categories. There are 9 provinces of moderate morbidity rates which are distributed over Sumatera, Kalimantan, and Sulawesi islands, and the other 8 provinces with low morbidity rates.

4.2. Spatial Effect Tests

In SEM model, there are two spatial effect tests to be stratified, namely spatial dependence and spatial heterogeneity tests. The results of the tests are presented on Tables 1 and 2.

Table 1

The Result of Moran Index Test

Morans'I	*p-value*	Pattern
0.357063	0.017459	Grouping

Based on table 1, the p-value is 0.017459 < α which means H_0 rejection and there is spatial autocorrelation among adjacent provinces. The Moran's index is 0.357063 which shows positive autocorrelation. This means there are similarities of morbidity rates among adjacent locations and tends to grouping.

Table 2

The Result of Spatial Heterogeneity Test

Breusch-Pagan	**Probability**	**Description**
3.7045	0.71659	Accep H_0

Based on table 2, the probability of the BP test for this model is 0.71659 which is greater than 0.05, so no rejection of H_0. This result means that no heterogeneity among locations.

4.3. Initial Identification of Spatial Model

LM test detects the existence of spatial dependence more specific in term of lag, error, or lag and error. If LM (lag) is significant then the model is Spatial Autoregressive (SAR). But, if LM (error) is significant then the model is Spatial Error (SEM). While if both are significant then the model is Spatial Autoregressive Moving Average (SARMA).

Table 3

Result of LM Tests

Uji LM	**Statistic**	**p-value**	**Description**
Lagrange Multiplier (lag)	1.1780	0.27776	Accept H_0
Lagrange Multiplier (error)	4.9320	0.02636	Reject H_0

Based on table 3, *p*-value of LM (error) test is less than 0.05 then the decision is to reject H_0. This means there is spatial error dependence on morbidity and we continue to SEM model construction.

4.4. Spatial Error Model (SEM)

In model detection, it was concluded that the appropriate model is SEM. Hence, we are going to use SEM. The following is the result of SEM output based on parameter estimation with level of significance at 5%.

Table 4

Parameter estimation dan testing of SEM model

Parameter	Coefficient	Probability
Constant	32.8322	0.0000
X_1	-1.8299	0.0000
X_2	- 0.0754	0.0018
X_5	0.0004	0.0007
Lambda	0.6601	0.0000

Based on table 4, it can be seen that the variables affecting morbidity in Indonesia are average duration of school attendance (X_1), health insurance (X_4) and population density (X_5). Using these significant variables, SEM model is then constructed.

The equation of SEM model is as follow.

$$\hat{Y} = 32{,}8322 - 1{,}8299X_1 - 0{,}0754X_4 + 0{,}0004X_5 + U_i$$

$$dengan: \; U_i = 0{,}6601 \sum_{j=1, j\neq i}^{34} W_{ij}U_j + \varepsilon_i$$

Based on the model with some significant variables, the interpretations are as follows:

1. The coefficient for average duration of school attendance is -1.8299 which means if we increase the average duration of school attendance for one year and other variables remain constant, then the morbidity rate in Indonesia will decrease 1.8%.
2. The coefficient for health insurance is -0.0754 which means if this variable increase ten percent, the morbidity rate tends to decrease 0.75%.
3. The coefficient for population density is 0.0004 which means if the population increases 100% then the morbidity rate will also increase as much as 0.04%.

Coefficient of determination (R^2) of the SEM model is 77.60 % which represents that the model is good enough to explain the morbidity rate in Indonesia.

5. Conclusion

Based on the Moran's index testing, it can be concluded that there is spatial autocorrelation on morbidity rates, which means similarities among adjacent provinces exist. The variables that affect morbidity rates in Indonesia are average time duration of school attendance (X_1), health insurance (X_4) and population density (X_5), where the SEM model can be written as:

$$\hat{Y} = 32{,}8322 - 1{,}8299X_1 - 0{,}0754X_4 + 0{,}0004X_5 + U_i$$

$$with\ U_i = 0{,}6601 \sum_{j=1, j\neq i}^{34} W_{ij}U_j + \varepsilon_i$$

From the model obtained, it can be seen that the factors significantly affect morbidity cases in Indonesia. The results imply the need for the government to further formulate measures in reducing the percentage of morbidity, especially the factors that have the greatest influence, namely the average length of schooling and health insurance. The results clearly show that strengthening the education of the population greatly reduces morbidity rate. Taking this in the context, it is a challenge to the government to further improve the quality of education and health insurance in the country. The model suggests a country with healthy mind and healthy body to reduce morbidity rate. Given the limits of the study, further research is recommended considering the number of predictor variables and types of variables to obtain a better model.

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Assessing Students' Mastery and Misconceptions in the Fundamental Operations on Integers

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Abstract

One of the common misconceptions affecting mathematics performance of high school students involves operating integers. Evidently, students who were exposed to modular learning demonstrate poor mastery of the pre-requisite skills. This study aimed to assess the mastery level and misconceptions of the Grade 7 students involving operations on integers. A descriptive research design was used with a total of sixty-two (62) conveniently chosen Grade 7 students were twenty-nine (29) were males and thirty-three (33) were females. The Mean Percentage Scores (MPS) per operation on integers were calculated to describe the mastery level and the assessment results were analyzed to identify possible misconceptions of the students in operating integers. Similarly, data were analyzed using the Welch t-Test to determine if there is a difference in the level of mastery between the male and female students. Findings show that the overall MPS result is 50.56%, indicating that the students demonstrated Average Near Mastery (AVR) of the concepts involving operations on integers. In addition, there was no significant difference between the mastery level of male and female grade 7 students. Although the students demonstrated Average Near Mastery (AVR) in the given assessment, the item analysis showed various misconceptions and errors exhibited by the students regardless of sex and section. Students' misconceptions include subtracting integers and dealing with negative numbers. Hence, an intervention is needed to address the misconceptions in subtracting integers and a reinforcement is proposed to enhance the students' mastery in other operations on integers.

Keywords: *Operations on Integers, Mastery Level, Mean Percentage Score, Misconceptions*

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1. Introduction

As mathematics is an integral part of human's daily life, the Philippines Department of Education (DepEd) K-12 curriculum aims to help students master the core skills which includes the critical thinking and problem solving (DepEd, 2016), which are essential competencies in the 21st century. To achieve proficiency, students must be actively involved in the learning process and should be given opportunities by the teachers to acquire and enhance their mathematical skills. However, the two years exposure of students to modular distance learning due to pandemic caused troubling impact on their mathematical abilities.

Mathematics is one of the difficult subjects to learn even before the pandemic started (Lalian, 2019). It is not a surprise that many incoming high school students who moved from modular distance learning to face-to-face classes post-pandemic school year have poor basic mathematics skills. In fact, Basilio et al. (2022) pointed that students must be assessed accurately to address the learning losses in mathematics and "identify students at risk of developing low math skills" (Mejias et al., 2019, p. 2). Misconception about mathematical concepts is one of the factors affecting mastery of competencies. This means that low mastery and misconceptions in mathematics are intertwined issues. "Misconception is a type of error in understanding each mathematical concept and solving mathematical problems" (Purwaningrum & Bintoro, 2019, p. 174). If this problem remains unsolved, it will affect students' achievement in mathematics.

One of the basic mathematics competencies that many high school students struggled and had misconceptions involve operating signed numbers or integers. Khalid and Embong (2019) accentuated that student facing difficulties in solving integers has been known throughout the world. Students often encountered errors and misconceptions in understanding the concepts and operations on integers because students learn basic operations involving integers procedurally without understanding and analyzing the concepts (Dube & Robinson, 2018). Moreover, students were confused in operating integers, and they tend to mix-up the rules especially when the signs of integers involve both the positive (+) and the negative (-) signs. In addition, students struggled to perform operations on integers especially when dealing with negative numbers. As a result, students struggled to solve problems involving operations on integers (Alsina & Nelson, 2006). This misconception can affect students' skills in solving mathematical problems (Booth & Koedinger, 2008).

Based on the Most Essential Learning Competencies (MELC) for Mathematics provided by the DepEd, the concepts of fundamental operations on integers are introduced to students as early as grade 6 in the Quarter 2 and the same concepts are re-introduced in grade 7 Quarter 1 for one week. This is where the problem could stem from poor basic mathematical skills and misconceptions about the rule of operations on integers because grade 7 students enrolled during the school year 2022-2023 were migrant learners from two-year modular learning due to the COVID-19 pandemic. The concepts of integers and the four basic operations on integers are expected competencies students must be able to demonstrate as they move to high school. However, Basilio et al. (2022) reported that grade 7 students who were exposed to modular distance learning have not fully acquired the mathematics pre-requisite skills which made them not ready for high school mathematics. In addition, the study found no significant difference in the elementary math skills of grade 7 students when analyzed by gender (Basilio et al. 2022). On the other hand, Pandey (2017) reported that male students performed better than female students.

Most studies that uncover students' misconceptions involving operations on integers made use of descriptive design. Sadler (2012) developed a 20-item assessment "to assess the students' knowledge of various aspects of integer operations" (p. 24). This assessment is composed of equational problems using all four operations in mathematics to identify which operation students exhibit poor mastery and misconceptions (Sadler, 2012). At present, there is a limited study that evaluates misconceptions of students in mathematics involving integers in post pandemic. Similarly, gender divide in terms of mastery and misconceptions involving fundamental operations on integers remains to be unexplored.

The purpose of this study is to determine the mastery level and the misconceptions of the grade 7 students in mathematics, particularly in solving integers with the involvement of the four (4) mathematical operations: addition, subtraction, multiplication, and division of integers. Also, this study compares the mastery level of the male and female students in the fundamental operations on integers and design intervention to enhance the students' mathematical skills. In addition, the study aims to test the significant difference in the mastery level of the grade 7 students on operations of integers when analyzed by sex.

2. Literature review

2.1. Integers and Fundamental Operations on Integers

Integers are set of numbers that can either be positive or negative numbers or zero (0) (Setyawati & Indiati, 2018). Integers are also described as a signed number with a positive (+) and negative (-) sign on a number. The concepts of integers are fundamental mathematics competencies students must master. Rosyidah et al. (2021) stated that "integer is an essential part of the number concept" (p. 1). Similarly, Nurnberger-Haag et al. (2022) pointed out that "integer operations are crucial aspects of numerical competence necessary for all subsequent mathematics" (p. 1). In addition, Lamb and Thanheiser (2006) stated that "the subject of integers is a very important part of the middle school mathematics curriculum as it symbolizes a move from concrete to abstract thinking" (p. 176). In other words, learning concepts about operations involving integer is a serious topic that must be focused on to prepare students for higher mathematics.

The fundamental operations performed on integers include addition, subtraction, multiplication, and division. Rules of integer operations differ when dealing with integers with like signs and unlike signs.

For addition of integers, there are two cases to consider (1) adding integers with like signs and (2) adding integers with unlike signs. To add integers with like signs, add the absolute values of the two integers and put the common sign of the numbers. To get the sum of the two integers with unlike signs, get the difference of their absolute values then copy the sign of the larger number.

To subtract integers, change the sign of the number being subtracted and perform the addition. In other words, if a and b are integers then a – b = a + (-b).

For multiplication of integers, there are two cases to consider. When multiplying integers with like signs, the product of the two integers is always positive, that is $negative\ (-) \times negative\ (-) = positive\ (+)$ and $positive\ (+) \times positive\ (+) = positive\ (+)$. On the other hand, when multiplying integers with unlike signs the product of the two integers will always be negative. In other words, $negative\ (-) \times positive(+) = negative\ (-)$ or $positive(+) \times negative\ (-) = negative\ (-)$.

The rules for division of integers are similar to the rules when performing multiplication of integers. When two integers of like signs are divided, the quotient will

always be positive. However, when two integers of unlike signs were divided, the results will always be negative.

2.2. Students' Misconceptions in the Fundamental Operations on Integers

Several studies about students' misconceptions in mathematics revealed that learners often encountered errors and misconceptions when dealing with integers (Jamaludin & Maat, 2020).

Sadler (2012) found that students who have misconceptions in dealing with integers usually arrived at an answer either having the (1) wrong sign, (2) wrong value, or (3) wrong sign and value. Students were confused what sign should be placed on the number after solving it because they have not understood well the rules on operating integers. Also, students have the tendency to solve problems involving integers and arrived at a wrong value because they are confused what to do with the signed numbers. In some cases, students arrived at an answer with a wrong sign and value because they do not know what rules to observe when performing operations on integers.

Fuadiah et al. (2016) determined the misconceptions of the 96 Grade 7 students Palembang, Indonesia and found out that most students encountered difficulties in understanding the "concept of integer particularly which is related with negative numbers" (p. 35). Most of the students struggled and tend to get confused with the negative numbers and misapplied the rules in operations involving integers. Makonye and Fakude (2016) pointed out that "negative numbers are difficult to teach" (p. 2). Students get confused of the signed numbers especially when the equation contained either a positive (+) or negative (-) number, hence, they often encountered misconception of "rule mix-up" where they just remember the rules of each operation of integers and apply it erroneously (Khalid & Embong, 2019). Similarly, Permata et al. (2019) found that students struggled in subtracting integers. The most common misconception of the students in subtracting integers is when the minuend is a negative integer. Also, Rubin et al. (2014) pointed out that students often have difficulties in understanding the rules of subraction of integers with opposite signs. Badarudin and Khalid (2008) claimed that the concepts of subtraction of integers involving negative numbers is difficult for the students to assimilate. On the other hand, Sadler (2012) and Ali Rahman et al. (2017) found that students have misconceptions in multiplying integers by 0.

Students also exhibited errors in calculation because of "poor proficiency in English language" (Makonye & Fakude, 2016, p. 9). This misconception is usually observed in subtraction of integers. The use of the switch word "from" in problems involving subtraction of integers confuses students in translating a verbal phrase to mathematical phrase. For example, when students were asked to "subtract 10 from 30", the common error in translating this phrase to mathematical phrase is 10 – 30, which lead to an incorrect answer.

Khalid and Embong (2019) stated that "good knowledge of operations in integers is important for manipulation of numbers and letters in algebra" (p. 11). Permata et al. (2019) revealed that the "students understanding of algebra is still low" (p.1). Moreover, Alsina and Nelson (2006) claimed that students are still struggling whenever they try to solve simple mathematical problems involving integers. To overcome this, students must deepen their knowledge in operating integers before proceeding to higher math concepts. Using models such as number lines could help students in learning integers easily. Number line is "the basic metaphor in understanding mathematics" (Nunez & Lakoff, 2013, p. 29-30). The role of using this model is significant in "the period of transition from concrete operations to abstract operations and encounter the concept of integer for the first time" (Cetin, 2019, p. 365). According to Fadillah and Susiaty (2019), correcting student's misconceptions that is fundamental to the new concepts to be learned is a must before introducing new concepts to students. Therefore, identifying students' misconceptions and how to overcome these must be done continuously to enhance students' competencies in mathematics (Jamaludin & Maat, 2020).

2.3. Students' Mastery level in Mathematics

Mathematics achievement of students is very low (DepEd, 2019). Pandey (2017) revealed that the male students performed better than female students in Mathematics when analyzed by sex. Undeniably, this problem worsens due to pandemic (Delos Santos et al. 2022). At present, most of the grade 7 students were exposed to modular distance learning. Basilio et al. (2022) reported that grade 7 students are not ready for high school mathematics because they have not mastered the pre-requisite skills regardless of gender. These learning issues affect the student's level of academic achievement in mathematics, particularly in learning the concepts of integers. As a result of poor performances of the students in mathematics, an intervention is needed to overcome learning loss. Khun-Inkeeree et al.

(2016) emphasized that the achievement of the students can be improved if they give importance to mathematics and "this will automatically boost their self-confidence" to be participative in learning mathematics (p. 97).

Students' misconceptions and errors in integers can affect the level of their mastery and performance in mathematics. Studies that evaluate the mastery level of students and gender difference in the fundamental operations on integers is very limited. Moreover, there is also limited study on how to overcome the misconceptions of the students (Jamaludin & Maat, 2020). Basilio et al. (2022) pointed out that students from elementary moving into the secondary level "should be assessed to monitor who need intervention" (p. 81). Hence, the mathematics teacher can design teaching strategies that will students improve their performance in mathematics and overcome the misconception. Moreover, teachers have to choose the appropriate strategies to increase the students' achievements in Mathematics (Sadler, 2012) and to focus on least mastered competencies of the students specifically in solving integers using four operations.

3. Methodology

3.1 Research Design

This study made use of a descriptive research design to determine and describe the students' mastery level and misconceptions involving operations on integers since it can generate both "qualitative and quantitative data" (Koh & Owen, 2000). Most studies that identify misconceptions of the students in mathematics made use of a descriptive design (Sadler, 2012).

3.2 Respondents of the study and sampling techniques

The respondents of this study were sixty-two (62) Grade 7 students enrolled during the school year 2022-2023 of which twenty-nine (29) are males and thirty-three (33) are females. These respondents were conveniently chosen from the two sections of Grade 7 of which thirty-four (34) were from Grade 7A and twenty-eight (28) were Grade 7B.

3.3 Research Instrument

Assessment on Integers (AI) is a 20-item researcher-made assessment which aims to determine students' mastery level and misconceptions in operating integers. AI is a multiple-choice assessment with four (4) options where students are required to provide and show

their solution for each item. The AI was carefully validated by the research adviser and the mathematics 7 teacher before it was pilot tested to twenty-two (22) Grade 7 students. The data collected from the pilot test were analyzed to ensure the reliability of the instrument. The AI was found to be acceptably reliable with a Cronbach alpha value of 0.72.

3.4 Data Gathering Procedures

Before the implementation of the study, the researchers seek approval from the office of the school principal and consulted with the Grade 7 adviser and math teacher. Once the researchers secured all the pertinent documents needed for the implementation of the study, the list of the Grade 7 students both A and B were determined. These students were already exposed to mathematics instructions involving operations on integers in Grade 7.

During the first quarter of the school year, students attended three-day in-person classes and two-day modular learning. The concepts of operations on integers were introduced to learners in face-to-face classes and independent exercises were given in the two remaining days in the given week. In this study, grade 7 students were assessed after being introduced to the concepts of integers and the fundamental operations on integers.

During the implementation, the researchers presented first the keywords used for different operations on integers. Afterwards, the researchers, with the guidance of the mathematics 7 teacher, administered the AI to 62 Grade 7 students of Sections A and B to identify their mastery level and misconceptions on operations of integers.

3.5 Statistical Treatment

The researchers computed the MPS per operation of the AI by section and sex using the formula $MPS = \frac{Computed\ Mean}{Total\ number\ of\ items}\ x\ 100$ and was interpreted using the descriptive equivalent of mastery level as stipulated in DepEd Order No. 160 series of 2012. The result of the AI was analyzed and interpreted using R statistical package. On the other hand, the researchers checked the normality and homogeneity of the data set using R statistical package. The Shapiro-Wilk test results for male and female showed no significant departure from normality were found: W(29) = 0.95879 , p = 0.3069 and W(33) = 0.93782, p = 0.05872, respectively. Moreover, the Levene's test results revealed that the homogeneity of variance assumption was not met. Hence, a Welch t-test was employed to determine the significant difference in the mastery level of the students when analyzed by sex.

To diagnose the misconceptions of the grade 7 students on operations on integers, an item analysis was carried out to identify which item in the assessment students failed to answer correctly and examine their solution in the problem. Misconceptions per operation on integers were identified and analyzed carefully. This served as the basis for designing class intervention and reinforcement for the grade 7 mathematics.

3.6 Ethical Consideration

The researchers strictly observed the following ethical guidelines in conducting this study: (1) a communication letter was presented to the concerned authorities; (2) the identity of the respondents and all the data gathered were kept confidential; (3) health protocols and social-distancing measures set by the Ministry of Basic, Higher, and Technical Education (MBHTE) were strictly followed; and (4) the dignity and wellbeing of students was protected at all times.

4. Findings and Discussion

4.1 Mastery Level of the Grade 7 students on Assessment on Integers (AI)

To determine the mastery level of the Grade 7 students involving operations of integers, the Mean Percentage Score (MPS) per operation was calculated. Table 1 shows the mastery level per operation by section.

Table 1

Mastery Level per Operation on Integers

Operations	Grade 7A MPS%	Grade 7B MPS%	OVERALL MPS%
Addition	60.59 (AVR)	40.00 (AVR)	55.16 (AVR)
Subtraction	45.29 (AVR)	25.88 (L)	39.03 (AVR)
Multiplication	55.88 (AVR)	44.12 (AVR)	54.84 (AVR)
Division	51.18 (AVR)	45.88 (AVR)	53.23 (AVR)
OVERALL	**53.24 (AVR)**	**38.97 (AVR)**	**50.56 (AVR)**

Legend: 96-100%-Mastered (M); 86-95% -Closely Approximating Mastery (CAM); 66-85% -Moving Towards Mastery (MTM); 35-65% -Average Near Mastery (AVR); 15-34% -Low Mastery (L); 5-14% -Very Low Mastery (VL); 0-4% -Absolutely No Mastery (ANM).

