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Evaluating the Effectiveness of Proportional Nodes Method in Curve Fitting for Surfaces: Application to Data of Dynamic Viscosity of Ammonia-Water Solution

[1]S. N. Mumah, [2]H.F. Akande, [3]S. Alexander, [4]K.Y. Mudi,

[5]O. Olaniyan & [6]F. Samuel

Abstract

This study used the proportional nodes method, a novel curve fitting approach to correlate data for dynamic viscosity of ammonia-water solution. The approach integrates polynomial equations, generated at various temperatures, with those calculated at selected mole fraction nodes. These nodes are scaling factors that account for variations in dynamic viscosity at different temperatures at selected mole fractions. The accuracy of the polynomial equations ensures a high degree of fitting accuracy. The proportional nodes, computed systematically, were integrated into a robust and highly accurate polynomial model to generate correlations that fit the data for the surface. This model exhibited minimal average percentage differences between predicted and actual viscosity values (±0.2614293 for temperature range, 273.15K to 303.15K and ±1.11 for temperature range, 303.15K to 423.15 K), indicating a high level of predictive accuracy. The proportional nodes method offers a significant contribution to both academic research and industry. It provides a more precise and adaptive model for predicting the dynamic viscosity of ammonia-water solution, which is critical for optimizing and designing various industrial applications, including refrigeration systems.

Keywords: *correlations, proportional nodes, curve fitting, dynamic viscosity, ammonia-water solution*

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1. Introduction

The dynamic viscosity of ammonia-water solution plays a crucial role in numerous industrial applications, particularly in refrigeration systems. Accurately predicting this viscosity is paramount for optimizing and designing such systems. Historically, multiple regression techniques have been extensively employed to understand the relationships between diverse quantities. However, when dealing with multiple variables, especially when fitting data for surfaces, the efficacy of such regression techniques is often challenged. An alternative that garnered attention in this context is the use of polynomials such as Chebyshev Polynomial. Renowned for their numerical interpolation capabilities, Chebyshev Polynomials attempt to emulate a function at multiple points based on a specified polynomial order. While they have proven more accurate than some multi-linear regression methods, challenges arise, especially when handling large datasets. The intricacies further intensify when correlating for surfaces.

This paper seeks to address these challenges by introducing the proportional nodes method in curve fitting. This innovative approach, aiming to construct models with multiple variables, promises a meticulous and systematic method to compute dynamic viscosity. It is designed to overcome the limitations posed by polynomials such as Chebyshev Polynomial. The proportional node method was used to generate correlations for the dynamic viscosity of ammonia-water solution. By integrating polynomial equations generated at various temperatures with those calculated at selected mole fraction nodes, this method aims to offer a more accurate and adaptive model for predicting dynamic viscosity.

This study aims to present a novel method for data fitting which allows models to be constructed with multiple variables on both sides of an equation and which can be computed easily by using a series of least squares regression lines in combination with the equation of the nodes of the various lines at its largest point of dispersion. The underlying principle is finding the best equation of these nodes and the equations of the upper and lower lines. If the equations of the lower and upper lines and that of the nodes of each of the lines are computed accurately, the correlation for the surface can be calculated. This study followed the proportional nodes method introduced by Mumah (2021) in calculating the dynamic viscosity of the ammonia-water solution. In this study, correlations were first developed for the pure components and then used to develop models for ammonia-water solution. The data

generated by these models were compared with values generated from the procedure presented by Conde-Petit (2006).

2. Literature review

Data fitting provides users with a mathematical representation that closely aligns with a sequence of data points, keeping the data's constraints in mind. The curve-fitting process identifies a mathematical formula that best aligns with a designated set of data points by minimizing the difference between the given points and the determined equation. When addressing two or three-dimensional data, the tool of polynomial regression comes into play. At the heart of data analysis lies correlation—a statistical measure that assesses the association between multiple variables. In essence, it examines how closely two variables move in tandem. A positive correlation indicates that as one variable escalates, so does the other and vice versa. Conversely, a negative correlation reveals that as one variable goes up, the other comes down and vice versa. When two variables exhibit no discernible pattern or relationship, it is termed as a neutral correlation (Jaadi, 2019).

Differing from correlation, regression is another pivotal statistical method. It foresees the probable value of a dependent variable (Y) rooted in the known values of one or more independent variables (X), utilizing a fitting equation. This approach aims to fathom the connections between a result variable (Y) and its predictor variable(s) (X), as highlighted by Yang (2017). Notably, understanding correlation can pave the way for accurate predictions. Stanovich (2007) reported that numerous scientific propositions are structured around correlations or their absence, making correlation-centric studies pivotal to these theories. Under feasible conditions, evidence gleaned from correlation studies can be subjected to rigorous experimental testing. In the spheres of science and engineering, correlations play an indispensable role in ascertaining the trustworthiness and accuracy of various measurements. Understanding that a statistical bond between two variables does not automatically imply a cause-and-effect relationship is imperative. There are scenarios where one variable's movement could influence another, or a third distinct factor could impact both (Rajiv et al., 2019).

The meticulous determination of data correlations is quintessential for the systematic design, simulation, and fine-tuning of chemical processes. In certain instances, obtaining

experimental data proves challenging, prompting researchers to turn to manufactured data. While such data has its merits in societal experiments, its application is relatively restricted in scientific and engineering research (Petricioli et al., 2020). Delving deeper, Banerjee and Hero (2016) introduced a sequential testing mechanism for pinpointing and isolating hubs within a correlation graph. Their approach tackled situations where variables, initially unrelated, underwent sudden correlation shifts due to unforeseen events. The expansive applications of this methodology span fault identification, anomaly tracking, and even shifts in time series or financial datasets.

The dynamic viscosity of ammonia-water solution is a key property necessary for design and optimization purposes of refrigeration systems. Numerous studies have been conducted to develop and evaluate different methodologies to understand the dynamic viscosity of ammonia-water better solutions. While several correlation-generating methods for data fitting exist, each brings a unique degree of complexity and accuracy. Viscosity is one of the thermodynamic properties necessary to design and simulate flow equipment and systems. Viscosity can be considered the energy that makes a fluid flow as the molecules interact. Generally, viscosity decreases with increasing temperature in liquids and increases with increasing temperature in gases. Because of this property's role in the design and simulation of flow systems, various correlations have been developed to express the relationship between it and temperature. For gases, pressure also becomes a factor. One of the areas where accurate viscosity values play an important factor is the design and simulation of ammonia-water absorption refrigeration. Poor design, verification or simulation emanating from wrong or inaccurate viscosity values result in inefficient processes or products that do not meet specifications.

Ma et al. (2022) delved into the calibration of the viscous boundary’s adjustment coefficient based on the water cycle algorithm, aiming to enhance the accuracy of dynamic response analysis. Their study incorporated the conventional viscous boundary theory into particle discrete elements through programming. Their model, employed in the seismic response analysis of a rockfill slope, authenticated the calibration's precision and the feasibility of the viscous boundary. While the research provides insights into viscous boundaries, it lacks a direct correlation with ammonia-water solution viscosity and offers no mention of the proportional nodes method, indicating a potential gap in the literature.

In another study, Bhattacharjee et al. (2022) showcased a novel approach for real-time viscosity measurements using a differential pressure sensor system. While their model can measure viscosity changes, the research predominantly focused on water and glycerol mixtures, and there was no apparent applicability to ammonia-water solutions or any reference to the proportional nodes method. Similarly, Rezaei et al. (2022) proposed a model that combines the radial basis function neural network with ant colony optimization, specifically for gas viscosity estimations under high-pressure and high-temperature conditions. Though the research presented a commendable model with high accuracy, its specific application to gases renders it tangential to the context of ammonia-water solutions. Moreover, the proportional nodes method is conspicuously absent.

There are numerous studies conducted on viscosity but majority of them have different focus. For example, Thol and Richter (2021) critically reviewed dynamic viscosity models of binary fluid mixtures, emphasizing asymmetric mixtures. They assessed several models, such as the extended corresponding states method, entropy scaling approaches, and the friction theory, pointing out inherent shortcomings in both experimental data and modelling techniques. Melaibari et al. (2021) centred on predicting the viscosity behaviour of hybrid nano-antifreeze solutions using the Artificial Neural Network and the Response Surface Method. Even though the research provided accuracy metrics and comparisons between methods, the focus was on nanofluids. Similarly, Rahmanifard et al. (2021) advocated for supervised machine learning algorithms in predicting gas component viscosity. Despite the impressive accuracy of their proposed model, their research is confined to gas component viscosities. Barkhordar et al. (2021) took a statistical lens towards nanofluid viscosity correlations, aiming to determine their relationship with variable parameters. While their study provides insights into the accuracy and reliability of certain correlations for nanofluids, it does not directly pertain to ammonia-water solutions. This is similar to Kumari et al. (2021) who investigated the peristaltic transport of fluid, focusing on bile flow in ducts. Their in-depth exploration of linear and nonlinear viscosity variations offered insights into bile's behaviour. Still, with its specificity to bile and the absence of any exploration its direct relevance is minimal. Furthermore, Abbas et al. (2021) focused on ammonia flow boiling in a vertical tube bundle, particularly on a dimple tube's performance. This research is tangentially related due to its focus on ammonia, but it centred on heat transfer coefficients.