As shown in Table 1, the MPS of Grade 7B was relatively low (25.88%), particularly on the operation that involves subtraction of integers. This indicates that the students

demonstrated low mastery of the concepts involving subtraction of integers. It also follows that students have possible misconceptions about the rules involving subtraction of integers. This finding corroborates with the studies of Badarudin and Khalid (2008), Rubin et al. (2014), and Permata et al. (2019) that the students often encountered misconceptions on subtraction of integers.

On the other hand, for operations of integers involving addition, multiplication, and division, students in both sections demonstrated Average Near Mastery (AVR). It is noteworthy to mention that among the operations, the addition of integers has the highest MPS. Based on the assessment given, students find it easy to add integers with like signs. Comparing the MPS of the two sections, the overall MPS of Grade 7A is relatively higher than the Grade 7B by 14.27%. This shows that the Grade 7A students got more correct answers in the Assessment on Integers (AI) compared to the Grade 7B students. Overall, the MPS of the grade 7 students in the given Assessment on Integers (AI) is 50.56% indicating that the students exhibited Average Near Mastery (AVR).

The MPS will be the basis for conducting intervention and reinforcement to help students enhance their skills involving operations on integers. Based on these findings, the focus of the intervention for Grade 7B shall be on the subtraction of integers. In addition, a reinforcement is needed for addition, multiplication, and division of integers because even though the MPS for these operations is relatively higher than the subtraction of integers, students still exhibited misconceptions in these operations of integers. Similarly, Grade 7A should be exposed to reinforcement to improve their competence in solving problems involving integers.

4.2 Mastery level of the Grade 7 Students when analyzed by Sex

A Welch t-test was used to determine if there is a significance difference in the mastery level of the Grade 7 students on the operations of integers when analyzed by sex. Table 2 shows the mastery level of male and female students on the given AI.

As shown in Table 2, the p-values in all four (4) operations were not significant. This indicates that there is no significant difference in the mastery level on operations of integers when analyzed by sex. This result contradicts the findings of Pandey (2017) that male students performed better than female students in Mathematics.

Table 2

Mastery level per Operation on Integers when analyzed by Sex

OPERATIONS	MALE		FEMALE		*Df*	*T*	*p*	Cohen's *d*
	M	SD	M	SD				
Addition	2.41	1.81	2.42	1.36	58.69	-0.92	.36	0.23
Subtraction	1.55	0.91	1.73	1.25	53.54	-1.60	.12	0.39
Multiplication	2.45	1.41	2.42	1.21	58.37	-0.18	.85	0.05
Division	2.55	1.37	2.31	1.26	59.74	0.07	.95	0.02
OVERALL	**8.95**	**2.92**	**8.88**	**3.39**	**54.21**	**-0.89**	**.38**	**0.22**

Legend: Significant at p<0.05 (two-tailed).

4.3 Misconceptions of the Grade 7 students in the AI

The researchers analyzed the AI results to determine the misconceptions made by the Grade 7 students in both sections and these were categorized accordingly into four operations: (1) addition, (2) subtraction, (3) multiplication, and (4) division. These misconceptions are common to all grade 7 students regardless of their section and sex.

4.3.1 Misconceptions in Addition of Integers

The concept of adding integers has two (2) cases: Case 1) adding integers with the same signs is just simply add the integers and apply the common sign to their sum; and Case 2) adding integers with unlike signs requires to subtract first the integers and apply the sign of the bigger integer to their difference.

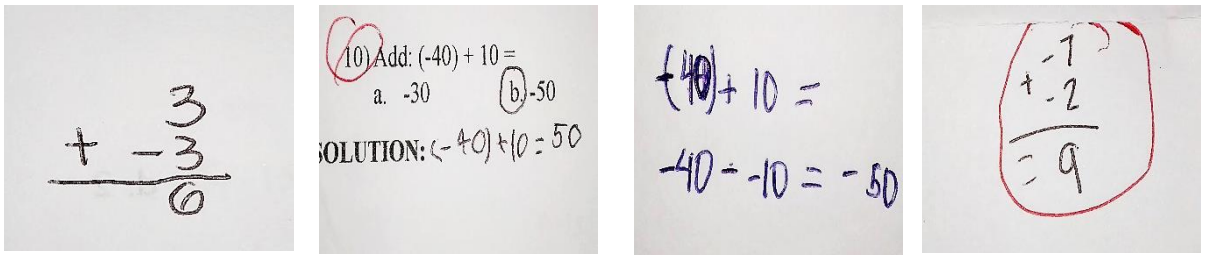
Students were struggling in adding integers with unlike signs and tend to get confused with signed numbers and the appropriate sign to use in the result. For example, in item 2, the question is 3 + (-3). However, students disregard the negative sign and wrote this in their solution as 3 + 3 = 6 instead of 3 + (-3) = 0. Likewise, in item 10 which asked students to simplify this expression, (-40) +10. The students simplify this as (-40) + 10 = 50 and (-40) + 10 = -50 instead of applying the rules in adding integers with unlike signs that should be (-40) + 10 = -30.

Another misconception is found in item 13 which involves adding integer with the same signs, and both are negative signs. The expression is (-7) + (-2) and they solved this as 7 + 2 = 9, ignoring the negative signs present in the expression where the final answer should be (-7) + (-2) = -9. This result coincides with the findings of Fuadiah et al. (2016) that

students struggled in understanding the concepts of negative numbers in terms of operations on integers.

Figure 1

Misconceptions on Addition of Integers



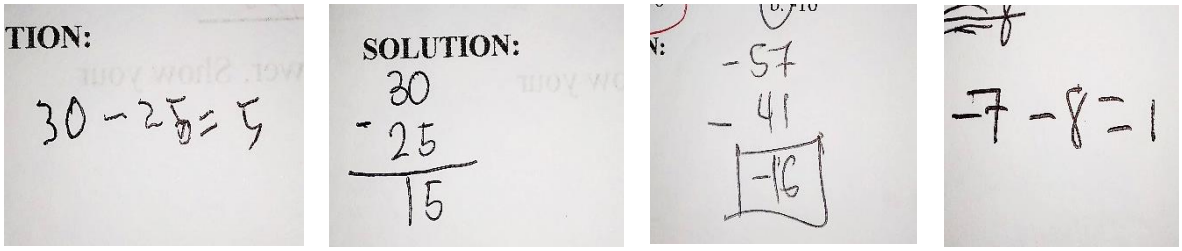
4.3.2 Misconceptions in Subtraction of Integers

In subtracting integers, there are also two (2) cases which differs from the addition of integers: Case (1) for subtracting unlike sign integers, it requires to change the sign of the second integer (subtrahend) and apply the rules in adding integers with unlike signs; and Case (2) subtracting a bigger number from a smaller number will leads to a negative answer.

Students encountered most of the misconceptions in subtracting integers based on the MPS. In item 6, only eight (8) students out of sixty-two (62) got the correct answer. The question asked students to “subtract 30 from 25”, where most of the students translated this expression into 30-25. The students were confused and have no idea about the use of the switch word “from” in an expression that instead of simplifying it as 25 – 30 = -5, they ended up with 30 -25 = 5. The same error can be found item 16, “subtract -57 from 41”. This expression must be solved in this way, 41 – (-57) = 98, applying the rules in subtracting unlike sign integers. However, the students solved this as, -57 – 41 = -98 while others calculated it in this way -57 – 41 = 98. There were also students who solved in this way, -57 - 41 = 16, where they just directly subtract the integers and applying the sign of the bigger number, -57, to its difference just like in the rules of adding unlike sign integers. This misconception is known as “rule mix-up” and it corroborates the findings of Khalid and Embong (2019) wherein the students tend to remember the rules of the operations of integers but misapplied these rules in solving integers. Morever, these findings coincide with Badarudin and Khalid (2008) and Rubin et al. (2014) that students struggled to subtract integers with unlike signs.

Figure 2

Misconceptions in Subtraction of Integers



4.3.3 Misconceptions in Multiplication of Integers

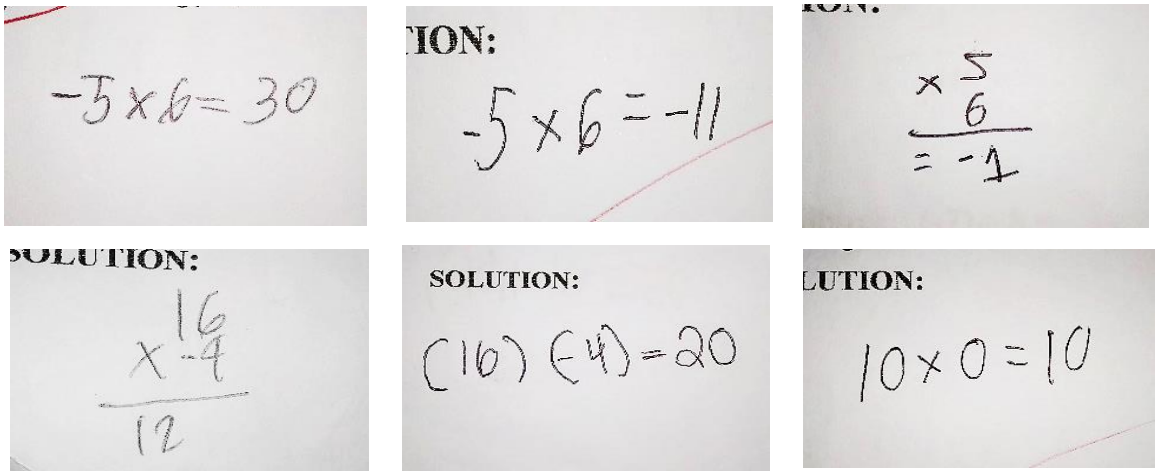
In multiplication of integers, there are three (3) cases: Case 1) the product of two integers with like signs is always positive; Case 2) the product of two integers with unlike sign is always negative; and Case 3) the product of an integer and zero is zero.

In the AI, students encountered misconceptions in multiplying unlike sign integers. For example, in item 4 the students were asked to evaluate (-5) (6). Some of the students got the correct answer which is (-5) (6) = -30. However, there were some who ignored the negative sign and wrote it as (-5) (6) = 30. Rule mix-up misconception is also present in this item where students solved it as (-5) – 6= -11, applying the rules in subtracting unlike sign integers and some also applied the rule in adding unlike sign integers, (-5) + 6 = 1. The same misconceptions were also determined in item 20, 16 x (-4). Students often disregard the negative sign that leads to a wrong answer that instead of solving it as 16 × (-4) = -64, it became 16 × (-4) = 64. They also misapplied the rules and solved it in these ways, 16 – (-4) = 20; 16 + (-4) = 12.

Another misconception can be found in item 7, which asked the students to evaluate 10 x 0 or multiplying an integer by zero. Most of them applied the rules in addition or subtraction of an integer and zero; 10 + 0 = 0 and 10 – 0 = 10, instead of using the zero-property rule of multiplication which should be equal to 0. This is the same with the findings of Rahman et al. (2017) and Sadler (2012) that the students have not mastered the property rule of multiplication in terms of multiplying a number by zero.

Figure 3

Misconceptions in Multiplication of Integers



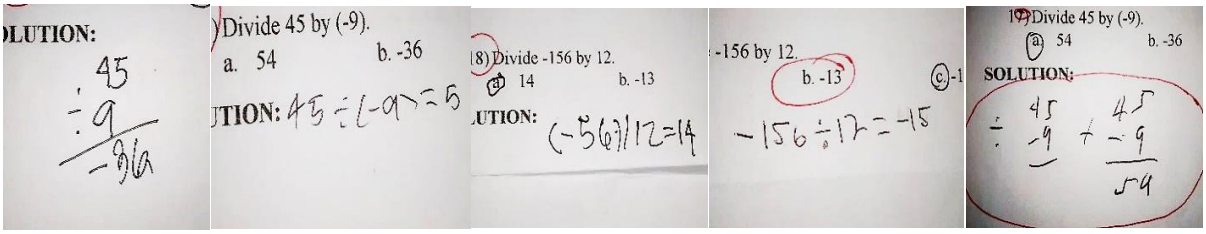
4.3.4 Misconceptions in Division of Integers

The rules and cases in dividing integers are the same with the multiplication of integers, the only difference is the operations used.

Aside from the difficulties in dividing unlike sign integers and rule mix-up, another misconception was identified in this operation. Based on the AI results, students struggled in dividing numbers. In item 17, they were asked to solve 45 ÷ (-9). The students were still ignoring the negative sign and solved this as 45 ÷ (-9) = 5 instead of -5. However, there are some students who used the rules in adding unlike sign integers [45 + (-9) = 36] and subtracting unlike sign integers [45 – (-9) = 54]. In contrast, the misconception that was identified in item 18 shows that most of the students do not know how to divide numbers. The expression is, -156 ÷ 12, and the quotient must be -13 by applying the rules of dividing unlike sign integers. However, because of the poor knowledge in dividing numbers, the students arrived at the answer of either 14 or -15 to that given expression. These misconceptions found in this study are similar to the findings of Dube and Robinson (2018) that students have a poor conceptual understanding of the division of numbers and that students also struggle to perform division of integers which led to wrong sign and value (Sadler, 2012).

Figure 4

Misconceptions on Division of Integers



5. Conclusion and Recommendation

This study aimed to determine the mastery and misconceptions of the students in the fundamental operations on integers. The findings showed that grade 7B students have misconceptions in operations on integers particularly in subtraction with a Mean Percentage Score (MPS) of 25.88% indicating Low Mastery. Moreover, there is no significant difference in the mastery level of Grade 7 students when analyzed by sex. Although the overall MPS of the Grade 7 is 50.56% which translated to Average Near Mastery (AVR), the students still have misconceptions in the fundamental operations of integers. Students tend to "mix-up rules" in performing the operations on integers. Moreover, grade 7 students struggled to perform subtraction of integers, especially when dealing with negative numbers.

Based on these findings, an intervention and reinforcement are needed to address these misconceptions in operations on integers and improve students' mastery level. Intervention will be needed for grade 7B class particularly for subtraction of integers since it is the only operation that both sections got the lowest MPS. As suggested by the mathematics teacher in grade 7, the intervention will be done one (1) hour for two weeks to ensure that students have more time to practice subtracting integers with negative numbers. However, the researchers suggest that reinforcement should be carried out to grade 7B for addition, multiplication, and division of integers while for grade 7A all the fundamental operations on integers should be the focused of the reinforcement since the MPS showed that students exhibited Average Near Mastery (AVR) of the competencies.

Proposed Intervention and Reinforcement for Operations of Integers

The researchers proposed an intervention and reinforcement based on the identified misconceptions of the Grade 7 students in the AI. This intervention and reinforcement program was designed based on the least mastered competencies found through the MPS. It aims to address the misconceptions of the students in the fundamental operations on integers that can possibly affect students' achievement in Mathematics.

Table 3

Designed Intervention and Reinforcement for Integers

A. INTERVENTION			
OPERATION	**OBJECTIVES**	**TARGET STUDENTS**	**PERIOD**
Subtraction	Students should be able to: a) illustrate the rules of subtracting integers with like signs. b) Illustrate the rules of subtracting integers with unlike signs. c) Translate verbal phrase to mathematical phrase using the switch word "from" in subtraction of integers. d) Perform subtraction of integers.	Grade 7B students	1 hour session every afternoon for 2 weeks
B. REINFORCEMENT			
OPERATIONS	**OBJECTIVES**		**PERIOD**
Addition	Illustrate the concepts of adding integers specifically in adding integers with unlike signs [(+) + (-)] or [(-) + (+)]. Perform addition of integers.	Grade 7A and 7B students	30 minutes session every afternoon for 1 week
Multiplication	Illustrate the concepts of multiplying integers particularly with the negative integers. Illustrate the zero property of multiplication. Perform multiplication of integers.	Grade 7A and 7B students	30 minutes session every afternoon for 1 week
Division	Illustrate the concepts of dividing integers especially in dividing unlike sign integers. Perform division of integers.	Grade 7A and 7B students	30 minutes session every afternoon for 1 week
Subtraction	Illustrate subtraction of integers with unlike signs. Perform subtraction of integers.	Grade 7A students	30 minutes session every afternoon for 1 week

The researchers together with the mathematics 7 teacher developed and designed learning interventions to address the misconceptions of the students in the fundamental operations on integers. The intervention is intended for students in the Grade 7B class who exhibited poor mastery of the competencies involving subtraction of integers. The two-week intervention aims to enhance students' mastery in subtracting integers with unlike signs and deal with negative integers. the intervention will be done one-hour per session every afternoon for two weeks. The intervention will be carried out by the teacher teaching in grade 7.

On the other hand, the researchers also proposed a reinforcement to enhance further the mastery level of the Grade 7B students in operating integers specifically for addition, multiplication, and division of integers. Similarly, the Grade 7A students will be exposed to a reinforcement for one (1) week per operation on integers. The researchers proposed that the intervention and reinforcement should be done per operation, in separate and granular sessions, to enable the students to master the skills and remove the possibilities of committing the same errors in solving integers, particularly the "rule mix-up" issue as made mentioned by Khalid and Embong (2019). Furthermore, the proposed intervention and reinforcement is submitted to the Office of the School Principal for the inclusion to the priority programs of the school to address learning losses and gaps in learning mathematics.

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Development and Evaluation of Design Thinking-based Learning Packets for Enhancing Innovation Skills

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Abstract

Innovation skills such as creativity, empathy, experimentation, communication and collaboration are vital for the 21st century learners. Hence, this study determined the effectiveness of design thinking-based learning packet in enhancing the innovation skills of grade 11 learners. Descriptive statistics and t-test were utilized to look at associations between the pretest–posttest and survey questionnaire. The pretest and posttest results measured the effectiveness of the learning packet in enhancing the innovation skills of the learners, whereas the survey results were utilized to describe the students' innovation skills. A content validation tool from the Department of Education was utilized to determine the level of acceptability of the learning packet before its usage. The findings indicated that the level of acceptability of the learning packet was very high which implies that the experts recommend its use. The survey results showed that students' innovation skill is high while the pretest and post-test showed a significant difference in all terms. The findings suggest the use of design thinking-based learning packet as a supplemental learning material in teaching Physical Science to enhance the innovation skills of learners.

Keywords: *design thinking approach, design thinking-based learning packet, innovation skills, constructivist learning theory*

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1. Introduction

As the face-to-face classes come in full blast on November 2022, teachers were able to assess and identify personally various educational gaps that the students had been facing which are the after effect of the latter distance learning that they went through during the period of the pandemic. With the use of the learning materials from the Department of Education (DepEd) which include the learning modules and different assessment materials for Science subjects, teachers were able to assess the level of innovation skills of the learners. During everyday assessments, teachers were able to identify that innovation skills among learners has a low level (Ludewig et al., 2022; Schult et al., 2022; San Luis. & Villafranca, 2022).), which is a component of the 21st century skills learners need to be globally competitive (Soderlund. 2020; Stehle et al., 2019; Ozturk, 2023). As supported by Lee and Benza (2015), innovation skill is a key driver of difference and competitive advantage in the in the 21st century's complicated and accelerating competitive environment.

As the competitive climate is growing in the changing and developing world, students cannot succeed in the real world by having knowledge alone. To survive in the current world, students must develop 21st century skills including problem-solving, creativity, innovation, collaboration and communication. Hence, teachers are challenged to provide materials and classroom environment that foster these skills (Bao & Koenig, 2019; Kong, 2021; Habók & Nagy, 2016; Ojetunde & Ramnarain, 2023; Agbo et al., 2023; Murillo-Zamorano et al., 2021; Smeda et al., 2014; Price, 2015; Fischer & Barabasch, 2023). While many of the previous studies focused on the use and integration of technology in the teaching and learning process, majority of the studies in the Philippines involved development of learning materials (Malipot, 2022; Tarrayo & Anudin, 2023) in response to the modular distance learning imposed in the educational institutions. For example, this study employed the developed design thinking-based learning packet for science subjects to fill the educational gaps brought about by the pandemic. While the learning packet follows the design thinking approach, it initiates the development of innovation skills among students. For instance, design thinking approach can provide teachers with a clear pedagogical process and tools to effectively instill innovation skills such as creativity, empathy, experimentation, communication, and collaboration (Lee & Benza, 2015). Rusmann and Ejsing-Dunn (2022) add that students learn

through tackling issues in the real world, which is the foundation of the innovative educational strategy.