Dolomatov et al. (2020) introduced a QSPR model to forecast the dynamic viscosity of saturated arenas vapors. Their model adeptly links dynamic viscosity to molecule descriptors. However, the focus is on vapours and so its relevance is limited.

There are several studies that addressed temperature-dependent viscosity. For instance, Ahmed et al. (2020) and Jouenne and Heurteux (2020) delved into the influence of temperature-dependent viscosity on specific flows, with the former focusing on carbon nanotubes-based nanofluid and the latter on HPAM solutions. Wahab et al. (2020) also investigated the effects of temperature-dependent viscosity flow of a non-Newtonian fluid. Their numerical analysis scrutinized various parameters, shedding light on how they impact velocity, temperature, and concentration profiles. The study of Ahmadi et al. (2019) emphasized temperature as dominant factor affecting the dynamic viscosity of nanofluids by applying three algorithms (ANN-MLP, MARS, and MPR) and found that ANN-MLP had the highest R^2 value of 0.9998, closely followed by MARS and MPR. The most significant finding was the elevated importance of temperature in predicting viscosity when compared to other parameters such as size and concentration. Meanwhile, Irani et al. (2019) found that the viscosity of nanofluid samples displayed non-Newtonian behaviour in alignment with the Power law model, hence, it was proposed mathematical correlations based on temperature and volume fraction. Despite the paper's relevance in discussing curve fitting, if focused on a different type of fluid.

In another study background, Zare et al. (2019) explored the fluidity equation for various functionalized ionic liquids in assessing the temperature-dependent viscosity of diverse functionalized ionic liquids. They found that this equation accurately represented experimental viscosity data, with the dynamic crossover temperature of new ionic liquids being estimated through its parameters. While this paper's application to the ammonia-water solution is not directly addressed, it does highlight the importance of temperature, a factor relevant to other studies. For this, Zare et al. (2019) proposed two generalized correlations for estimating viscosity in evolving generalized correlations based on Peng-Robinson equation of state. The study confirmed these developed models' significant performance and accuracy in estimating supercritical fluid viscosity. The connection of this study to the ammonia-water solution's viscosity remains less clear, indicating a potential gap in the literature. To address accuracy, Wietecha and Kurzydło (2019) introduced the Stokes

viscometer in the determination of the dynamic viscosity coefficient of the stokes viscometer, where they achieved results aligning closely with literature values. The study hints at potential advancements in accuracy, but the direct relevance to the proportional nodes method for ammonia-water solution viscosity indicates a potential gap in the literature. Similarly, Eberhard et al. (2019) discussed a semi-analytical expression for local viscosity profile using a Carreau-type fluid in the determination of the effective viscosity of non-newtonian fluids flowing through porous media. The model showcases great accuracy without requiring additional input parameters, yet its relation to the review theme remains tangential.

The study of Valderrama et al. (2019) presented a generalized viscosity equation for ionic liquids in correlation and prediction of ionic liquid viscosity and showcased consistent results, outperforming other models in terms of simplicity and accuracy. However, ammonia-water solution was not considered in the study. In another study, Razmara et al. (2019) used Molecular Dynamics Simulation to study the viscosity of a specific water-based nanofluid and proposed a correlation that remains accurate for specific volume fractions. Still, its direct application to ammonia-water solution was not considered, indicating a potential gap in the literature. Manesh et al. (2019) discussed applying Fuzzy inference system and ANFIS to model viscosity. While the model shows acceptable accuracy, its direct relevance to the review theme is not strongly established.

According to Habibi et al. (2019), viscosity models significantly influence flow and temperature distributions. For instance, Miyara et al. (2019) introduced the tandem capillary tube method with reliability verified by comparing measured viscosities with reference values. However, the relevance to the current study is not clearly stated, indicating a potential gap in the literature. Moreover, Udawattha et al. (2019) developed a new correlation that effectively expresses the viscosity of various nanofluids while Jayeoba and Okoya (2019) derived analytical solutions for a third-grade fluid flow. While the papers present in-depth analytical solutions, their direct relevance to the current study is not extensively detailed.

3. Methods

This study evaluates the effectiveness of the proportional nodes method in curve fitting, specifically targeting the prediction of dynamic viscosity of an ammonia-water

solution over varying temperatures and mole fractions. The research method used was quantitative approach based on a novel curve-fitting technique. The dynamic viscosity data of ammonia-water solution as presented by Conde-Petit (2006), are used. Polynomial equations are formulated across various temperatures, incorporating them with calculations at specific mole fraction nodes. These nodes, termed as proportional nodes, act as scaling factors, accounting for variations in dynamic viscosity across different temperatures at selected mole fractions.

The proportional nodes method is utilized to correlate the dynamic viscosity data of ammonia-water solution. The model is validated by comparing predicted viscosities of the ammonia-water solution with the actual values, emphasizing R^2 values nearing 1 and minimal deviations between predicted and real data. The R^2 values associated with each equation and the average percentage deviations for two temperature ranges (273.15K to 303.15K and 303.15K to 423.15K) are investigated. The consistency of the model's predictions with the actual data is established by tabulating percentage differences. The findings are related to existing literature, particularly the established relationship between temperature and viscosity in fluid dynamics. The advantages of the new method over traditional polynomial fitting techniques are examined.

4. Results

In this study, the dynamic viscosity values of an ammonia-water solution presented by Conde-Petit (2006) were used. They are tabulated in Table 1, which clearly depict a decrease in dynamic viscosity as the temperature increases for various mole fractions. This is a common behaviour observed in fluids where an increase in temperature tends to reduce the internal resistance to flow, thereby reducing the viscosity (Lide, 2005).

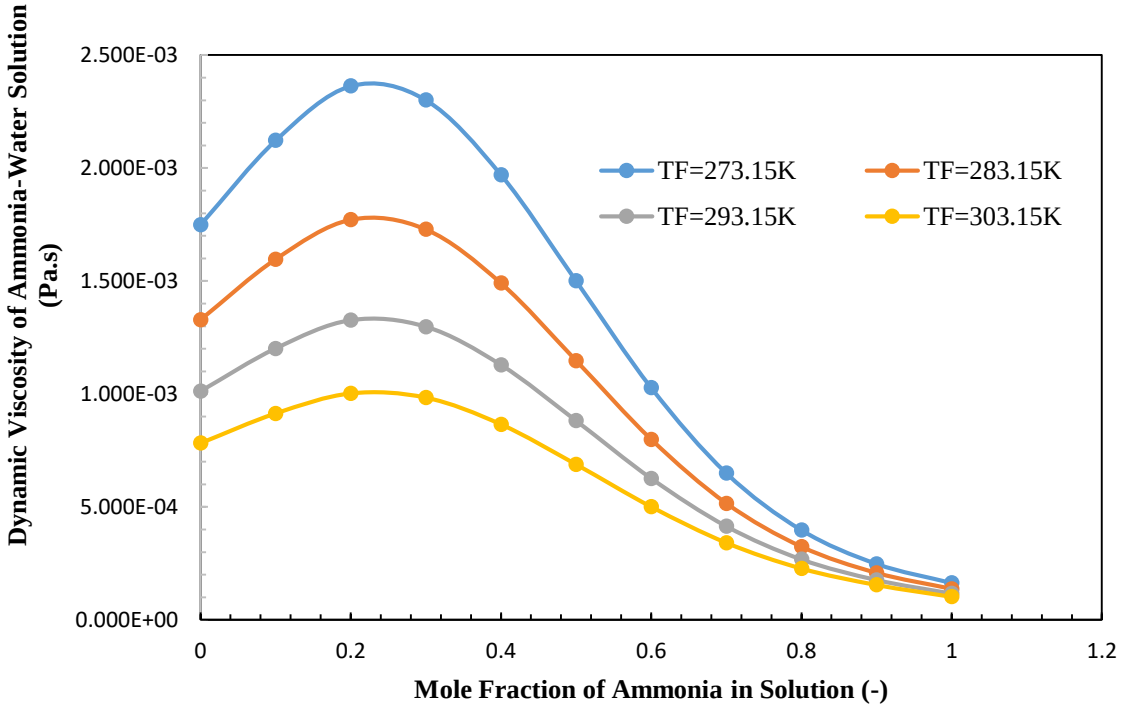
Table 1
Dynamic viscosity of ammonia-water solution for various temperatures and mole fraction