This study evaluated the developed learning packets in Physical Science as a tool in enhancing the innovation skills of the students. As Jolly (2009) suggested teachers to engage learners, this learning materials expects students to interpret concepts and create new meanings, analyze the underlying patterns of their thought processes, and design experiences to change their beliefs so that they are consistent with the accepted scientific norms, which will foster innovation skills. While there are many studies that evaluated the developed learning materials in various subjects (Yongco & Del Valle, 2022; Estrellado, 2021; Origenes, 2021; Anives & Ching, 2022; Aquino & Ching, 2022; Arida et al., 2022; Lopez, 2021; Chozas & Cuenca, 2022; Reyes & Salvador, 2022; Malaluan & Andrade, 2023; Magpantay & Pasia, 2022; Aguilar & Panoy, 2022), this study also considered the academic performance of the students before and after the utilization of the learning packets.

2. Literature Review

2.1 Design thinking approach

Design thinking is a constructivist learning approach wherein students are expected to learn how to create from their own experiences (Trevors et al., 2016; Pande & Bharathi, 2020). According to Brown and Katz (2009) and Kisker (2021), the design thinking approach provides a method to frame the problem into a question, understand what people need, generate creative ideas, prototype those ideas and test and learn. In addition, this approach could help everyone practicing it to solve real-world problems by conceiving original and inclusive ideas, conduct research, do experimentation and then analyze the solution for the real-world problem (Malele & Ramaboka, 2020). Linton and Klinton (2019) add that it emphasizes a practical approach where students step outside the classroom to learn. Using this approach, students are motivated to explore, trust is built between student and teacher to provide confidence for self-exploration, and team competencies are fostered to allow students to express their opinions and share their knowledge (Scheer et al., 2012). The groundwork for the creation of design thinking approach was provided by Herbert A. Simon in 1969. Dam and Siang (2021) cited the seven-step procedure laid by Simon on the thinking process to find original solutions. However, the Hasso Platner Design Institute (Stanford University in the United States)

embraced the design thinking methodology with their own 5-step process, which comprises empathize, define, ideate, prototype and test (Vallis & Redmond, 2021).

For the past years, design thinking has been a topic of teaching, research, and practical application in practically every area of education, research, and industrial activity (Pande & Bharathi, 2020). Several research in the field of education have demonstrated that the standard of classrooms rises when teachers apply the design thinking methodology when developing lessons and lectures for students (Jamal, 2022). To date, several projects have been launched in K-12 classrooms to encourage and investigate design thinking as a modern learning paradigm or learning model (Barrie, 2006; Goldman and Zielezinski, 2016; Noel & Liub, 2017). It is now a popular framework that educators have applied in a variety of K-12 extracurricular contexts to bring more creativity into learning (Linton & Klinton, 2019).

2.2 Innovation Skills

Innovation skills is among the 21st century skill components which have been the center of attention and one of the most desired skills since they are the first requirements of job qualification in the 21st century (Soland et al., 2013; Demirkol-Orak & İnözü, 2021). According to Niruttimatee and Sanrattana (2022), innovation skill is significant in the 21st century society and teachers must focus on developing students' innovation skills in order for them to succeed in work and life. In a world that was developing quickly, the ability to think creatively and innovatively was among the most important. These abilities help people comprehend and address actual issues (Tiyaswati, 2021). As to Magulod (2018), innovation and originality are essential in 21st-century education. Niruttimatee and Sanrattana (2022) added that innovation skills are included in what are considered as ‘essential skills.’ In academic studies, innovation skills are usually accompanied by creative skills because innovation skills lead to the creation of new or different ideas or methods.

People with innovative concepts can do their work with full confidence and are willing to take risks in order to achieve their goals (Henderson, 2017). Hence, Amabile (1996) refers innovation to the successful implementation of creative ideas. According to Sawyer (2006), innovation is an outcome of an innovation process whereby collaboratively

created ideas are transformed into a single product or other end result, often through interactions with several stakeholders. As a cognitive process, Barak et al. (2013) viewed innovative thinking that leads to implementing new or significantly improved ideas. While Drucker (2007) believes that innovation has the ability to put different products out of the ordinary and commercialization, it requires thinking outside of the patterns in mind, go beyond the standard thinking style and develop original practical ideas with use-value (Çellek, 2002).

2.3 Learning Packet

A learning packet is a unit of study materials on a certain subject that enables the student to operate in some degree independently from their teacher. Most learning packets contain a self-assessment test to find out exactly where the student is with respect to a particular skill (Sincoff & Reid, 1974). According to the Department of Education, Dasmariñas (2020), learning packet is an instructional guide that learners can use in the absence of modules and or other learning materials while Sincoff and Reid (1974) call a learning packet as a range of combined multisensory exercises. While they ought to be created around performance goals, it needs to ensure consistency and organization of the foundational topics within a school.

According to Marzahi (2001), one method of communicating between a student and/or a small group of students and the instructor where the content of a particular topic or activity is explained is through the use of self-directed learning packet. For example, Barnhill (1998) developed the science learning activity packets (SciLAPs) where students find explicit directions to complete a specific science activity and what activities they should perform to acquire the knowledge and abilities expected from them. The packet approach inspires students to excel and shed their ingrained notions about education (Barnhill, 1998; Basho, 2005). Furthermore, students will be responsible for accomplishing a task in a specific amount of time. This instructional method promotes students to take the initiative to complete an activity and be able to utilize digital technology to learn more outside the class and continue working on completing the tasks designed in each packet. It also encourages them to work collaboratively with peers and may consult a resource person, as needed. If students experience difficulties, the instructor is available as a resource. When not serving as

a resource, the instructor continually monitors student progress (Barnhill, 1998; Basho, 2005).

The intent of the learning activity packets is to improve students learning performance as they further enhance their understanding as well as improve mastery level in problem-solving by taking enough time to repeatedly practice tasks. Galos (2022) emphasized that the use of learning activity packets as an intervention may be applicable to any subject area and would help teachers increase the subject literacy of their students in a self-directed manner.

2.4 Theoretical Framework

Constructivist Learning theory served as the basis for conceptualizing this study. It has its historical roots in the work of Bruner (1961) and Vygotsky (1962). Constructivist learning theory focuses on the social interaction occurring in the learning process within a certain environment through collaboration, encouragement, scaffolding, and mentoring (Amarin & Ghishan, 2013; Ayas, 2006; Chitanana, 2012; Gold, 2001; Rasha Essam, 2016). The view of constructivism learning theory is that learning is an active and constructive process (Bada & Olusegun, 2015; Goriss-Hunter et al., 2023). This theory looks at the classroom as a community where learners engage in problem solving activities, conversations, negotiations, and reflections (Karagiorgi & Symeou, 2005; Amarin & Ghishan, 2013; Rasha Essam, 2016). Meanwhile, Wilson (1996) and Shah (2019) describe constructivist learning environment as a place where learners may work together and support each other as they use a variety of tools and information resources in the guided pursuit of learning goals and problem-solving activities.

According to Sjoberg (2007), constructivist approach to learning is where knowledge is actively constructed by the learner, not passively received from the outside. For Sithara et al. (2017), constructivist teaching and learning theory advocates a participatory approach in which students actively participate in the learning process. Richardson (2003) calls constructivist pedagogy “the creation of classroom environments, activities, and methods that are grounded in a constructivist theory of learning, with goals that focus on individual students developing deep understandings in the subject matter of interest and habits of mind that aid in future learning.”

Moreover, constructivism is a paradigm that hypothesizes learning as an active, contextualized, or constructive process (Shah, 2019), which advances meaning-making and knowledge construction as its foremost principles (Crotty, 1998; Fosnot, 1996; Phillips, 1995). In applying the principles, individuals are assumed to construct their own meanings and understandings, which involve interplay between existing knowledge and beliefs and new knowledge and experiences (Richardson, 1997, 2003; Schunk, 2004). For VonGlaserfeld (1989), it puts forward two principles: "knowledge is not passively received but actively built up by the cognizing subject; and the function of cognition is adaptive and serves the organization of the experiential world, not the discovery of ontological reality."

Many teachers are hesitant to try the constructivist model because it requires additional planning and a relaxation of the traditional rules of the classroom (Scheurman, 1998). Teachers often feel as though they aren't doing their job if the students are working together and actively discussing the material instead of busily taking notes (Sprague & Dede, 1999). However, teacher-centered lessons can be less or non-productive, and in some cases, detrimental to the students' learning process (Zoller, 2000).

3. Methodology

This study used descriptive developmental research design since the purpose of the study is to produce a design thinking-based learning packet for enhancing the innovation skills of the learners. In addition, quantitative design was used to look at associations or relationship between variables.

The study utilized different instruments including survey questionnaire, a 60-item pre-test and post-test based on the learning competencies and innovation skills, with their corresponding table of specification, a validation tool for the learning materials developed and a lesson exemplar to guide the teacher in the whole process. The survey questionnaire was used to assess respondents' perception on the level of innovation skills and problem-solving skills. The pre-test was used to determine the level of innovation skills of the respondents before the use of the design thinking-based learning packets. The lesson exemplar used was developed in accordance to the K-12 Basic Education Curriculum Guide of the Department of Education. The post-test was conducted after the utilization of the design thinking-based learning packet to assess significant enhancement on the

innovation skills of the respondents. All the instruments used in the study undergone content validation, by the Education Program Supervisor (EPS), school head and six master teachers who were purposely chosen based from their specialization. A validation tool was utilized to determine to what extent the teacher-made research instruments were contextualized. The validators' comments and recommendations were integrated in the revision of the research instruments. The instruments also passed the validity and reliability test using the Cronbach's alpha coefficient. The reliability test performed on the assessment of the level of innovation skills of the learners in terms of creativity skills, empathy skills, experimentation skills, communication skills and collaboration skills are 0.724, 0.765, 0.741, 0.728, 0.713, interpreted as acceptable.

The researcher developed the learning packet following the most essential learning competencies of Grade 11 Physical Science reflected in the K to 12 curriculum guide, under the third quarter of the school year 2022-2023. The learning packet was validated by the experts, using a validation tool that was adapted from the Department of Education's assessment tool for a learning material. The variables evaluated by the experts during validation include content, format, presentation and organization and accuracy and up-to-datedness of information. Their comments and suggestions were incorporated in the final copy.

Participants of the study were 50 grade 11 students from the heterogeneous section of an Integrated High School in the Philippines. They were chosen as the respondents of the study as they experienced distance learning in 2020 and were identified to have low innovation skills on classroom-based assessments. Respondents' profile was assessed which includes the age, gender, and socio-economic status.

The following statistical treatment used were: descriptive statistics such as percentage and frequency distribution and mean and standard deviation; and inferential statistics such as t-test.

4. Findings and Discussions

Table 1 shows the result of the survey on the students' level of innovation skills in terms of five categories namely: creativity skills, empathy skills, experimentation skills, communication skills and collaboration skills.

The table presents creativity skills with lowest mean of 4.43 that implies learners think they possess lesser than the others. Although it has the least mean, still it has a high verbal interpretation. This implies that learners think they have the ability to think outside the box, to approach problems from multiple perspectives and to apply imagination to find new and original solutions in the most creative way. According to Palupi et al. (2020), creativity skills involve the activities of complex skills and cognitive abilities, personality factors and motivations, styles, strategies, and metacognitive skills.

Table 1

Students' Level of Innovation Skills

Innovation Skills	Mean	SD	VI
Creativity Skills	4.43	0.39	High
Empathy Skills	4.57	0.33	Very High
Experimentation Skills	4.45	0.38	High
Communication Skills	4.49	0.29	High
Collaboration Skills	4.47	0.37	High
Overall	**4.48**	**0.04**	**Very High**

Legend: 4.50 – 5.00 Strongly Agree (Very High), 3.50 – 4.49 Agree (High), 2.50 – 3.49 Moderately Agree (Moderate), 1.50 2.49 Disagree (Low), 1.00 – 1.49 StronglyDisagree (Very Low)

Empathy skills got the highest mean of 4.57 showing students are very empathic and always thinks of the benefit of other people when they create or do something. According to Yuksel (2015) and Gokap and Inel (2022), it is a skill that plays an active role in helping individuals establish a healthy communication with self and others, helps them to socialize and get along with others better. Therefore, good empathy skills help learners to be more aware of the situation of other people around them, this will enable them to understand other people better.

The overall mean is 4.48, which implies very high level of innovations skills. With high innovation skills, students are expected to have a good creativity skill, identify a problem when things arise, they are able to make hypothesis and they are able to organize ideas and analyze facts. In addition, they are able to convey information clearly and effectively through various mediums, including spoken, written and non-verbal means, a good trait of a learner who has good communication skill (Velentzas, 2014). They have the

ability to work together to achieve common goals, the description of someone with good collaboration skills (Handajani & Pratiwi, 2018; Boyraz, 2021).

Table 2

Level of Acceptability of the Design Thinking-Based Learning Packet

Level of Acceptability	Mean	SD	VI
Content	3.81	0.17	VS
Format	3.75	0.22	VS
Presentation and Organization	3.73	0.21	VS
Accuracy and Up-to-datedness of information	4.00	0.00	VS
Overall	**3.82**	**0.10**	**VS**

Legend: 3.50 – 4.00 Very Satisfactory, 2.50 – 3.49 Satisfactory 1.50 – 2.49 Poor, 1.00 – 1.49 Not Satisfactory

Table 2 presents the experts' perceived level of acceptability of the design thinking-based learning packet. It is composed of four categories namely: content, format, presentation and organization and accuracy and up-to-datedness of information.

For the content, the table presented a mean of 3.81 and SD = 0.17 with a verbal interpretation of very satisfactory since it was based on the present K-12 curriculum of the DepEd. The objectives of the said learning packet were based on the present learning module used by the DepEd as well as with the subject matter Physical Science. The activities provided elicit higher order thinking skills, and innovation skills such as creativity skills, empathy skills, experimentation skills, collaboration skills and communication skills.

As for the format, it gained a mean of 3.75 and SD=0.22 with a verbal interpretation of very satisfactory. For a learning material to have a very high rating in terms of format, it should follow the guidelines of the DepEd in making a good learning material. In this study, the researcher used an evaluation tool for a learning material from the DepEd following the indicators: clear and nice prints, accurate and vivid illustrations, appropriate design and layout and paper and binding. As per experts' evaluation using the learning material evaluation tool, the result implies that it was able to meet the necessary requirements and highly acceptable and highly recommended for use. Gray and Diloreto (2020) emphasized that good format will help the students to be more interested or engaged in the lesson that needs to be tackled.

As for the category presentation and organization, the table presents a mean of 3.73 and SD = 0.21 with a verbal interpretation of very satisfactory. A good learning material rated to have a very satisfactory level in terms of presentation and organization according to the DepEd's evaluation tool for a learning material should meet the following indicators: presentation should be engaging and understandable; there should be logical and smooth flow of ideas; vocabulary level is adapted to target reader's likely experience and level of understanding; length of sentences is suited to the comprehension level of the target reader; and sentences and paragraph structures are varied and interesting to the target reader. According to the validation and evaluation of the experts, result implies that the packet is highly acceptable and recommended for use. DepEd emphasized that good presentation and organization promotes engagement and supports understanding by the target user. Presentation stimulates active rather than passive learning.

Lastly, the accuracy and up-to-datedness of information gained a mean of 4.00 and SD=0.00, with a verbal interpretation of very satisfactory. According to the DepEd's evaluation tool for a learning material, indicators for accurate and up-to-date information include: no obsolete information found; no grammatical errors: and no factual errors.

In summary, the design thinking-based learning packet has a very high acceptability rate as per experts' evaluation in terms of content, format, presentation and organization and accuracy and up-to-datedness of information and is highly recommended for use.

Table 3 shows the scores of the students on the pre-test and post-test in innovation skills in terms of creativity, empathy skills, experimentation skills, communication skills and collaboration skills. The pre-test scores revealed that most of the respondents are in the average level. After the implementation of the strategy and the use of the design thinking -based learning packet, the post-test scores show that most of the respondents fall under closely approximating mastery level.

In terms of creativity skills, among the 50 student-respondents in pre-test scores 76% got 79-83% points which has an interpretation of average mastery level. Meanwhile, on the post-test scores, most of the learners accounting to 38% got a score of 91-95% which has a verbal interpretation of closely approximating mastery. In terms of empathy skill, among the 50 student-respondents in pre-test scores, 80% got 79-83% points which has an interpretation of average mastery level.

Table 3
Pre-test and Post-test scores of students exposed to the use of Design Thinking-based Learning Packet

Range of Scores	Pre-test		Post-test		Interpretation
	Frequency	Percent	Frequency	Percent	
			Creativity Skills		
96-100%	--	--	2	4%	Mastered
91-95%	--	--	19	38%	Closely Approximating Mastery
84-90%	5	10%	17	34%	Moving Towards Mastery
79-83%	38	76%	12	24%	Average
71-78%	7	14%	--	--	Low Mastery
			Empathy Skills		
96-100%	--	--	2	4%	Mastered
91-95%	--	--	18	36%	Closely Approximating Mastery
84-90%	1	2%	18	36%	Moving Towards Mastery
79-83%	40	80%	12	24%	Average
71-78%	8	16%	--	--	Low Mastery
66-70%	1	2%	--	--	Very Low Mastery
			Experimentation Skills		
96-100%	--	--	17	34%	Mastered
91-95%	--	--	18	36%	Closely Approximating Mastery
84-90%	4	8%	12	24%	Moving Towards Mastery
79-83%	33	66%	3	6%	Average
71-78%	8	16%	--	--	Low Mastery
66-70%	4	8%	--	--	Very Low Mastery
60-65%	1	2	--	--	Absolutely No Mastery
			Communication Skills		
96-100%	--	--	22	44%	Mastered
91-95%	--	--	26	52%	Closely Approximating Mastery
84-90%	15	30%	2	4%	Moving Towards Mastery
79-83%	18	36%	--	--	Average
71-78%	13	26%	--	--	Low Mastery
66-70%	4	8%	--	--	Very Low Mastery
			Collaboration Skills		
96-100%	--	--	12	44%	Mastered
91-95%	--	--	20	40%	Closely Approximating Mastery
84-90%	1	2%	11	22%	Moving Towards Mastery
79-83%	30	60%	7	14%	Average
71-78%	14	28%	--	--	Low Mastery
66-70%	5	10%	--	--	Very Low Mastery
Total	**50**	**100**	**50**	**100**	

Legend: 0-1 Absolutely no mastery, 2 Very low mastery, 3 Low mastery, 4-5 Average, 6 Moving towards mastery, 7 Closely approximating mastery, 8 Mastered

However, on the post-test scores 36% of the learners got a score of 91-95% having a verbal interpretation of closely approximating mastery. As for the experimentation skill, in the pre-test scores, 66% got 79-83% points with an interpretation of average mastery level and on the post-test scores most of the learners, accounting to 36%, got a score of 91-95% having a verbal interpretation of closely approximating mastery. As for communication skill, 36% got 79-83% points in the pre-test having an interpretation of average mastery level while 52% got a score of 91-95% on the post-test which has a verbal interpretation of closely approximating mastery. Lastly, in terms of collaboration skills, in pre-test scores 60% got 79-83% points which has an interpretation of average mastery level while on the post-test scores most of the learners accounting to 40% got a score of 91-95% which has a verbal interpretation of closely approximating mastery.

In summary, results imply that the learning material used helped the learners in enhancing their creativity skills, empathy skills, experimental skills, communication skills and collaboration skills, since most of the results showed that they had improved their scores from having an interpretation of an average level in the pre-test results to having closely approximating mastery level on the post-test results. Improvement of their scores with the use of the design thinking-based learning packet was possible since the learning materials was highly recommended as per experts' evaluation of very high acceptability rate.

Table 4

Test of Difference between the Pre-test and the Post-test Scores

INNOVATION SKILLS	Pre-test		Post-test		T	df	Sig. (2-tailed)	95% Confidence Interval of the Difference	
	Mean	SD	Mean	SD				Lower	Upper
Creativity	8.30	1.92	12.56	2.37	-24.248	49	.000	-4.613	-3.907
Empathy skills	7.56	1.98	12.40	2.18	-24.880	49	.000	-5.231	-4.449
Experimentation skills	3.84	1.13	6.98	1.04	-22.911	49	.000	-3.415	-2.865
Communication skills	6.08	1.38	10.18	1.16	-26.999	49	.000	-4.405	-3.795
Collaborations skills	3.72	0.93	6.70	0.97	-33.857	49	.000	-3.157	-2.803

$p \leq .01$, significant; $p > .05$, Not significant, Df = 49

Table 4 presents the test of difference between the pre-test and the post-test scores of the learners exposed in the design thinking-based learning packets. There is a significant difference between the pre-test and the post-test scores of the learners who were exposed to the use of the design thinking-based learning packets. All the variables present a p-value < 0.01 which indicates that there is a significant difference in all of the innovation skills which are creativity skills, empathy skills, experimentation skills, communication skills and collaboration skills.