T (K)	Mole fraction (-)										
	0	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**
273.15	1.749 E-03	2.122 E-03	2.363 E-03	2.301 E-03	1.970 E-03	1.500 E-03	1.027 E-03	6.492 E-04	3.971 E-04	2.478 E-04	1.631 E-04
283.15	1.328 E-03	1.596 E-03	1.771 E-03	1.728 E-03	1.490 E-03	1.147 E-03	7.982 E-04	5.152 E-04	3.233 E-04	2.073 E-04	1.367 E-04
293.15	1.012 E-03	1.201 E-03	1.326 E-03	1.297 E-03	1.128 E-03	8.811 E-04	6.258 E-04	4.144 E-04	2.678 E-04	1.769 E-04	1.168 E-04
303.15	7.819 E-04	9.134 E-04	1.002 E-03	9.834 E-04	8.651 E-04	6.878 E-04	5.004 E-04	3.411 E-04	2.274 E-04	1.547 E-04	1.023 E-04

Generally, data are not depicted into 2 forms in published papers, but this paper argues the necessity to do so. The variation of dynamic viscosity of ammonia-water solution for various mole fractions, *x*, and temperatures is shown in figure 1.

Figure 1

Variation of dynamic viscosity of ammonia-water solution for various mole fraction and temperatures



The next step is to generate polynomial equations for each curve as shown in figures 2 to 5. The polynomial equations and coefficient of determination, R^2, generated by Microsoft Excel as shown in table 2, provided a high degree of fitting accuracy, as indicated by R^2 values very close to 1. These R^2 values range from 0.999663 to 0.99985, indicating that over 99.96% of the variation in dynamic viscosity can be explained by the variation in the mole fraction of ammonia in the solution for a given temperature. This high degree of fit is consistent with the previous studies on the viscosity of ammonia-water mixtures (Kumar & Gardas, 2010).

The equations generated for each temperature show that a fifth-order polynomial was used to fit the data. The choice of a fifth-order polynomial, as maintained across different temperatures, is guided by the R^2 values as per the analysis. It is observed that the

coefficients of the polynomials change with temperature, which is a logical outcome, considering that temperature is a fundamental factor affecting viscosity.

Figure 2

Equation at T = 273.15K

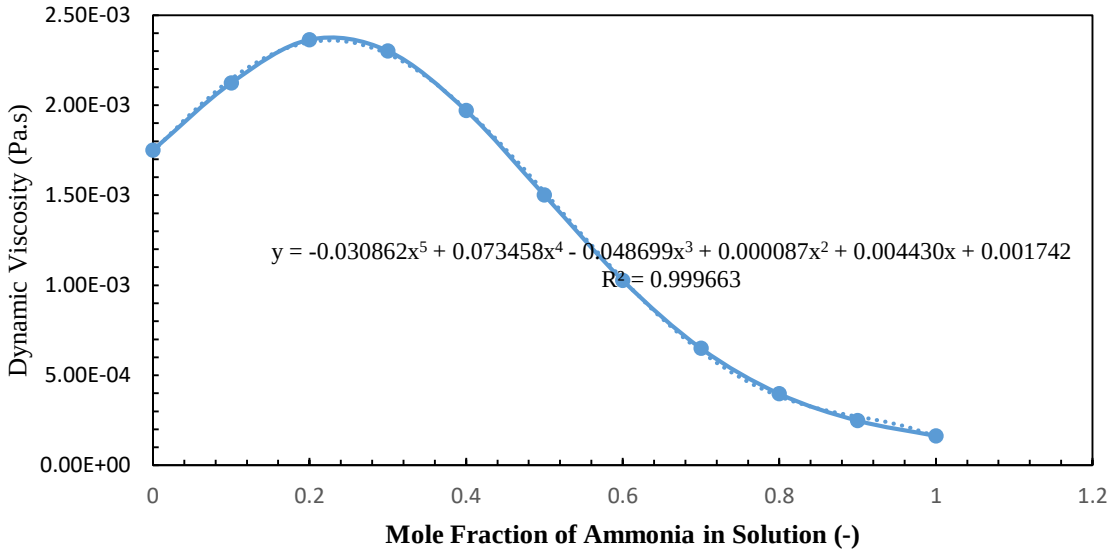


Figure 3

Equation at T = 283.15K

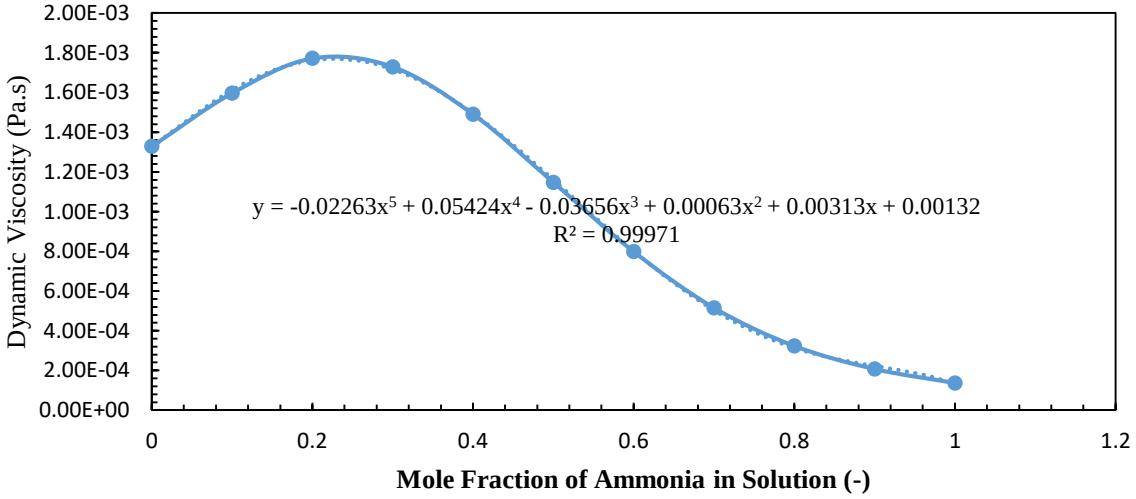


Figure 4

Equation at T = 293.15K

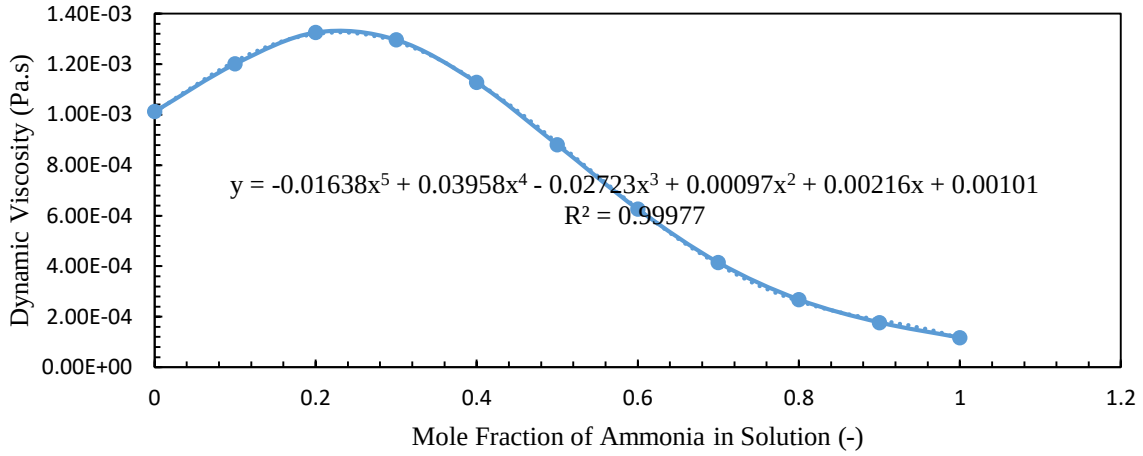


Figure 5

Equation at T = 303.15K

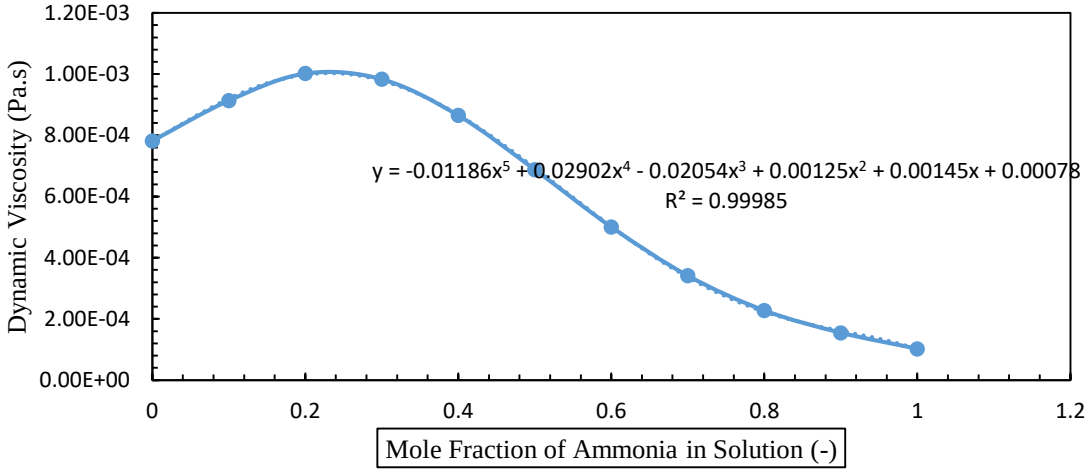


Table 2

Equations and coefficient of determination for dynamic viscosity at each temperature