The creativity skills show a significant improvement with a t-value of 24.248 at p < 0.01. This means that the learning material used was effective in developing the creativity skills described by Lee and Benza (2015) with creative thinking skills such as ideation, problem solving skills and flexibility. Similarly, empathy skill has t-value of 24.880 at p < 0.01 implying high level of empathy associated positively with the ability to perceive, express, understand, use and manage emotions (Eisenberg et al., 2003 cited by Salovey & Detweiler, 2008; Gulec, 2020). As for the experimentation skills, there is a significant difference in the scores as manifested by the t-value of 22.911 at p < 0.01 upholding Nguyen et al. (2019) that students can make logical reasoning to find out what to investigate. For the communication skills (t-value of 26.999 at p < 0.01), most of the activities are group activities promoting communication that affirms with Sabbah et al. (2020). Lastly, collaboration skills (t-value of 33.857 at p < 0.01) affirm Davidsen et al. (2020) and Ilma et al. (2022) on working productively, showing respect, compromise, and responsibility.

5. Conclusion

The results of this study showed a significant difference between the pre-test and the post-test scores of the Grade 11 learners exposed to the design thinking-based learning packets. This means that the innovation skills of the learners such as creative thinking skills, empathy skills, experimentation skills, communication skills and collaboration skills were enhanced through the use of the design thinking-based learning packet. Hence, the study recommends the use of the design thinking-based learning packet. The findings of this research may help the teachers to customize their teaching approaches, methodologies, strategies, and techniques to suit the students' needs.

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Case and Project-Based Learning Lessons in Enhancing Science Process Skills

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Abstract

The purpose of this study was to determine the significant difference in the pre-assessment and post-assessment performance of the students as to their science process skills and to assess the feedback of case and project-based learning lessons in enhancing the science process skills of the Grade 9 Students. The study used the descriptive-experimental methods of research with selected 70 Grade 9 students as participants. In line with the findings of the study, the students' pre-assessment performance revealed that they are "moving toward mastery" as to their basic science process skills and are at "low mastery" level as to their integrated science process skills while the post-assessment performance revealed "mastery" and "near mastery" levels as to their basic and integrated science process skills, respectively. Therefore, there is significant difference in the pre- assessment and post-assessment performance of the students as to their science process skills in terms of basic and integrated science process skills. Align with this, the respondents perceived case and project- based learning strategy as highly effective. Based on the conclusion laid, teachers may consider the use of lesson exemplar with case and project- based learning strategies as a mode of assessing and improving students' science process skills.

Keywords: *basic science process skills, case-based learning, integrated science process skills, project-based learning*

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1. Introduction

In the Philippines, the new science education framework focuses on students' development of 21st century science process skills, where students are expected to be confident, with skills, attitudes and capacities to be globally competitive. Furthermore, the science curriculum was created to produce scientifically literate individuals capable of making responsible decisions and applying scientific knowledge to community problems. A scientifically literate individual who has mastered these skills can comprehend the very nature of science, thus increasing the standard and quality of his life and allowing him to survive the challenges of everyday life. As a result, these process skills have an impact on an individual's personal, societal, and global lives as they offer the necessary tools to address everyday problems, conduct scientific research, and generate novel scientific knowledge and information. Individuals can learn these skills through well-designed science activities (Derillo, 2019).

The National Scientific Teachers Association (2018) states that the science curriculum should focus on developing learners' science process skills. In general, research shows that learners can gain science process skills when they are planned a specified outcome in science curriculum. Subsequently, Basic Education programs tend to bring out the best education that the learners have, especially about how they learn. It asserts that people build their own knowledge and understanding via personal experience and reflection. When learning something new, students have to reconcile it with prior beliefs and knowledge that may require revising opinions or disregarding the new information as unimportant. In any case, they actively create the knowledge that they have. To do this, they must investigate, evaluate current knowledge, and raise new ones. It is with regard to the modification of the strategies and instruction for the learners to give their best of understanding to the lesson. While the content of the Basic Education leads to the best generation of the 21st Century learners, a science teacher guides and instructs students to explore and understand key ideas in science, such as how to solve problems and gather data to back up theories or conclusions (Quia & Chua, 2022).

According to Darmaji et al. (2019), science process skills are the capacity for processing scientific ideas as well as the capacity for processing actions to create a comprehension of scientific concepts. The scientific process skills of students are crucial

skills that need to be cultivated in the classroom (Maison et al., 2020). Process skills are another type of scientific approach that is used to teach students how to conduct experiments and find things. The ability to employ scientific procedures in the development of science is essential for all students since they are expected to learn new information or advance their existing knowledge.

Science classes should include science experiments to help students learn the subject. Science experiments conducted in labs help students develop their science process skills. These abilities are classified as basic science process skills and integrated science skills by NARST (2020). Observing, measuring, classifying, and predicting are basic science skills while controlling variables, formulating hypotheses, interpreting data, and defining operationally are all examples of integrated science skills. However, a prevalent issue as seen in educational contexts is that science process skills acquisition is hindered by some circumstances, such as the methods used to generate skills in scientific classrooms (Derillo, 2019). Science Education Institute-Department of Science and Technology reports that Filipino students struggle to retain concepts, have weak analytical and reasoning abilities, and have poor communication skills (they cannot express ideas or explanations of events and phenomena in their own words).

Children should learn through making connections between concepts and real-world examples from their surroundings and their course material. For example, a project-based learning is a type of activity-based education that exposes students to real-world scenarios. Align with this is another strategy that is related and supported the context-based learning; the case-based learning. It uses cases the hypothetical, or real-life problems that will supplement theoretical knowledge. In this learning strategy, students are given cases to solve, allowing practical application of the concepts learned in class (Professional Learning Board, 2022).

According to studies, the conventional strategy (COS) should only be used sparingly during the teaching and learning process because it prevents students from developing conceptual understanding and problem-solving skills, making chemistry teaching and learning challenging, boring, and irrelevant to learners' real-life experiences (Jodi, 2010). This has caused some students to believe that science is a body of information that must be memorized without deep comprehension (Okafor, 2014). In addition, Ambag (2018) stated

that science is not always engaging because of the theories and terminologies that Filipino students are constantly exposed to. Scientists ask questions, make predictions, and actually carry out experiments rather than simply memorizing and regurgitating information.

Aligned with all the problems encountered in teaching-learning process in science, this study aimed to determine how effective in enhancing the science process skills of Grade 9 students using the case and project-based learning lessons. This study determined the significant difference in the pre-assessment and post-assessment performance of the students as to their science process skills and assessed the feedback of case and project-based learning lessons.

2. Literature review

2.1 Science Process Skills

As expressed in the investigation of Mulyeni et al. (2019), dominating the science process skills is significant for future comprehension in science and these abilities are gainful in day-to-day existence for tackling issues as well (Charlesworth & Lind, 2010). According to Aka et al. (2010), the foundation of a student's understanding of the science process and ability to solve problems lies in their early education. Students benefit from the science process skills by being able to comprehend phenomena, respond to inquiries, construct hypotheses, and discover information (Martin, 2009). They are fundamental in creating thoughts (Harlen & Qualter, 2004) and they increment scholastic accomplishment in science. According to a study by Ozgelen (2012), science process skills are linked to cognitive development while Ismail and Jusoh (2001) confirmed that these abilities are correlated with logical thinking abilities.

Science process skills are one of a set of high-order thinking skills, abilities, and learning dispositions that students must master in order to be prepared for a technologically advanced society (CEMASTEA, 2017), often referred to as skills for the 21st century. As anchored by Turiman et al. (2019), science process skills are used as a teaching approach in science teaching and learning. Science process skills are behaviors that encourage the development of skills used to acquire knowledge and then disseminate it, thereby increasing the use of optimal mental and psychomotor skills. By comprehending the nature of science, every individual could use these skills in of his/her daily life to increase the quality of life

and become scientifically literate. Moreover, scientists use science process skills to build knowledge, solve problems, and carry out experiments (Okafor et al., 2015). Students in these classes pay attention to their instructors and take notes, but they rarely ask questions or make comments. There are two types of science process skills: Basic and Integrated Science Process Skills.

Integrated science process skills are a definitive ability for taking care of issues and leading logical investigations. According to Mutlu and Temiz (2013), integrated science process skills are science process skills that combine or make use of a variety of underlying these skills, these are high-level cognitive skills. However, basic science process skills, focuses on where the students use observing, measuring, classifying, and predicting as foundational tools in learning science.

2.2 Case-Based Learning

Case-based learning refers to a strategy that helps the students to understand the lesson by relating the topics to real-life scenario. Nkhoma (2016) found that the Revised Bloom's Taxonomy attached the knowledge dimension to the skeletal structure, which formed the intersection of knowledge and cognitive process categories, to support the development of learning strategies and facilitate learning assessment. To help with academic skills including case analysis, evaluative judgment, and case solution, the Revised Bloom's Taxonomy has been offered. As explained by Schadt (2021), students are encouraged to use their critical thinking abilities through case studies to identify and narrow a problem, create and assess potential solutions, and build alternatives.

Ellet (2015) describes case analysis as an educational tool used to instruct students on how to evaluate and think critically about a real-world, practical issue that arises in an organizational setting. In almost all cases, teacher provides and even writes the case for case analysis assignment. Either everyone in the class is given the case to analyze alone or in small groups, or the students choose a case to study from a predetermined list. A case analysis requires simply laying the foundation for analyzing a scenario in practice; as a result, it might be fully made up or partially or entirely modified from an actual circumstance.

Evaluative judgment, according to Tai et al. (2018), is the capacity to conclude the character of one's work as well as that of others. In their study, they proposed that increasing students' evaluative judgment should be a goal of higher education: a requirement for graduates. This would assist students better their work and satisfying their future learning demands. Investigating evaluative judgment inside an instructional technique discussion as opposed to primarily within an evaluation discussion is one way to incorporate and coordinate a variety of educational approaches.

Beghetto (2021) explains that creative learning by giving creative solution in schools is a particular type of learning that incorporates creative expression within the framework of academic learning. Larger-scale initiatives that can have a positive and long-lasting impact on people's learning and live both inside and outside of classrooms and schools are also possibilities for students to engage in creative learning. These opportunities can range from smaller-scale curricular experiences that are beneficial to their own and others' learning to larger-scale initiatives. In this approach, initiatives that encourage creative learning serve as an essential component of positive education.

2.3 Project-Based Learning

Project-based learning (PBL) are typically neither teacher-led, scripted, or packaged (Thomas, 2022). PBL projects do not result in predetermined courses or outcomes but offer students significantly more autonomy, choice, unsupervised work time, and responsibility than traditional instruction and projects.

Projects are pragmatic as opposed to scholastic. The characteristics that venture show give them a genuine vibe to understudies. The subject, the assignments, the roles that students play, the setting in which the work is done, the mentors who work with students on the project, the final products, the audience for the final products, or the standards by which the final products or performances are evaluated are all examples of characteristics of a project. As explained by Renton Prep Christian School (2019), in its purest form, during PBL, both the teacher and the student are involved. Students actively investigate problems found in the real world using this method. It is a dynamic process that involves an instructional method to create a product or presentation. Additionally, PBL adheres to general principles where students collaborate to research and address a real-world,

challenging subject. Use of technology, collaboration, creativity, communication, and critical thinking are all 21st century skills that authentic tasks should require.

PBL emphasizes student participation in a project. The term "project" in this context refers to a task that requires students to conduct inquiries into problems, work independently to acquire their own expertise, and ultimately produce tangible deliverables. Nuraini (2019) stated in his study that each PBL stage's product features are as follows: (1) start with an essential question; (2) build a plan for the project; (3) establish a schedule; (4) keep track of the students and the project's progress; (5) evaluate the result; and (6) evaluate the experience. In addition, Ark (2018) argues that PBL is a crucial method of instruction. It enables students to master intellectual achievements and subject-matter knowledge, acquire skills essential for future success, and develop the personal agency required to face difficulties in life and the wider world.

Harsma et al. (2021) states that the students are provided with problems or issues throughout class that must be resolved utilizing the knowledge they are learning. They decide together what they already know about the topic, what they need to know to address the problem, how to apply the answers, and how to evaluate the outcomes. Case-based learning (CBL) is an educational paradigm that is similar and related to the project-based learning (Williams, 2022). This PBL method uses contextualized questions that are based on "real-life" issues that might be clinical or non-clinical. It is andragogical (adult teaching/learning).

A case, problem, or inquiry is used to promote and support the development of knowledge, skills, and attitudes. This is one of the primary characteristics of CBL that derives from PBL. Cases are typically written as problems that give the learner background information about a patient or other clinical setting. Cases place occurrences in a context or environment that supports authentic learning. Recent research articles, vital signs, clinical signs and symptoms, and laboratory data are all supplied as supporting evidence. CBL enables learners to adopt a cooperative, team-based educational philosophy (Williams, 2022).

Proponents of CBL believe that CBL still offers an open-ended approach to problems, encouraging discussion, debate, and addressing ambiguity, while providing students with more structure in an efficient and purposeful way. However, while PBL is an easy way to

tackle a student with a serious challenge, it requires a well-structured, continued, and supported experience to reap all possible benefits.

2.4 Conceptual Framework

As for the background knowledge and ground principles, there are varieties of concepts, theories and studies were explained to discern the objectives of this research. The study included the case and project-based learning and its components, as the independent variables and for the dependent variables, it includes science process skills and feedback for using case and project-based learning.

Padilla (2005 as cited by Ediyanto et al., 2018), there are two types of science process skills; the basic and integrated science process skills. Basic science process skills include observing, measuring, classifying and predicting. Integrated science process skills include controlling variables, formulating hypotheses, interpreting data and defining operationally. Align with this, Okafor et al. (2015) explains that in order for the learners to foster skills acquisition, learners should engage in creating pattern of relationship and thinking by actively participating and constructing meaning from their interactions in the environment and relate them to the previous experiences. Moreover, Holbrook (2014) proposes a context-based learning to scientific instruction that could encourage creativity and the development of basic and integrated science process skills by relating the lessons in real-life situation. Real life learning activities may be designed as inquiry activities to be completed as group work, and the approach may overlap with project-based (Taber, 2022).

According to Nkhoma (2016), who examined the benefits of creating case-based learning activities based on Bloom's Taxonomy of thinking skills, this strategy promotes deep learning through critical thinking: Evaluative judgment positively increases skills in creative solution, case analysis positively increases skills in evaluative judgement, and knowledge application positively increases skills in case analysis. However, with the support of the Project Management Institute Education Foundation and the William and Flora Hewlett Foundation, the Buck Education Institute uses Getting Smart to create a 27-member Steering Committee and a 90-member Advisory Board, and convened a framework for project-based learning. was developed. This framework includes his six criteria designed to serve as a foundation for educators, organizations, parents and students. Technology

integration, public products, working in team, intellectual challenge, reflection, and project management. Integrating all these benefits of deep learning into projects and ensuring a quality student experience requires a holistic approach.

3. Methodology

3.1 Research Design

This study used descriptive-experimental research design. Experimental method was used in determining the mean mastery level of science process skills among the respondents and significant difference between the pre and post-assessment performances of the groups of students as to their science process skills in terms of basic process and integrated process skills. This method shows an information-gathering experiment described as having a variation present or not, and it must be carried out entirely within the researcher's control. Typically, controlled experiments use this term. To make the results more reliable, these tests minimize the impacts of the variable. In this design, a group of people, plants, animals, etc. may participate in an experimental unit's procedure (Byjus, 2022).

The descriptive method, on the other hand, was applied in determining the association of respondents' case and project-based learning and science process skills. According to Mc Combes (2019), a group, situation, or phenomenon is intended to be accurately and systematically described by a descriptive research design. What, where, when, and how questions can be answered, but why questions not. Descriptive research strategies allow him to explore one or more variables using a wide range of research techniques.

3.2. Participants of the Study

The study involved the participation of Grade 9 students from a public high school during the School Year 2022-2023, composed of 70 students. All the students in a single group were given pre-assessment and post-assessment. The study was conducted during March and April 2023. Respondents were selected by purposive sampling. Purposive sampling, also known as judgmental, selective, or subjective sampling, is a sequence that relies on the researcher's judgment in selecting study units (participants, cases, tissues, events, data points, etc.) (Sharma, 2017).

3.3. Research Instruments

The instruments used in the study to gather data were lesson exemplar aligned in case and project-based learning, modified and adapted pre-assessment and post-assessment in DepEd learner's module with researcher-made table of specification (TOS), and a survey questionnaire.

The researcher administered two kinds of assessment and those are as follows:

- **Pre-Assessment and Post-Assessment**

Basic and Integrated Science Process Skills. The researcher provided the pre-assessment and post-assessment with a total of 80-item questions for basic science process skills and integrated science process skills; 40-item for basic science process skills and 40-item 40 for integrated science process skills. The assessment was aligned and adapted to the Most Essential Learning Competencies (MELC) of DepEd. The pre-assessment and post-assessment were given and administered to the selected Grade 9 students to determine students' mastery of basic and integrated science process skills.

- ***Feedback on using Case and Project-Based Learning***

A survey questionnaire was given to selected Grade 9 students of participating school. The indicators included were adapted from Ark's (2018) Framework of Project-based Learning. The purpose of the questionnaire was to get feedback from the respondents on how effective the case and project-based scenario was in enhancing the science process skills. To ensure the accuracy of the instruments, the researcher submitted the questionnaires through external and internal validation. After the instruments were validated, the instruments were modified based on the comments and suggestions of the validators.

3.4. Research Procedure

The stages of conceptualization were followed while conducting the study. The procedure of this study was as follows:

***Implementation*:** Immediately after validation of the copies of the questionnaires, the researcher gave a request letter asking permission through the Schools Division Superintendent, from the principal of the participating school and to the 70 respondents to

conduct a study by performing a face-to-face discussion of the lesson using lesson exemplar, distributing preassessment and post-assessment and a survey questionnaire.

The researcher implemented a face-to-face discussion with the 70 students using the case and project-based learning lessons. The researcher taught first the single group of students the topics of weather using case-based learning, and after the two sub-lessons related to weather being taught to the Grade 9 students, the same single group where the subjects to the discussion of the two sub-lessons for climate using another strategy, which is the project-based learning. The researcher administered the 80-item adapted-modified-pre-assessment to the students before the face-to-face discussion of the lesson using the learning strategies, case and project- based learning to measure and assess the prior knowledge of the students to the lesson. The researcher assessed and analyzed the basic and integrated science process skills of the students in a face-to-face learning modality within almost a month to determine how effective the case and project-based learning lessons were in enhancing the science process skills of grade 9 students. In this study, the researcher administered the 80-item adapted post-assessment and modified to DepEd Learner's Module for Basic and Integrated Science Process skills to the respondents after teaching the lesson covered in the third quarter, of School Year 2022-2023.

Data Analysis. After the implementation of the strategy and survey, the questionnaires were collected and tallied immediately, and gave the data to the statistician for treatment. The data were statistically computed, interpreted, and verbally analyzed.

Ethical Consideration. With utmost confidentiality, the researcher assured that all the respondents' information and results were accessible only to the researcher and the thesis adviser.

3.5. Statistical Treatment of Data

The following statistical tools were utilized in providing solutions and analysis to the problem of the research: mean and standard deviation; and t-test.

4. Findings and Discussion

Table 1 presents the mastery level of basic and integrated science process skills in pre-assessment performance. The computed overall mean for basic science process skills is

17.90 that shows students "moving toward mastery" level in observing, measuring, classifying and predicting, However, in integrated science process skills, students' falls under "low mastery" level in controlling variables, formulating hypothesis, interpreting data and defining operationally with overall mean of 18.56.

Table 1.
Mastery Level of Students in Basic and Integrated Science Process Skills in Pre-Assessment Performance

Science Process Skills	Pre-Assessment Performance		
	Mean	**SD**	**Remarks**
Basic Science Process Skills			
Observing	4.40	1.601	Low Mastery
Measuring	4.37	1.416	Low Mastery
Classifying	4.27	1.483	Low Mastery
Predicting	4.86	1.311	Moving Toward Mastery
Overall	**17.90**	**4.334**	**Moving Toward Mastery**
Integrated Science Process Skills			
Controlling variables	4.69	1.291	Moving Toward Mastery
Formulating hypothesis	4.19	1.448	Low Mastery
Interpreting data	4.73	1.318	Moving Toward Mastery
Defining operationally	4.96	1.268	Moving Toward Mastery
Overall	**18.56**	**2.733**	**Low Mastery**

Legend: 0-2 (No Mastery); 3-4 (Low Mastery); 5-6 (Moving Toward Mastery); 7-8 (Near Mastery); 9-10 (Mastery)

This shows that during the actual learning process, students struggle to develop comprehensive science process skills. This skill is usually more difficult to develop because they are not used to being taught, and students struggle to answer questions related to unfamiliar job application questions. One of the reasons for this, in addition to the fact that hands-on activities are not always carried out due to time constraints, it is difficult for teachers to observe each student's new science process competencies, especially their overall science process competencies (Sulistri, 2019).