Mole Fraction of Ammonia in Solution	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
273.15K	1.749E-03	2.122E-03	2.363E-03	2.301E-03	1.970E-03	1.500E-03	1.027E-03	6.492E-04	3.971E-04	2.478E-04	1.631E-04
Generated Equation 1 and R^2 from Microsoft Excel	$\eta = -0.030862x^5 + 0.073458x^4 - 0.048699x^3 + 0.000087x^2 + 0.004430x + 0.001742$ $R^2 = 0.999663$										
283.15K	1.328E-03	1.596E-03	1.771E-03	1.728E-03	1.490E-03	1.147E-03	7.982E-04	5.152E-04	3.233E-04	2.073E-04	1.367E-04
Generated Equation 2 and R^2 from Microsoft Excel	$\eta = -0.02263x^5 + 0.05424x^4 - 0.03656x^3 + 0.00063x^2 + 0.00313x + 0.00132$ $R^2 = 0.99971$										
293.15K	1.012E-03	1.201E-03	1.326E-03	1.297E-03	1.128E-03	8.811E-04	6.258E-04	4.144E-04	2.678E-04	1.769E-04	1.168E-04
Generated Equation 3 and R^2 from Microsoft Excel	$\eta = -0.01638x^5 + 0.03958x^4 - 0.02723x^3 + 0.00097x^2 + 0.00216x + 0.00101$ $R^2 = 0.99977$										
303.15K	7.819E-04	9.134E-04	1.002E-03	9.834E-04	8.651E-04	6.878E-04	5.004E-04	3.411E-04	2.274E-04	1.547E-04	1.023E-04
Generated Equation 4 and R^2 from Microsoft Excel	$\eta = -0.01186x^5 + 0.02902x^4 - 0.02054x^3 + 0.00125x^2 + 0.00145x + 0.00078$ $R^2 = 0.99985$										

The novel concept of proportional nodes was introduced to account for variations in the dynamic viscosity of the ammonia-water solution at different temperatures. To illustrate this method, the mole fraction with the greatest difference in dynamic viscosity was considered, which, for demonstration purposes, was assumed to be at 0.2 moles. This is main argument that a graphical illustration (figure 1) is necessary. Generally, a computer program can be generated to determine the exact mole fraction. Table 3 highlights that the dynamic viscosity decreases consistently as temperature increases, affirming the inverse relationship between temperature and viscosity, commonly observed in fluid dynamics (Holman & Gajda, 2001).

Table 3

Dynamic viscosity values of ammonia-water Solution at 0.2 wt fraction for Various Temperatures

Temperature (K) (y -value)	Dynamic Viscosity (Pa.s) (x-value)
273.15	2.363E-03
283.15	1.771E-03
293.15	1.326E-03
303.15	1.002E-03

The procedure for calculating the proportional nodes for each temperature is shown in table 4.

Table 4

Procedure for calculating the proportional nodes

Temperature (K) (y value)	Dynamic viscosity (Pa.s) (X value)	Values of proportional nodes (x values)	
273.15	2.363E-03 =A	(A-A)/(A-D)	0.0000
283.15	1.771E-03 = B	(A-B)/(A-D)	4.35E-01
293.15	1.326E-03 = C	(A-C)/(A-D)	7.62E-01
303.15	1.002E-03 = D	(A-D)/A-D)	1.0000

The equation of the proportional nodes is gotten by applying Microsoft Excel. The details are extracted from Table 4 and is shown in Table 5.