On the other hand, table 2 presents that in post-assessment performance, the overall remarks of Grade 9 students in basic science process skills shows that students have "mastery" in observing, measuring, classifying and predicting. However, in overall remarks, integrated science process skills such as controlling variables, formulating hypothesis, interpreting data and defining operationally, the students' considered in the level of "near mastery".

Data reveal that after the influence of case and project- based scenario in the learning process, students' basic science process skills have highly increased, most especially in

observing skill. Observing is the most significant skill of science process wherein collecting information using senses will help students to gain knowledge about the world and make learning experiences stored in their long-term memory (Mulyeni et al., 2019).

Table 2

Mastery Level of Students in Basic and Integrated Science Process Skills in Post-Assessment

Science Process	Post-Assessment Performance		
	Mean	SD	Remarks
Basic Science Process			
• Observing	9.57	.809	Mastery
• Measuring	8.87	1.062	Mastery
• Classifying	8.87	1.048	Mastery
• Predicting	8.86	1.026	Mastery
Overall	**36.17**	**2.126**	**Mastery**
Integrated Science Process Skills			
• Controlling variables	8.16	1.337	Near Mastery
• Formulating hypothesis	8.74	.988	Mastery
• Interpreting data	8.97	.884	Mastery
• Defining operationally	9.30	.768	Mastery
Overall	**35.17**	**2.071**	**Near Mastery**

Legend: 0-2 (No Mastery); 3-4 (Low Mastery); 5-6 (Moving Toward Mastery); 7-8 (Near Mastery); 9-10 (Mastery)

In measuring skill, the result may imply that students mastered the different measuring instruments in science and they also understand the concept of solving conversion of units. Through observation, students increased their classifying skills. The students improved in this area by understanding the essence of grouping objects or events into categories based on characters or properties of objects or events. Students can strengthen the ability to classify objects with practice and appropriate coaching. On the other hand, the predicting in basic science process skills indicates that students improved their educated guess about what's likely to happen when you introduce changes in the given problem.

It can be seen also in the data that all the subskills in integrated science process skills have increased. The result in controlling variables may imply that students clearly identify the relationship between an independent variable and a dependent variable after engaging in lesson that will enhance their skills by making excellent way of determining relationships between variables that can be later validated in real world settings through descriptive or comparative studies.

Furthermore, this means students are better able to prove their predictions and answer the student worksheet questions provided by the teacher when forming hypotheses. This is consistent with research of Hirca (2015), who states that if individuals can prove their predictions, they reach a position where they can stimulate further thinking. Based on Piaget's theory, students can formulate problems and form hypotheses. Similarly, based on Piaget's cognitive development, high school students are in the formal operational phase. This allows students to form problems and hypotheses. During the ideation and reconstruction stages, an assimilation process occurs as students interact with their environment through observation, hands-on activity, and discussion.

In the aspect of interpreting the data, the students are able to connect the results of observations and solve problems as it is displayed on tables, figures or graphs. The increase in this subskill indicates that students do well after applying case and project-based scenario.

In defining operationally, students developed the “mastery” level. This implies that students gained and improved their skills by formulating operational definitions based upon the observable characteristics of the given problem in the post-assessment and during the implementation of the lesson.

Table 3.

Summary Table on the Feedback of the Respondents on Case-Based Learning

Indicators	Mean	SD	Verbal Interpretation
Case Analysis	3.45	0.49	Highly Effective
Evaluative Judgment	3.43	0.47	Highly Effective
Creative Solution	3.39	0.53	Highly Effective
Overall	**3.42**	**0.45**	**Highly Effective**

Legend of the Verbal Interpretation of the Weighted Mean:*1.00 to 1.74 -Not Effective, 1.75 to 2.49 -Slightly Effective, 2.50 to 3.24-Effective, 3.25 to 4.00 - Highly Effective*

Table 3 shows feedback after using case-based learning lessons in enhancing science process skills. The overall weighted mean distribution in case analysis, evaluative judgment and creative solution is 3.42, interpreted as highly effective.

The data revealed that after using case-based strategies to improve skills in the science process, students are able to reflect on the relationship between the facts described in the cases and critical incidents, this is supported by Ellet (2015). Case analysis places

students in “real world” situations and critiques complex scenarios within organizational settings in order to apply reflection and critical thinking skills on appropriate solutions, decisions, or recommended solutions. It is a problem-based teaching and learning method that analyzes systematically. This is considered a more effective teaching method than classroom role-plays and simulation activities.

The result in the actual study shown that the students assigned in an active role in applying standards while accumulating knowledge. Such student involvement in understanding and applying standards is consistent with current definitions of evaluative judgment as “the ability to make decisions about the quality of one's own and others' work” (Tai et al., 2018). Students develop the quality and formation of evaluative judgments so that they can act independently considering all kinds of information and feedback comments on future occasions without explicit external guidance from a teacher or teacher-like person need to understand.

This implies also that the students can more easily and effectively identify their own questions to address after discussing the lessons in the actual study, develop their own understanding of new and different ways to address those questions, and share and get feedback on their original ideas and insights. Explanation problems are the best teaching strategy for enhancing explanatory knowledge (Orias & Chua, 2021). According to Beghetto (2021), semi-structured learning experiences that require students to meet learning goals in novel and different ways help to ensure that students are developing academically and personally meaningful understandings. These experiences also give students the chance to possibly advance their peers' and teachers' understanding.

The students are better prepared to evaluate and explain complex issues as a result of case-based learning. The students were able to come up with varieties of solutions fit in the case scenario given by the teacher. Additionally, Harman et al. (2015) demonstrate how case-based learning mixed with group problem-solving improves the development of professional abilities. In view of this, case-based learning is thought to have a great potential for fostering systematic analysis, problem-solving abilities, and suggested courses of action. The teacher is responsible for helping students diagnose issues and offer workable solutions.

Table 4.

Summary Table on Feedback of the Respondents on Project-Based Learning

Project-Based Learning	Mean	SD	Verbal Interpretation
Intellectual Challenge	3.41	0.50	Highly Effective
Working in Team	3.49	0.55	Highly Effective
Technology Integration	3.36	0.56	Highly Effective
Public Product	3.32	0.62	Highly Effective
Reflection	3.44	0.64	Highly Effective
Project Management	3.43	0.57	Highly Effective
Overall	**3.41**	**0.50**	**Highly Effective**

Legend of the Verbal Interpretation of the Mean:*1.00 to 1.74 -Not Effective, 1.75 to 2.49 -Slightly Effective, 2.50 to 3.24-Effective, 3.25 to 4.00 - Highly Effective*

Table 4 presents feedback of the respondents after using project-based learning in enhancing science process skills. The overall weighted mean distribution of the respondents in intellectual challenge, working in team, technology integration, public product, reflection and project management is 3.41 which is interpreted as highly effective.

This implies that the participants in the study were better able to work on tasks that had personal significance and were important to their education. A high-quality project necessitates that student engage in critical thought over a difficult topic, question, or matter that has several solutions before working on it for days, weeks, or even months. Students must acquire crucial academic knowledge, ideas, and abilities in order to properly complete a project. Additionally, they should be encouraged and supported as they work to produce the best-quality work possible.

The data shows also that the students worked well as a team to accomplish the learning objectives. During the implementation of activities, each member from different groups did the activity cooperatively and asked suggestions to other members to perform successfully. As Jaiswal et al. (2021) point out, when students are engaged in problem-solving, working in teams enables them to cooperate with one another. Students need to learn how to work in teams, especially when they are working with groups from different fields. Students improve their motivation, persistence, and professional skills as they collaborate in groups. Cooperation abilities allude to all characteristics and capacities that empower people

to work actually with their friends when taken part in cooperative exercises like gatherings or ventures.

In the actual study, the students improved in integrating technology in making a successful project. Most of the students, expound their explanation by means of using different designs offered by the computer. According to research, children acquire technology skills as they work on projects like writing scientific reports and drawing cartoon stories. When children learn computer skills in solitude, it may not be engaging for them and may not fulfill their specific needs. Students perform technology projects with a focus on problem-solving activities through project-based learning (Love, 2011). Moreover, the students improved in making a public product or artifact that demonstrates knowledge to a real audience is a crucial component of project-based learning as supported by Wilson-McCain (2021). This shows that the pupils were successful in tying what they learned in school to difficulties, issues, or obstacles that they would encounter in the real world.

The students are able to recognize and articulate the reasons behind their actions and how they contribute to their final result or project. When students can relate personally to the work they are doing, it becomes more authentic and fosters greater student ownership and engagement. Students build a personal connection to the work and are nearly always more involved in the project when they are reflecting on their own work and the work of their group around a public project they are developing.

In project management, the students were seen engaged in lessons and hands-on activities and considered as effective for students' success in attaining learning goals. Aligned with this, project management offer a standard way for executing projects, exactly the way that researchers use the logical strategy as an aide while performing tests. According to Liegel (2004), this enables the students involved to concentrate on the content of the project rather than how to complete it. Because it also involves individuals who make up teams or work groups, teamwork and team or group learning are mentioned prior to working on learning in project management because they serve as a reference for learning and development in project management. Group learning is much of the time conceptualized as a ceaseless course of activity and reflection through which groups procure, consolidate, and apply information. This cycle is firmly connected with exercises like getting clarification on

pressing issues, looking for input, making do, examining mistakes, testing fundamental suspicions, and pondering explicit results or surprising outcomes (Gil & Mataveli, 2018).

This implies that the students acquire and develop more understanding of the lesson and improve science process skills using the categories under project-based learning on which students learned how to find information, use resources, combine what they find, and evaluate their findings critically. As seen in this study, the use of the project-based learning strategies is observed and effective to increase students' science success and support the results of this study (Ergül & Kargın, 2014).

Table 5.

Significant Difference between Pre and Post-Assessment in Basic and Integrated Science Process Skills

Science Process Skills	Pre-Assessment		Post-Assessment		Mean Difference	T	Df	Sig. (2-tailed)
	Mean	SD	Mean	SD				
Basic Science Process Skills								
Observing	4.40	1.601	9.57	.809	5.171	23.910	69	.000
Measuring	4.37	1.416	8.87	1.062	4.500	24.609	69	.000
Classifying	4.27	1.483	8.87	1.048	4.600	26.386	69	.000
Predicting	4.86	1.311	8.86	1.026	4.000	25.377	69	.000
Overall	**17.90**	**4.334**	**36.17**	**2.126**	**18.271**	**37.254**	**69**	**.000**
Integrated Science Process Skills								
Controlling variables	4.69	1.291	8.16	1.337	3.471	17.622	69	.000
Formulating hypothesis	4.19	1.448	8.74	.988	4.557	20.917	69	.000
Interpreting data	4.73	1.318	8.97	.884	4.243	22.298	69	.000
Defining operationally	4.96	1.268	9.30	.768	4.343	24.339	69	.000
Overall	**18.56**	**2.733**	**35.17**	**2.071**	**16.614**	**15.785**	**69**	**.000**

***Significant at .01 level*

Table 5 shows that there is significant difference in the level of students' science process skills before and after assessment.

It can be seen that in the actual conduct of study, all the categories for basic and integrated science process skills have significantly increase from pre-assessment to post-assessment. The result reveals that after the use of case and project-based learning lessons in teaching students to enhance their science process skills, students improve and learn to think critically and use information creatively. As supported by Charlesworth and Lind (2010),

mastering the science process skills is crucial for future scientific comprehension, and using these skills to solve problems in daily life is also helpful. Students can build on their initial learning to gain a deeper understanding of the science process and problem-solving skills (Aka et al., 2010). Students that are proficient in the science process skills are better able to comprehend facts, find information, and formulate theories. They improve scholastic success in science learning and are crucial in the development of concepts (Harlen & Qualter, 2004), and they increase academic achievement in science learning.

Table 6

Post-Assessment Performance of the Groups of Students as to their Basic and Integrated Science Process Skills

	Basic Science Process Skills		**Integrated Science Process Skills**		**Mean Difference**	**T**	**Df**	**Sig. (2-tailed)**
	Mean	**SD**	**Mean**	**SD**				
Post-Assessment	36.17	2.126	35.17	2.071	1.678	2.942	69	.004

Table 6 shows that there is significant difference in the level of students' science process skills in post-assessment. Basic science process skills show significant difference over integrated science process. This implies that in post-assessment, the students are able to grasp the different science process skills. This indicates also that the students improved a lot in integrated science process skills since the students engaged in the actual or hands-on activity even there are two different lessons and learning strategies being applied in the learning process. Moreover, the data reveals that using case and project-based learning strategy, it helped the students learned not just the concept of science but also how the science works using different process skills.

5. Conclusion

Findings of the study showed significant difference in the pre- assessment and post-assessment performance of the of the students as to their science process skills in terms of basic and integrated science process skills. Similarly, there is significant difference in the level of students' science process skills in post-assessment. Basic science process skills show significant difference over integrated science process. Hence, teachers may consider the use of lesson exemplar with case and project- based learning strategies as a mode of assessing

and improving students' science process skills since the findings of student's mastery level in basic and integrated science process skills are said to be nearly mastered.

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Analysis of the Inventory Management System Towards Enhanced University Service Delivery

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Abstract

Inventory management is an essential component of business operations including academic institutions. Using a quantitative descriptive research design, this study analyzed the processes involved in the use of the University of Baguio Requisition, Procurement, and Inventory System (UBRPIS), a software that automates inventory management by streamlining the operations required to efficiently maintain inventory and manage recording and updating records. The paper specifically determined the employees' familiarity of the inventory management, identified the system limitations and proposed necessary adjustments and modifications. The majority of respondents are familiar with the various processes involved in the use of UBRPIS, such as the request for non-consumable items, the use of barcodes, accountability transfer, the withdrawal of condemned non-consumable items, and physical inventory of accounted non-consumable items. On the other hand, nearly half of the respondents identified limitations in the process itself, while 38.60% and 46.50% identified the location of the barcodes and the lack of non-consumable items as the primary issues, respectively. Despite respondents' familiarity with the system, users face challenges in the processes involved in system use. It is therefore recommended that the University invests in inventory management system technology that best meets the requirements of all system users. Periodic staff training on the use of UBRPIS is likewise recommended.

Keywords: *Inventory Management System, benefits, limitations, recommendations, improvements*

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1. Introduction

Inventory management is an essential component of business operations. It refers to the activities of placing orders, storing inventory, using it, and releasing it as a whole. This includes the storage and processing of raw materials, parts, and finished goods. Depending on the needs of the company, there are several inventory management techniques available, each with advantages and disadvantages. Different inventory management techniques should be used depending on the sector (Guajardo et al., 2015; Atnafu & Balda, 2018; Riley et al., 2018; Fattah, et al., 2016; Sabir & Farooquie, 2018). The inventory management strategy is determined by the type of company and the services it provides. Given that each method of inventory management has advantages and disadvantages, there may not be a single ideal method. Using the most appropriate inventory management strategy, on the other hand, could be extremely beneficial (Hayes, 2022).

The most crucial guarantee of an enterprise's efficient operation is to have a single, continuous process for providing required inventories in optimal quantities and of defined quality to all systems of the manufacturing process. Before and after each processing stage, inventories are established of work objects. The efficiency of enterprise's internal and external material flow is largely determined by inventories, their placement, and their dynamic dependence on the requirements of the following phases of manufacture (Viktorovna & Ivanovich, 2016).

This study discussed the processes involved in the University of Baguio Requisition, Procurement, and Inventory System (UBRPIS), the inventory management system at the University of Baguio. It specifically determined employees' familiarity of the system based on age, job classification, and years of experience. It also acknowledged UBRPIS' limitations and recommended necessary adjustments and modifications in all areas for the system's improvement. One of the limitations is that the system must be regularly maintained and upgraded in order to improve and adapt to changes in the working environment in order to successfully implement processes and procedures.

The University of Baguio was founded by two educational leaders, Dr. Fernando "Tatay" Bautista and Mrs. Rosa "Nanay" Castillo Bautista whose lives have been dedicated to the education of the youth. In August 1948, they established a humble school named Baguio

Technical and Commercial Institute, otherwise known as “Baguio Tech”. From five course offerings, it now offers 29 undergraduate programs, 12 graduate programs and 9 short-term programs, a Laboratory Elementary School, a High School and a Science High School which both have Grade 7 to 12. Furthermore, it employs 741 employees overall and has an estimated 18,000 students enrolled in elementary, secondary, tertiary and graduate programs for the school year 2022-2023. To cater the needs of the stakeholders, using inventory management system helps understand if there is a sufficient, shortage, or surplus inventory that can be utilized by the stakeholders.

2. Literature Review

Inventory management has evolved significantly since the beginning of the second industrial revolution, with Herman Hollerith's invention of the first automatic calculation device (Writing Intern, 2018). The barcode, created in the mid-1970s, has become the industry standard for inventory management. Norman Woodland created the barcode in the late 1940s, and the National Association of Food Chains used it to reduce check-out times. RFID technology, developed in the 1970s, uses radio waves to scan microchips and antennas, transferring information to computers. Today, RFID technology outperforms barcodes in terms of efficiency and accuracy.

Inventory management systems play a crucial role in understanding the purchase phenomenon, including product value, timing, frequency, stock cover, inventory turns, and minimum sales thresholds. Understanding the role of each product and consumer, determining the type of product, purchase frequency, and who decides on purchasing is essential (Ganesha et al., 2020). Maintaining proficiency over time and dealing with the uncertainty of inventory flow are crucial for maintaining the system's reliability and robustness (Almaktoom, 2017).

In supply chain management, inventory management is a difficult problem to solve. Companies require inventory in warehouse to meet client demand; yet, these inventories incur holding fees, resulting in a frozen fund that could be wasted. As a result, inventory management’s goal is to locate the right amount of inventory to meet demand while avoiding overstocking (Plinere & Borisiv, 2015). The challenge of inventory replenishment planning is a major issue in supply chain management. It entails two key decisions: the lot sizing

decision, or determining the amount to order and the replenishment date determination, or replenishment schedule. When making these judgments, two crucial goals should be kept in mind: (1) lowering the total cost of ordering and holding the ordered items, and (2) decreasing the amount of storage space required. However, establishing a replenishment plan that minimizes both objectives at the same time is typically impossible (Boctor & Bolduc, 2015). The efficiency of product storage is determined by inventory management's operation. Moving load, delivery speed, service quality, operation costs, facility utilization, and energy savings all benefit from advances in technology and management principles. In the manipulation of logistics, inventory management plays a vital role. In order to link the manufacturing methods, a robust system requires a defined logistics frame, as well as adequate inventory implements and methodologies (Afolabi et al., 2017).

Inventory management efficiency is a critical component of a manufacturing company's ability to compete. Underproduction, overproduction, stock out situations, delays in raw material deliveries, and discrepancies in records were among the inventory management issues faced by manufacturing organizations. The elements of documentation/store records, planning, employee knowledge and staff skill, and money have all been found to have a substantial impact on inventory management in manufacturing small and medium firms (Chan et al., 2017).

Adoption of an appropriate combination of new inventory management approaches can improve corporate service delivery by guaranteeing a consistent flow of materials while simultaneously lowering carrying/handling expenses. As a result, the importance of ongoing staff training and retraining in order to improve store managers' professionalism and productivity, particularly in relation to technology-assisted inventory management systems, was emphasized (Aro-gordon & Gupte, 2016). According to QuickBooks (2018), IKEA is an illustration of a company that utilizes the most effective use of inventory management. IKEA, founded in 1943 by Ingvar Kamprad, has been the top furniture retailer globally since 2008. It is a Swedish international conglomerate with a presence in the Netherlands that creates and markets ready-to-assemble furniture, kitchen items, decorations, home accents, and a variety of other products and services. In contrast to IKEA, inventory management is a challenging business process in developing countries due to a lack of basic inventory control principles and methods. Additionally, because of procedural inefficiencies, bureaucracy, and

communication issues, emerging countries have trade deficits with developed nations. This causes supply uncertainty and lengthy lead times (Torrico & Oyola, 2021).

There have been few studies conducted in the Philippines involving inventory management in colleges and universities (i.e. Tungcul & Kummer, 2021; Arnesto et al., 2014; Castro, 2017). One study was conducted at Bestlink College of the Philippines, which needs to keep track of all equipment, but staff members have difficulty organizing and searching the logbook to quickly locate the equipment. Because it will make each transaction easy and trouble-free, the inventory system developed tends to replace the best transaction with good and high-quality products in the school's operations and future growth. The researchers used the systems development life cycle technique to finish the project (Bandiola et al., 2020). In addition, Tapado and Delluza (2016) conducted a study about the utilization of a prototype technique design to develop, implement, and deploy a system called equipment inventory management system (EIMS). The paper discussed the country's State Universities and Colleges' automated approach for managing the equipment inventories. In particular, the system gathers information about each employee's equipment records, tracks the history of the equipment given to each employee, performs automated inventory management, and generates reports about equipment inventory management.

2.1. Theoretical and Conceptual Framework

To optimize the production and storage of thousands of units of items and to help reduce costs, large organizations utilize a range of inventory control theories and mathematical formulas. Small business owners can manage production and storage based on demands for cost containment and customer service by drawing inspiration from a variety of inventory techniques.

The just-in-time (JIT) theory of inventory control encourages producing goods only when needed to fulfill orders rather than producing inventory in advance and holding it. As a result, carrying costs-which may include interest on credit used to fund the purchase of inventory-are reduced. If one of the supply chains, such as the capacity to procure goods or labor, is disrupted, this might be a risky venture. Consumable items are a good example of this because they are readily available when needed.

Another inventory control approach is levelized production, which tries to reduce labor costs by producing inventory steadily throughout the year rather than in peaks and valleys. If businesses wait to produce a product until there are sales orders, a rush may force companies to add a third shift, recruit overtime workers, or hire another producer to help satisfy orders. One may need to pay idle personnel when business is slow. Its production can be stretched out to maintain an even flow if it can predict demand precisely by month, quarter, or year. One can develop its own approach for controlling the inventory based on market conditions, the access to finance, and the production capabilities by combining elements of one or more of the current inventory control theories. If it is a retail business, it must stay in regular contact with the clients, lenders, and suppliers. Manufacturers must consider seasonal variations in labor and material availability as well as any price changes. If a company does not have enough storage space to maintain product on hand for all of its customers at once, it may need to pre-make inventory and send it to consumers for them to pay later. Production expenses may go up as a result, but the company will continue to operate. Once the organization has developed the ideal inventory control system, it should assess how it will affect expenses and adjust prices accordingly (Milano, 2023).

The periodic inventory system is a piece of software that enables stock counts on a regular basis. Companies enter stock numbers into the program, do a preliminary physical inspection of the products, and then input the data into the software to reconcile. Depending on their needs for their products and their bookkeeping, many businesses choose monthly, quarterly, or annual periods (Schwarz, 2022).

Considering the features that an organization needs is the fundamental step in selecting an inventory management system. Each inventory management system has these few essential components that make it useful for the industry. A system that offers the company real-time inventory monitoring can aid management in making important company decisions. Inventory management policies, which are guidelines for how to use the inventory system to enable users to maximize its potential, are just as crucial as the inventory management system. One component of inventory management is “asset monitoring”, which enables companies to track equipment using the barcodes on its items. In addition to using this monitoring system, certain modern inventory management programs can also make use of Radio-Frequency Identification (RFID) and wireless tracking technology (Jenkins, 2020).

2.2. The University of Baguio Inventory Management System

Figure 1

University of Baguio Requisition Procurement & Inventory System (UBRPIS) Interface

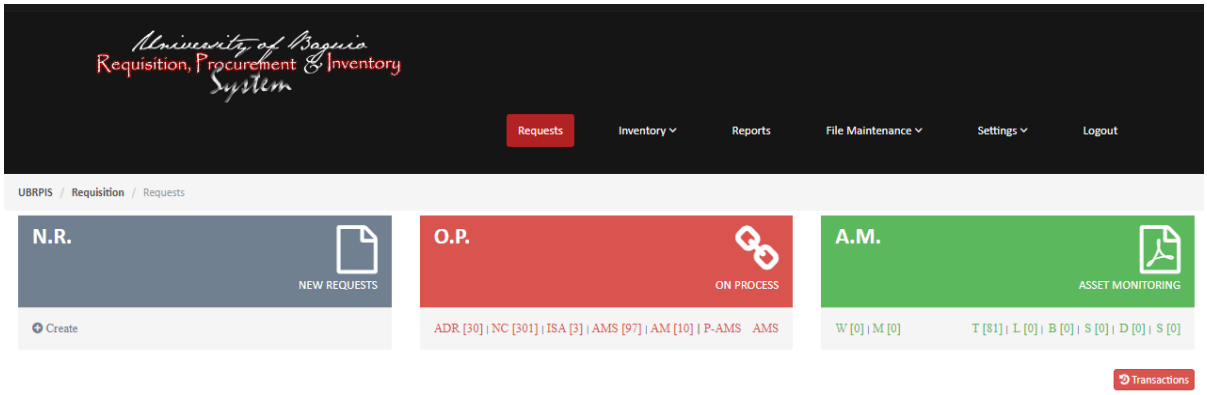
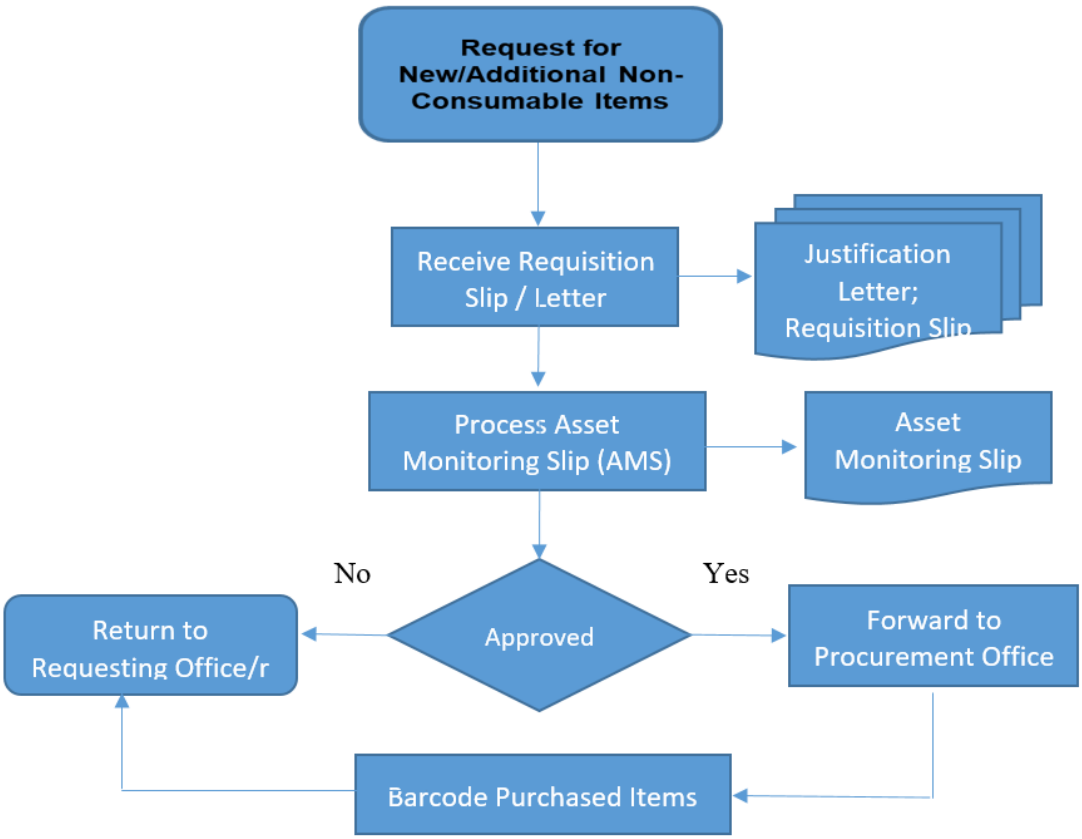


Figure 2

Request for New/Additional Non-Consumable Items



The University makes use of the following processes to acquire non-consumable assets for the institution. Figure 2 shows how to request for new or additional non-consumable items. Once the Property Section of the CPDO (Campus Planning and Development Office) submits requests, the procedure begins. The requisition slip and letter of justification are given to the inventory office. The inventory officer will next handle the request for attachment with an AMS (Asset Monitoring Slip) in the RPIS. The university accountant will then analyze the paperwork after it is sent to him. If approved, the request will be sent to the procurement office; otherwise, the requesting office or person will receive the documents back. If the item has been purchased, the inventory office will barcode it before giving it to the requesting officer.

Figure 3

Request for Replacement Non-Consumable Items

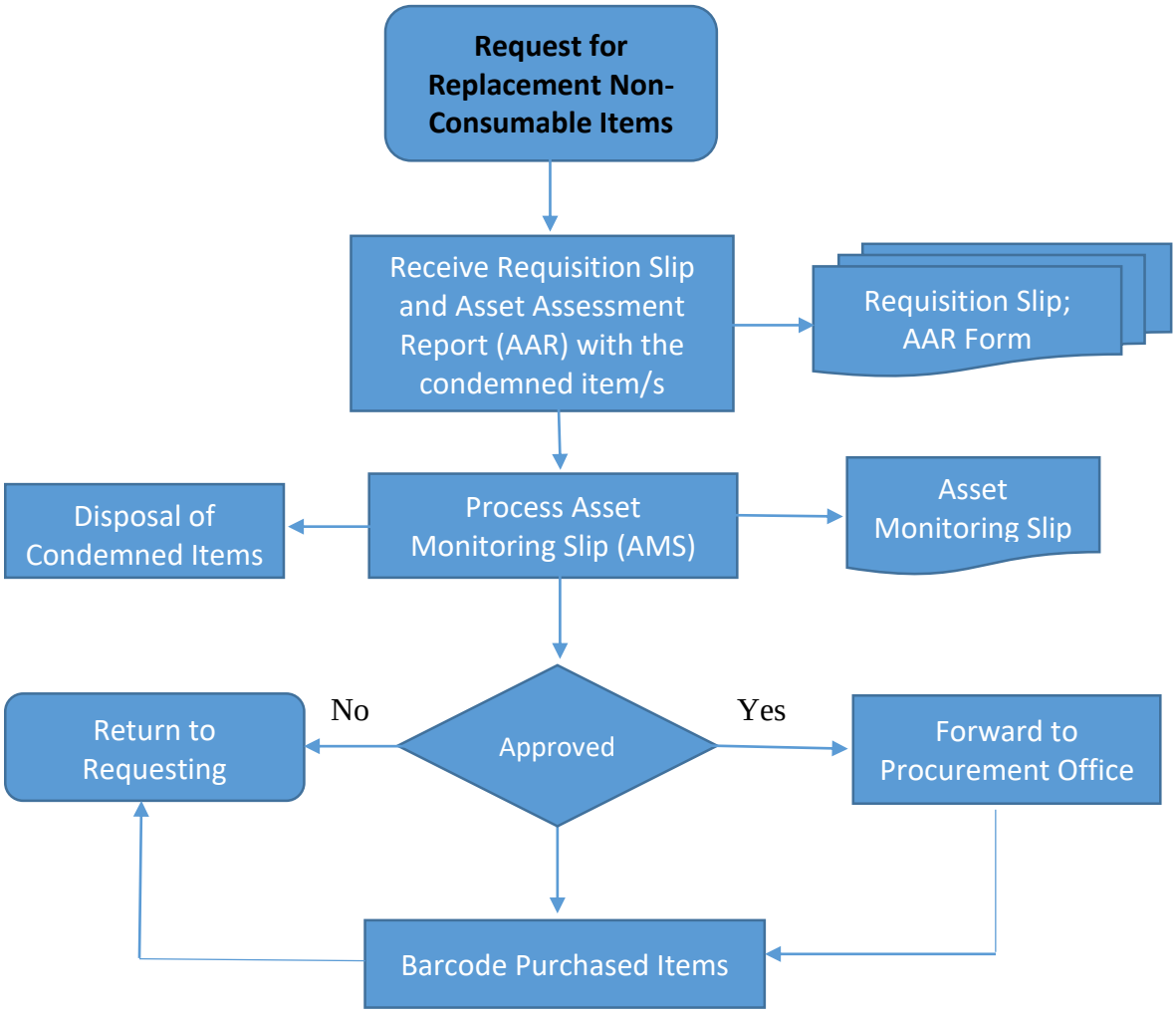


Figure 3 shows how to request replacement non-consumable items. The Inventory Office receives the requisition slip from CPDO, Property Section, together with the AAR (Asset Assessment Report) form and the item to be replaced. The requisition slip is processed by inventory officers using AMS from the RPIS. To ensure proper disposal, the condemned object will be put in the storage room. The documents will be sent to the university accountant, who will review them after receiving them. The requisition slip will be delivered to the procurement office if it is approved; if not, the documents will be returned to the office or person who made the request. Before sending it to the requesting officer, the inventory office will barcode the item if it has been purchased.

Figure 4

Transfer of an Asset from One Office to Another

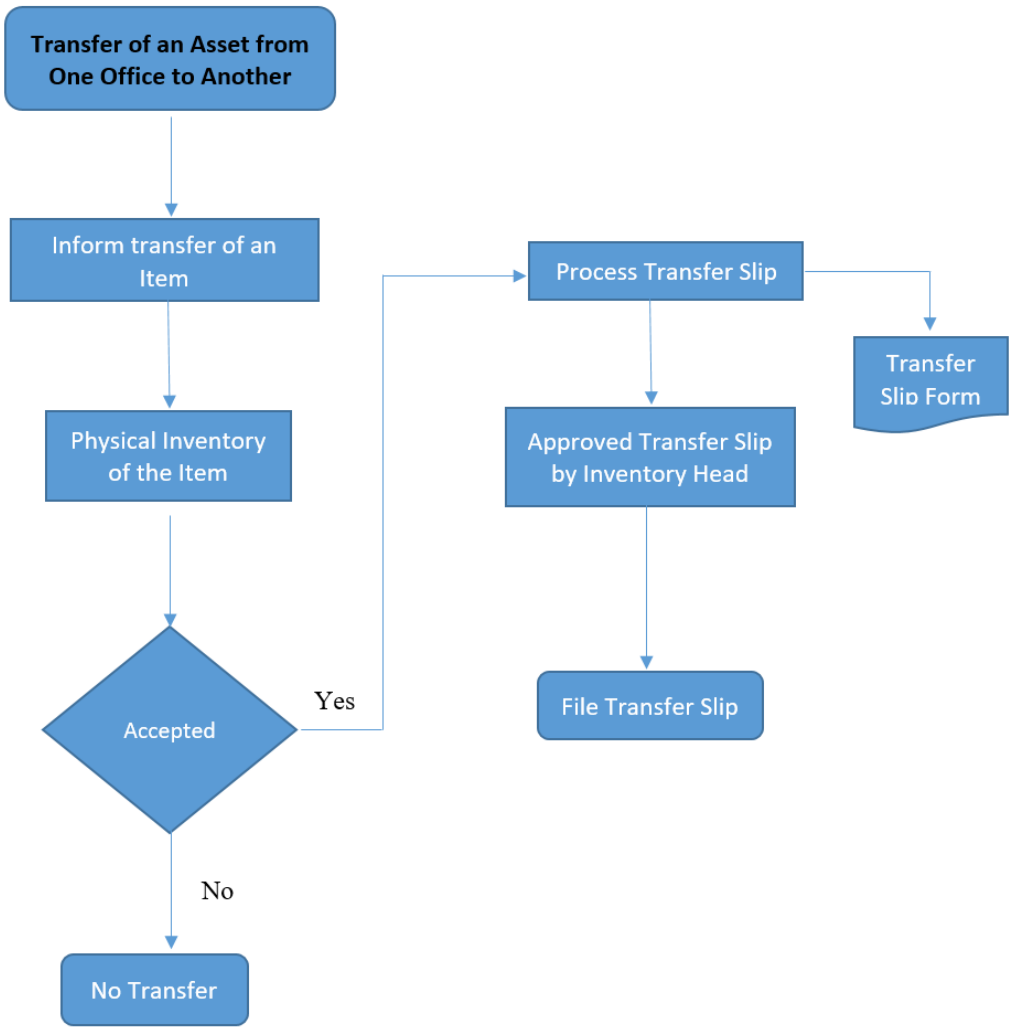


Figure 4 shows how to transfer an asset from one office to another. The inventory office will be notified by the department whenever an item is transferred from one department to another. The object to be transferred will be physically inventoried by the inventory office. The inventory officer will complete the transfer using a transfer slip from RPIS if the new accountable officer accepts the item; otherwise, no transfer will take place. The university accountant will sign the transfer slip and file it.

Figure 5

Transfer of Accountability of Non-Consumable Items from One Employee to Another

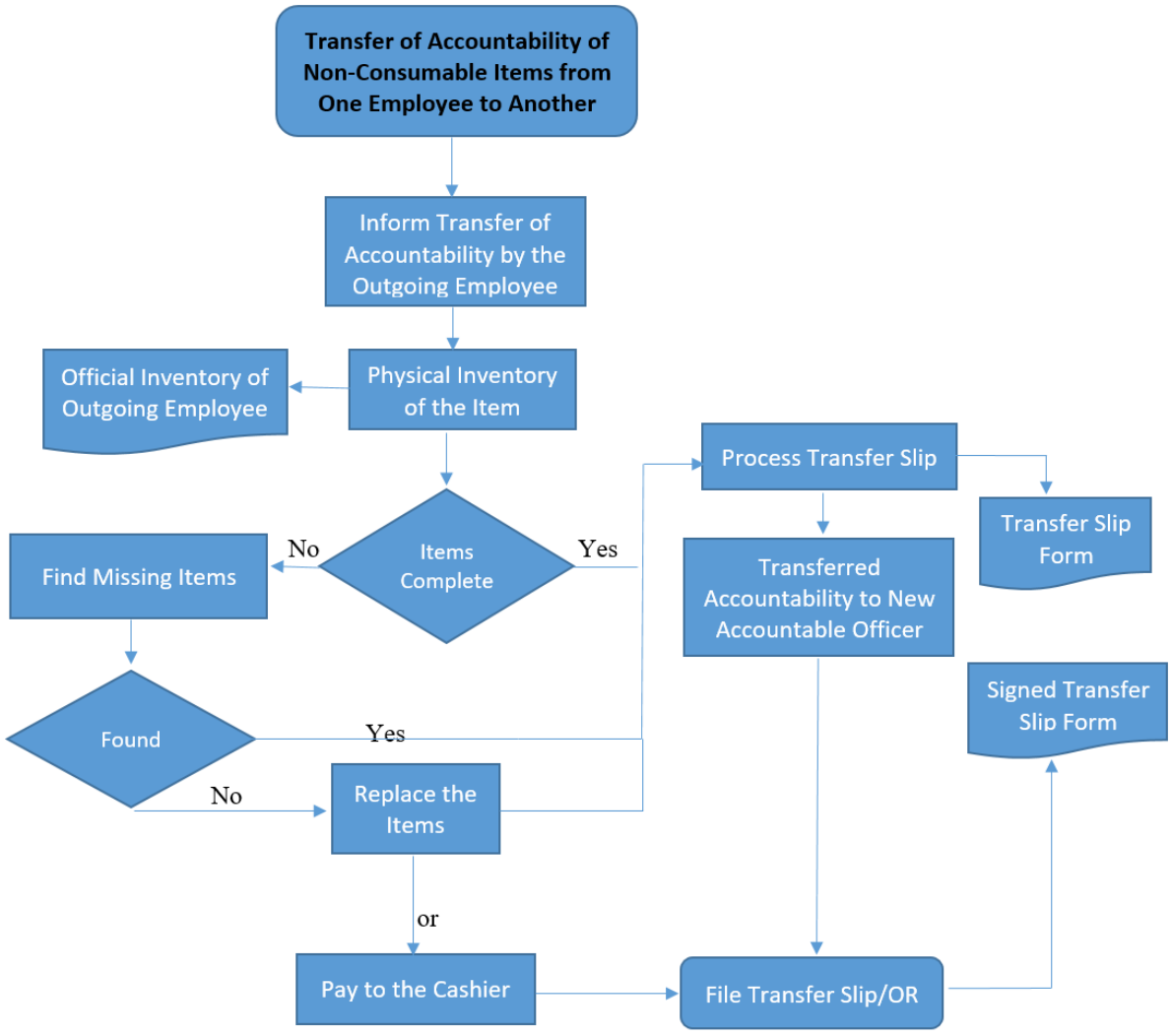


Figure 5 shows how to transfer accountability for non-consumable items from one employee to another. Accountability for non-consumable items transferred from one employee to another when that employee resigned, retired, or transferred to another

department. The inventory office will be notified of the employee's resignation, retirement, or transfer by the HR department or the person who resigns, retires or transfers. Then, along with the new accountable officer and using the official inventory of the outgoing employee, the inventory office will conduct a physical inventory of the accounted items for that employee. Using a transfer slip generated by RPIS, the inventory officer will transfer the items to the new accountable officer if they are complete. The transfer slip will then be filed by the inventory officer. The inventory officer will give the outgoing officer enough time to locate any missing items if the items are not complete. If the missing items are discovered, the inventory officer will process the transfer slip. If an item is lost, the inventory officer will give the outgoing employee the option of replacing it or paying the depreciated value to the cashier. If the outgoing employee replaces the lost item, the inventory officer processes the transfer of the item to the new accountable officer. If the outgoing employee pays to the cashier, the inventory officer files the OR (official receipt), removing the item from the official inventory.

Figure 6

Withdrawal of Condemned Items

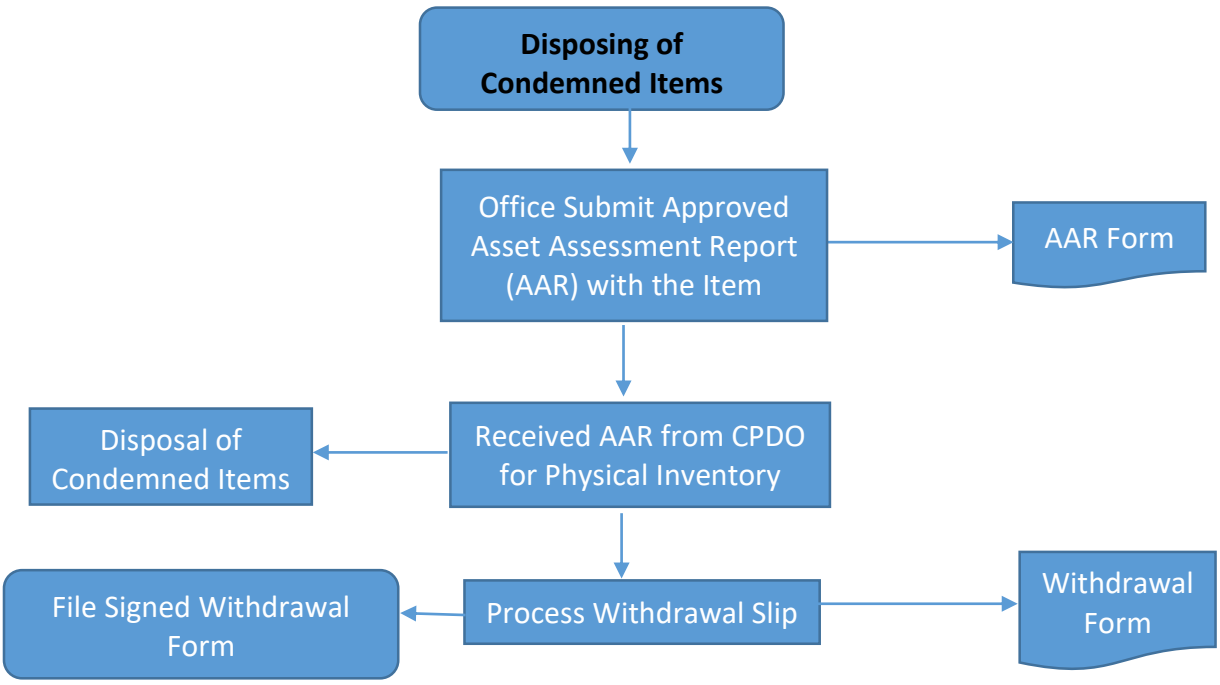


Figure 6 shows how to dispose condemned items. Items that have been disposed as condemned are non-consumables that are broken, beyond repair, or so out of date that the

department has decided to surrender them without a replacement. The item is handed over by the department to the CPDO's Property Section together with the approved AAR form. The AAR form and the condemned item were received by the inventory office, which then sent the condemned item to the store room for proper disposal. Condemned items are disposed of when the storage area is full, which typically occurs once a month. The withdrawal form is processed by the inventory office, which also gets the accountable officer and the university accountant to sign it before filing it.

Figure 7

Physical Inventory

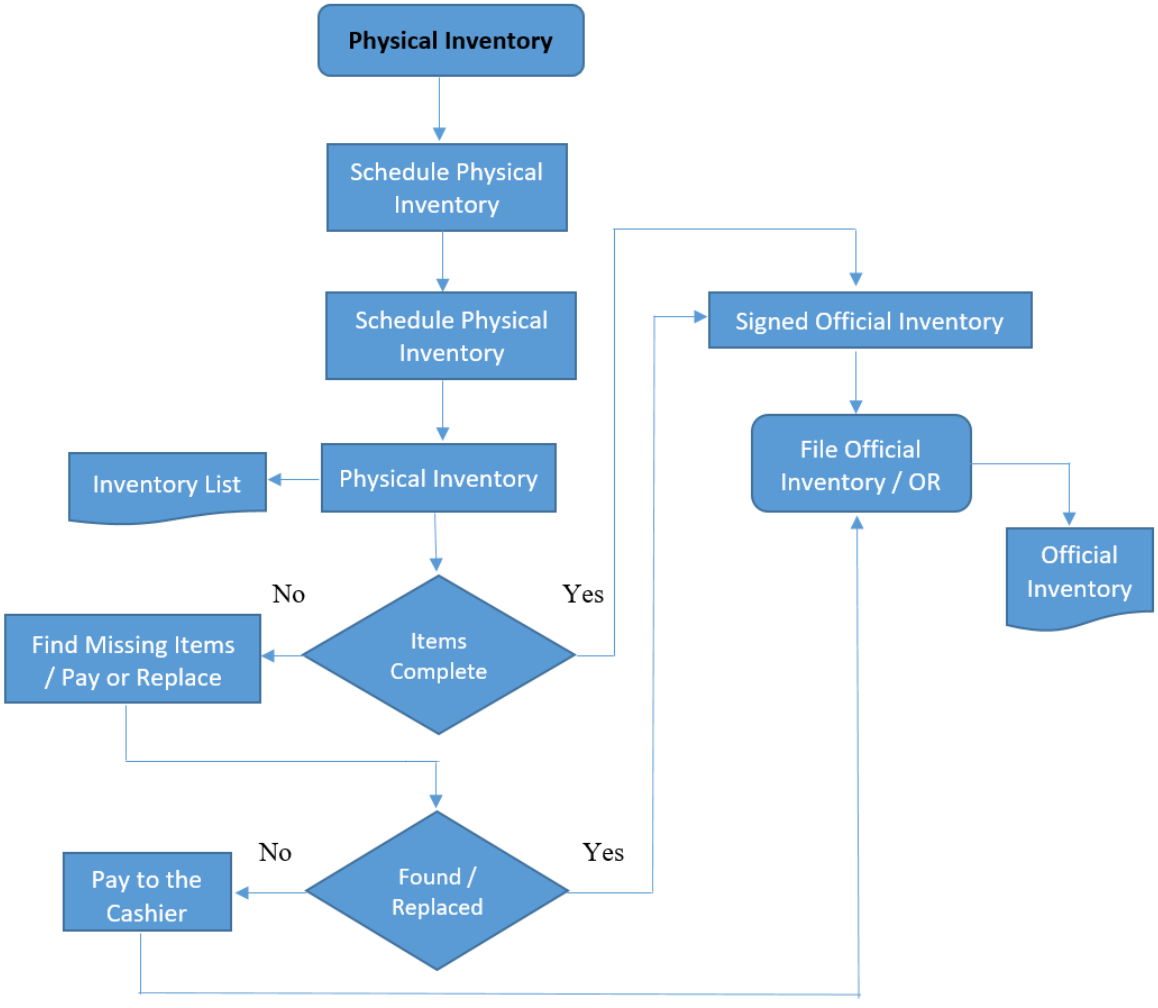


Figure 7 shows the physical inventory, which is done annually. The actual checking of non-consumable items by an accountable officer is recognized as physical inventory. The

physical inventory is scheduled by the inventory office. An accountable officer's inventory list is used to conduct a physical inventory. If all of the items have been checked, the inventory office will generate an official inventory, for the accountable officer and university accountant to sign. If not, the inventory office will allow the accountable officer enough time to search for the missing items. If the item is located or replaced, it will be added to the accountable officer's official inventory; otherwise, the item will be removed from the official inventory and the accountable officer will pay the cashier at depreciated value for it.

3. Methodology

3.1. Study Design

The study used a quantitative research design, specifically a descriptive - survey method. Using a questionnaire designed, the study determined the respondent's profile, their familiarity of the university's inventory management system, and identifies the limitations and suggests recommendations to address the limitations.

3.2. Population and Sample of the Study

The study's population consisted of university employees who used the UBRPIS. The system was first used at the university in 2016. A total of 101 people completed the surveys, which were distributed both electronically and on paper to all 105 system users.

3.3. Data Gathering Procedures

The researcher submitted a letter to the vice president of finance, which was signed by the department head, requesting permission to conduct a study within his department and permission to distribute questionnaires to the concerned personnel. Prior to data collection, the questionnaires were validated by the adviser and experts. Following approval from the adviser and experts, the questionnaires were distributed to respondents and collected using Google Forms and printed copies. The data collection took two weeks.

3.4. Treatment of Data

In the first and second parts of the questionnaire, frequency and percentages were computed. These data were used to achieve the study’s first two objectives. On the other hand, the third part was analyzed through content analysis.

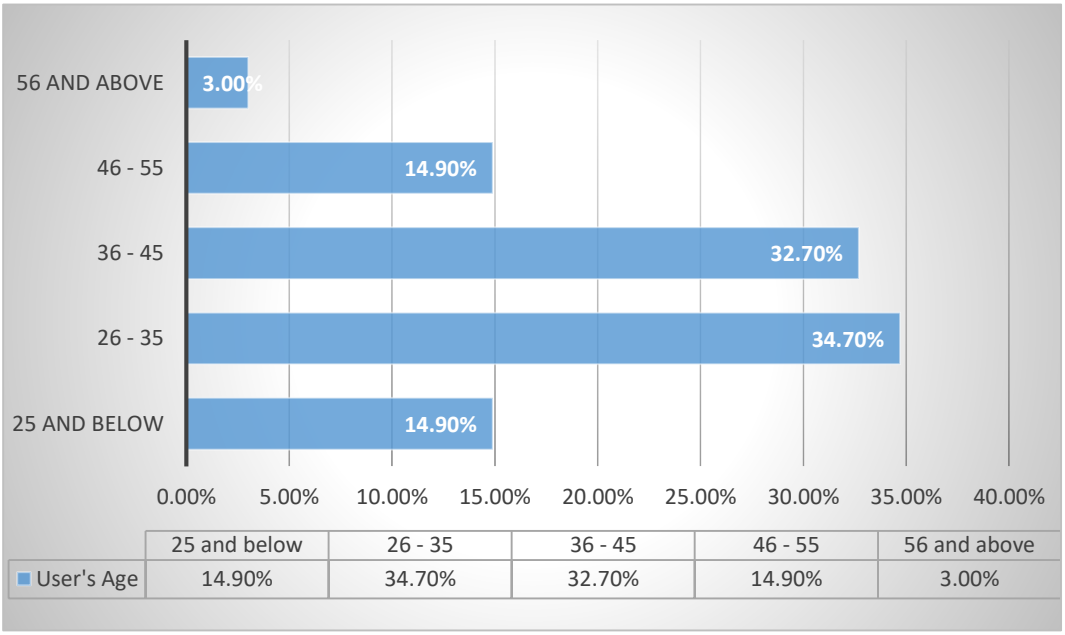
4. Findings and Discussion

4.1. UBRPIS user's profile

Figure 8 presents the age distribution of UBRPIS users. The majority of UBRPIS users are between the ages of 26 and 35, with a minority between the ages of 56 and up.

Figure 8

User's Age

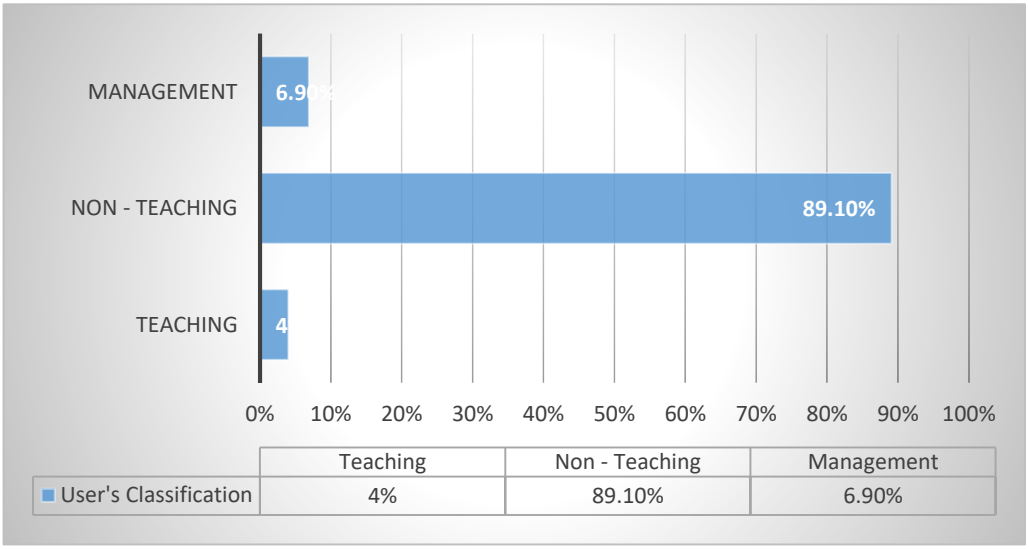


According to Rosell (2021), the use of technology in daily life is becoming more important. Information and communication services are rapidly becoming digitalized. People are constantly forced to adapt to "what is new" as a result of technological advancement. Those born before the "internet age" and outside of the digitally advanced world will undoubtedly face difficulties. Age does have an impact on how people use technology. However, the notion that older people's ability to pick up on technology is the main barrier should be rejected. People must accept responsibility for the fact that a large part of the problem is still based on assumptions about how difficult it is to learn new skills as people age.

Figure 9 displays the UBRPIS user classifications. Non-teaching personnel make up 89.10% of the users.

Figure 9

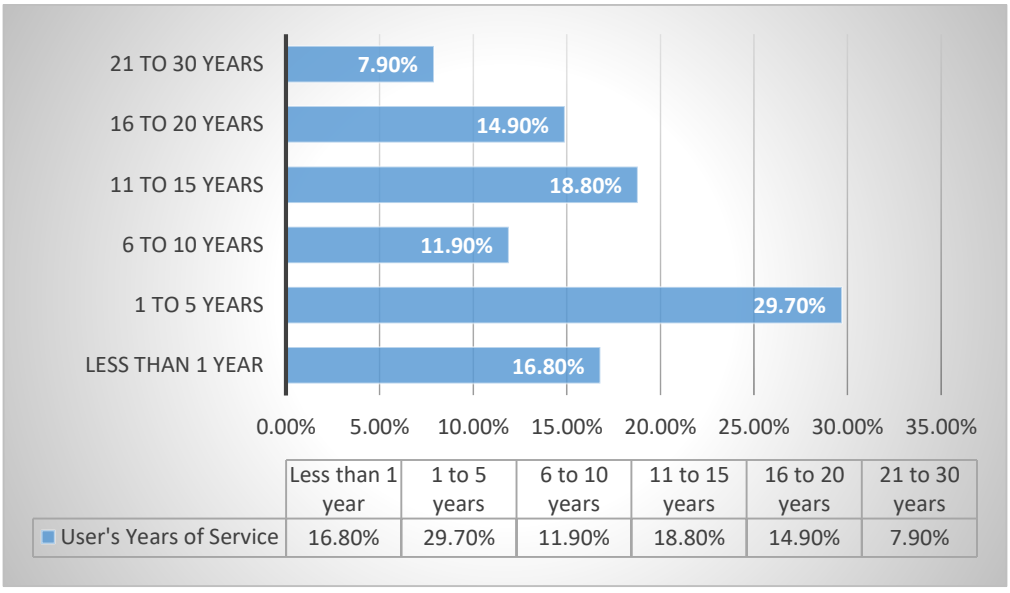
User's Classification



From the article Institutional Knowledge by Valamis (2022), what a corporation and its employees collectively know is known as institutional knowledge. This can include the know-how, procedures, principles, and experiences that span the whole history of the organization or are brought to the organization by new personnel. An essential component of managing a successful firm is maintaining knowledge and expertise. While innovation and fresh company strategies can result in significant growth, this is most effective when staff members are aware of the past and have a shared understanding of the workplace.

Figure 10

User's Years of Service in the University



The length of users' employment with the institution is presented in figure 10. Most of the users have worked in the institution for between one and five years. According to McCathy (2018), business all across the world use technology, a platform that is ever-evolving and getting better. Every day, technological development shapes the way people will work in the future. The younger generation are the huge importance for the future of business and technology, as they themselves will be part of the working generation. At GSM Barcoding, technology is a significant aspect of the business, and it is these improvements that have helped the company with the stock control software and solutions to assist businesses enhance the barcode tracking.

4.2. Determining the employees' familiarity of the inventory management system

Table 1, 2 and 3 illustrate the users' familiarity of the procedures involved in the university's inventory management system. The questions that were asked are listed in the first column, along with their frequency and percentages.

Table 1

Employees Familiarity of the Inventory Management System According to Age

Question	Age					
	25 and below (n=15)	26 to 35 (n=35)	36 to 45 (n=33)	46 to 55 (n=15)	56 and above (n=3)	Over-all (n=101)
1. Do you know how to request for new or additional non-consumable items?	13 (86.67%)	33 (94.29%)	33 (100%)	14 (93.33%)	3 (100%)	96 (95.05%)
2. Do you know how to request for new or additional non-consumable items?	13 (86.67%)	30 (85.71%)	33 (100%)	14 (93.33%)	2 (66.67%)	92 (91.09%)
3. Are you aware of the use of barcodes of the non-consumable items?	13 (86.67%)	31 (88.57%)	27 (81.82%)	11 (73.33%)	2 (66.67%)	84 (83.17%)
4. Do you know the process in transferring the accountability of non-consumable items to another accountable officer?	8 (53.33%)	18 (51.43%)	24 (72.73%)	10 (66.67%)	2 (66.67%)	62 (61.39%)
5. Do you know the process in withdrawing of condemned non-consumable items?	7 (46.67%)	18 (51.43%)	25 (75.76%)	12 (80%)	2 (66.67%)	64 (63.37%)
6. Do you know the process in the physical inventory of accounted non-consumable items?	6 (40%)	21 (60%)	25 (75.76%)	13 (86.67%)	2 (66.67%)	67 (66.34%)

Table 1 shows the employees' knowledge of the inventory management system in terms of age. Ages 25 and under have a low proportion of people who are aware of the processes involved in inventory management, whereas ages 36 and older have the highest percentage, according to table 1's overall trend. Ferguson (2023) states that long-term employees have a great deal of information about the company's culture, as well as its products and services. They are aware of what works and what doesn't because they have seen numerous changes in their line of work. They build a solid knowledge base through daily job performance, which leads to increased productivity because fewer errors are made. For instance, a manufacturing company's long-term employees have a thorough understanding of manufacturing processes, which ultimately results in better sales.

Table 2

Employees Familiarity of the Inventory Management System According to Employee Classification (n=101)

Questions	Employee Classification			Over-all (n=101)
	Teaching (n=4)	Non-Teaching (n=90)	Management (n=7)	
1. Do you know how to request for new or additional non-consumable items?	4 (100%)	85 (94.44%)	7 (100%)	96 (95.05%)
2. Do you know how to request for replacement non-consumable items?	4 (100%)	81 (90%)	7 (100%)	92 (91.09%)
3. Are you aware of the use of barcodes on the non-consumable items?	3 (75%)	74 (82.22%)	7 (100%)	84 (83.17%)
4. Do you know the process in transferring the accountability of non-consumable items to another accountable officer?	1 (25%)	55 (61.11%)	6 (85.71%)	62 (61.39%)
5. Do you know the process in withdrawing of condemned non-consumable items?	2 (50%)	56 (62.22%)	6 (85.71%)	64 (63.37%)
6. Do you know the process in the physical inventory of accounted non-consumable items?	2 (50%)	59 (65.56%)	6 (85.71%)	67 (66.34%)

Table 2 displays the employees' knowledge of the inventory management system based on employee classification. As a whole, management is the group that is most aware of the procedures involved in the system of inventory management. Perhaps this is due to the fact that upper-level managers, who must make numerous decisions on the operation of the organization, are informed of every detail.

Table 3

Employees Familiarity of the Inventory Management System According to Years of Service (n=101)

Questions	Years of Service						Over-all (n=101)
	< 1 year (n=17)	1 to 5 (n=30)	6 to 10 (n=12)	11 to 15 (n=19)	16 to 20 (n=15)	21 to 30 (n=8)	
1. Do you know how to request for new or additional non-consumable items?	12 (70.59%)	30 (100%)	12 (100%)	19 (100%)	15 (100%)	8 (100%)	96 (95.05%)
2. Do you know how to request for replacement non-consumable items?	12 (70.59%)	28 (93.33%)	12 (100%)	18 (94.74%)	15 (100%)	7 (87.5%)	92 (91.09%)
3. Are you aware of the use of barcodes of the non-consumable items?	11 (64.71%)	26 (86.67%)	12 (100%)	18 (94.74%)	13 (86.67%)	4 (50%)	84 (83.17%)
4. Do you know the process in transferring the accountability of non-consumable items to another accountable officer?	7 (41.18%)	16 (53.33%)	10 (83.33%)	13 (68.42%)	13 (86.67%)	3 (37.5%)	62 (61.39%)
5. Do you know the process in withdrawing of condemned non-consumable items?	7 (41.18%)	13 (43.33%)	12 (100%)	15 (78.95%)	13 (86.67%)	4 (50%)	64 (63.37%)
6. Do you know the process in the physical inventory of accounted non-consumable items?	9 (52.94%)	18 (60%)	9 (75%)	16 (84.21%)	11 (73.33%)	4 (50%)	67 (66.34%)

Table 3 presents the employees' familiarity with the inventory management system based on their length of employment. According to the table, users with an average tenure of six to ten years in the organization are more likely to be familiar with the inventory management system's operations, whereas users with shorter tenures of less than a year and those with 21 to 30 years of service are less likely to be. Perhaps this is due to the fact that employees who have been with the company for six to ten years are accustomed to the procedures, while those who have been there for less than a year are still new to the company, and those with 21 to 30 years of service forget the procedures due to advancing years.

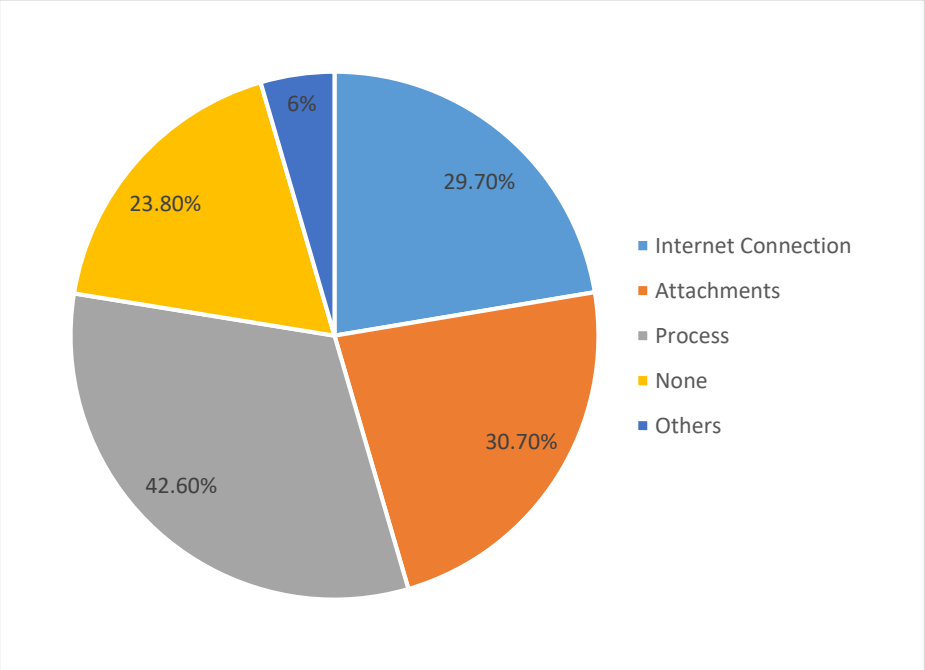
4.3. Recognizing the Limitations of the Inventory Management System and Making Recommendations

The figures below show the frequency of limitations encountered by the users on the given processes and is able to provide other constraints that are experienced when using the inventory management system. Figures 11 to 16 show the limitations of the inventory management systems.

In figure 11, process 1, the process itself has the highest frequency. This indicates that users have trouble requesting new or additional non-consumable items. The item name is not included in the system, and the attachment of a justification letter with proper signatories from heads is the most likely cause of this. When making a new or additional request, a letter of justification is required. The head/director/dean of the office, as well as the supervisory vice president, have signed this letter as evidence that this new or additional item is required in their department or office.

Figure 11

Process 1: Request for New or Additional Non-Consumable Items

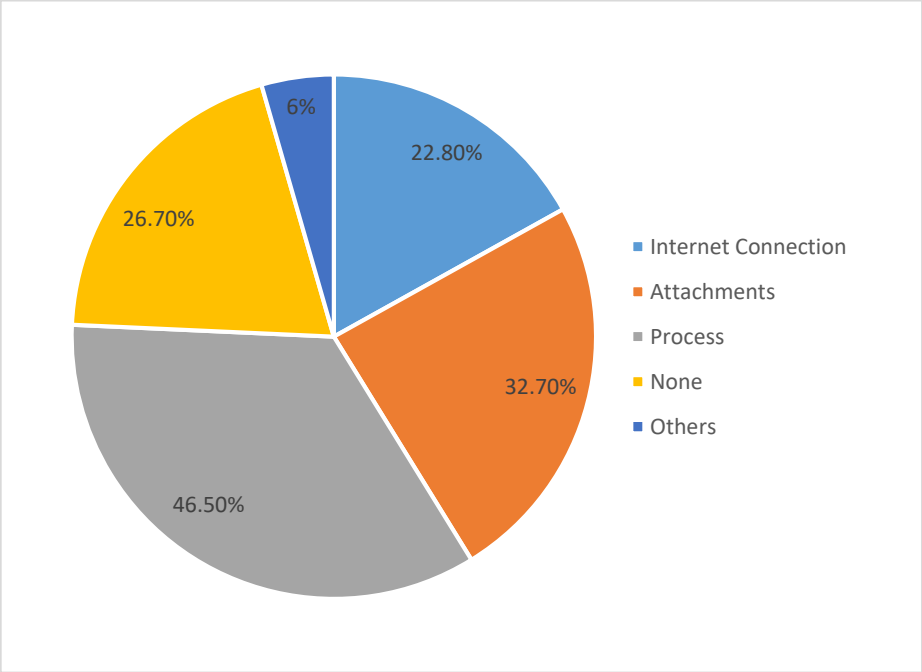


The process itself has the peak value in figure 12, process number 2, at 46.50%. This indicates that users are finding it difficult to request replacement assets. The fact that the replacement request must still be made manually on the requisition slip form is likely the primary factor. Jenkins (2020), states that organizations can better satisfy customers' needs

and cut costs by using an inventory management to keep track of all incoming and existing assets. Every key company functions, including budgeting, operations, inventory control, procurement, and customer service – is impacted by the system. The main requirements for an inventory management system include a means of storing, managing, organizing, and analyzing inventory data. Among the system requirements are: (1) a user-friendly interface that doesn't need special training, documentation, or support; (2) automation for functions relating to inventory management to get rid of manual processes; (3) a reliable, secure database that produces accurate, real-time data; (4) performance that makes fast, effective inventory control and monitoring viable; (5) sustainability of the system is ensured by administrators' ability to install software modules quickly and with little configuration; and (6) minimizing manual inventory updates or inputs through technological integrations and automated features.

Figure 12

Process 2: Request for Replacement Non-Consumable Items



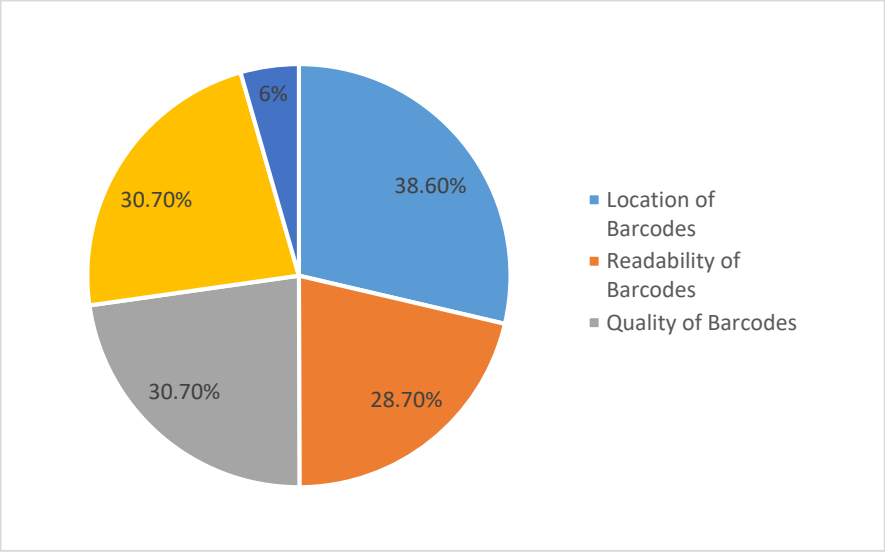
The client's primary concern in figure 13, process 3 is where the barcodes are located, which accounts for 38.60% of the total. Most likely, the main reason for this is that barcodes can sometimes be hidden, which make them difficult to locate. Camcode (2021) asserts that effective inventory programs depend on the placement and positioning of fixed asset identification tags and barcode stickers. Consistency in the positioning of such tags is a key factor. Accessibility for regular follow-up inspections is a good indicator. While it is always

possible to damage an asset when applying tags, they shouldn't be placed remotely so that it is difficult to connect them or locate asset tags during scanning verification.

As for the other limitations, certain items lack barcodes because there isn't a programmer available to update and improve software functionality, and there isn't enough manpower to complete the operation at hand.

Figure 13

Process 3: Barcoding for Non-Consumable Items



Regarding figure 14, process 4 which involves transferring the accountability of an asset to another person, the results, 51.50% for the process and 46.50% for the acceptance of the accountability of the new accountable person, are not too far apart. This suggests that users are having issues with the process, possibly because no one has been hired or transferred to the office to accept responsibility for the non-consumable items, therefore, the old employee who is still there is obliged to do so. Georgia.gov (2023) discusses the manner by which the state maintains accountability for the physical computing devices and software purchased with the public funds is through asset inventory, which is mandated under state asset management rules. Each state agency must keep perpetual and current records of all the hardware and software (including licenses) it has purchased using public funds. The hosting agency is in charge of this responsibility when resources are shared by between two or more Georgia state government agencies. The Official Code of Georgia Annotated section 50-16-60 et seq. and any applicable state or agency asset management policies must be followed when recording any asset.

Figure 14

Process 4: Transferring the Accountability of Non-Consumable Items to Another Accountable Officer

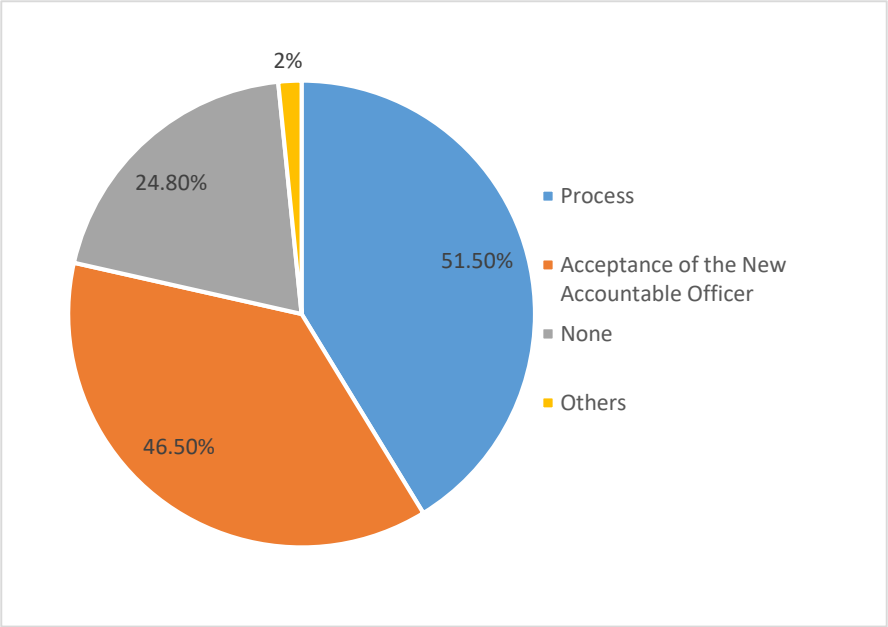
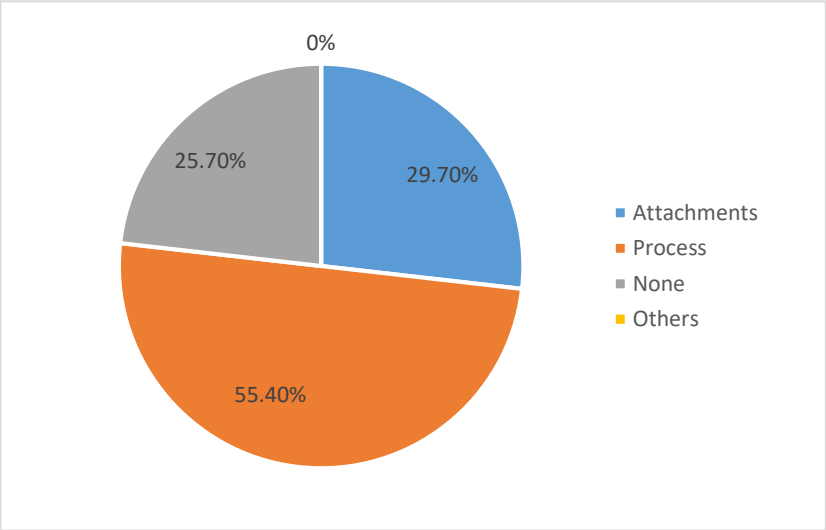


Figure 15, process 5 contains the process's highest value, which is 55.40%. This indicates that users are confused about the procedure for withdrawal of condemned non-consumable assets; the fact that only condemned items are allowed to be withdrawn from users' responsibility could be the cause of the issue. Sandham (2021) explains that the life cycle of equipment is rather simple, but deciding when to condemn and how to dispose of equipment appears to be the challenge. The expert in charge of the department should have the expertise, knowledge, and ability to determine when a piece of equipment should be scrapped and taken out of service when considering condemnation and disposal. Equipment condemnation is typically done for the following reasons: (1) beyond economical repair, this is the point at which the expense of repairing the equipment is deemed to be too high after considering its age, depreciation, and current worth; (2) technically out of date; no longer supported by parts and services; (3) clinically outdated; the maker (or the clinician using the equipment) recommends replacement for clinical grounds, due to advancements in imaging technology, diagnostic ultrasound imaging, typically becomes clinically obsolete after 5 years, but it can still be utilized and supported by the supplier; and (4) equipment that has been contaminated and damaged.

Figure 15

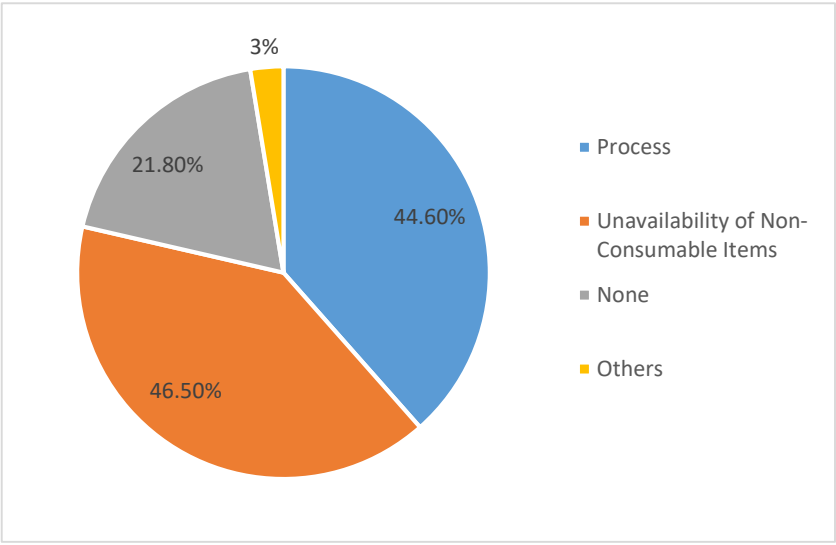
Process 5: Withdrawal of Condemned Non-Consumable Items



The results for figure 16, process 6, which entails a physical inventory of accounted non-consumable assets, are not too different: 44.60% for the process and 46.50% for the unavailability of non-consumable items. This suggests that clients could have issues with the process because physical inventory is not done on time, leading to the unavailability of non-consumable items. Paychex Worx (2022) mentions that only an actual count can disclose what is on hand and ensure it matches what is in the system, regardless of whether the use of inventory management software or other systems to track inventory throughout the year. For instance, it's crucial to identify "shrinkage," which is a decrease in inventory as a result of things being stolen, damaged, or counted incorrectly, so it's possible to remedy it.

Figure 16

Process 6: Physical Inventory of Accounted Non-Consumable Items



As a whole, the limitations encountered in the processes involved are the following: internet connection; the necessary documents or attachments; the process itself, which some employees are confused with; and the RPIS, some of whose modules are not yet functional.

The suggestions from the users for enhancing each procedure are shown in Table 4. These were taken directly from the respondent's responses.

Table 4

Recommendations for the Inventory Management System

FOR UBRPIS	FOR THE PROCESSES	OTHERS
1. More Options 2. Pictures and other documents can be downloaded from RPIS 3. System must be open every week and not just twice a month 4. Affix e-signature 5. Barcodes should be linked to an inventory system for easy monitoring and accountability 6. Barcodes should be visible immediately 7. Barcodes should be place on the item after being issued to avoid delays 8. Able to provide list of accounted non-consumable items to person concern every semester	1. Ensure awareness of PPG thru different platforms especially for new employees. 2. Process/instructions should be easier to follow 3. Make the process fully online since there are still parts of the process where hardcopies are being routed 4. Set limit of needed letter, not all non-consumable should have letter. 5. Once there is a new accountable officer, endorsed the items old accountable officer to the new accountable officer.	1. Limited manpower for the part of the office to process all transfer. Add more staff/student assistants

Table 4 shows the suggestions made by the users, which are collated and grouped into three categories: UBRPIS, process, and others. As can be seen in the first column, users ask

for more options that would allow them to access some modules that are not yet functional at their end and request items that are not yet included in the system. Signatories can attach their signatures to the UBRPIS, and images as well as other documents can also be submitted into the system. For quick tracking and checking of the goods, another possibility is to include a barcode that is immediately visible and can be scanned. Finally, they were allowed to access the inventory list that was issued to them.

Users wanted to be aware of and knowledgeable about the policies, procedures, and guidelines regulating the processes used in the inventory office, which is why they turned out the second column. Another is to completely automate the process online, impose limitations on products that require a justification letter, and immediately transfer inventory to the new accountable officer.

There are two inventory officers and one student assistant in the office. The final recommendation is to add more staff to the office to handle any inventory-related issues. These ideas are viable as long as the programmer is readily available and willing to make adjustments.

4. Conclusion

The following conclusions are drawn from the results of the study. All users within the company are not fully aware of the processes involved in the inventory office, indicating that they constantly inquire about the process from the office and does so repeatedly. Because users are not aware of the processes involved, the process itself is the biggest limitation identified in the inventory management system. The following recommendations are made based on the findings:

1. Because of the high employee turnover rate and the fact that certain offices only have one person assigned to handle item requests, there must be a continuous online webinar for all university employees about the inventory management system in the institution. The purpose of the online webinar is to familiarize employees with the policies and procedures for using UBPRIS.
2. Invest in inventory management system technology that best meets the requirements of all system users. The use of technology that integrates well the inventory

management software could help manage all non-consumable items with things like mobile scanners or barcode readers.

3. For the hardware, the printer and barcode reader have to be compatible with the RPIS system. Software that is constantly upgraded, and users of RPIS should have periodic webinars or seminars.
4. As a result of the inventory management system's connections to other sections like the property and procurement offices, their input and recommendations are greatly valued in advancing the system.
5. Additional manpower and a wider working area for the inventory officers to accomplish needed reports and tasks are proposed or requested.

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