Table 5

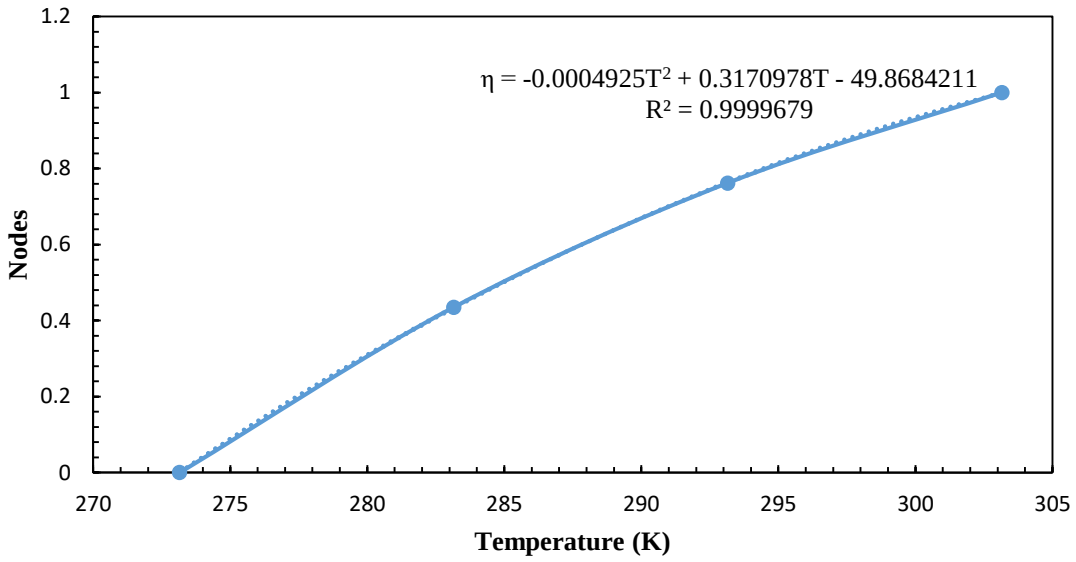
Proportional nodes data

Temperature (K)	Nodes
273.1500	0.0000
283.1500	4.35E-01
293.1500	7.62E-01
303.1500	1.0000

The Microsoft Excel plot of table 5 is shown in figure 6.

Figure 6

Plot of Nodes data



$$Nodes = -0.0004925\,T^2 + 0.3170978\,T - 49.8684211 \quad (1)$$

$$R^2 = 0.9999679$$

The proportional nodes were computed using a methodical procedure, as outlined in table 4. These nodes were then utilized to generate a second-degree polynomial as seen in equation (1), with an impressive R^2 value of 0.9999679. This polynomial represents how the viscosity changes as the temperature changes for a specific mole fraction, essentially acting as a scaling factor. The equations of each line is shown in table 2 including the proportional nodes equation. It must be stressed that for this method, the power of the polynomial should be maintained for each temperature. In addition, the Trendline Option (Microsoft Excel) should also be maintained for each process.

Therefore, the dynamic viscosity at any point within the temperature range is given by equation (2).

η (Pa.s)= (Equation of enthalpy at point where nodes =0) - [(Equation of enthalpy at point where nodes =1) – (Equation of enthalpy at point where nodes =0)] x Nodes Equation* (2)

** Please note that the sign is minus and not plus because dynamic viscosity decreases as temperature increases.*

The dynamic viscosity of ammonia-water solution can be represented by:

$$\eta\ (Pa.s) = y = (-0.030862X^5 + 0.073458X^4 - 0.048699X^3 + 0.000087X^2 + 0.00443X + 0.001742)-((-0.030862X^5 + 0.073458X^4 - 0.048699X^3 + 0.000087X^2 + 0.00443X + 0.001742)-(-0.01186X^5 + 0.02902X^4 - 0.02054X^3 + 0.00125X^2 + 0.00145X + 0.00078))x\ Nodes \quad (3)$$

or

$$\eta\ (Pa.s)=(-0.030862X^5 + 0.073458X^4 - 0.048699X^3 + 0.000087X^2 + 0.00443X + 0.001742)-((-0.030862X^5 + 0.073458X^4 - 0.048699X^3 + 0.000087X^2 + 0.00443X + 0.001742)-(-0.01186X^5 + 0.02902X^4 - 0.02054X^3 + 0.00125X^2 + 0.00145X + 0.00078))\ (-0.0004925T^2 + 0.31709775T - 49.868421081) \quad (4)$$

Simplifying the equation,

$-0.030862x^5 + 0.073458x^4 - 0.048699x^3 + 0.000087x^2 + 0.004430x + 0.001742$ - There is a bracket here	
$-0.030862x^5 + 0.073458x^4 - 0.048699x^3 + 0.000087x^2 + 0.004430x + 0.001742$ - $(-0.01186x^5 + 0.02902x^4 - 0.02054x^3 + 0.00125x^2 + 0.00145x + 0.00078)$	$*\ (-0.0004925T^2 + 0.31709775T - 49.868421081$

Subtracting first the coefficients in the bracket,

-0.030862	0.073458	-0.048699	0.000087	0.004430	0.001742
-					
-0.01186	0.02902	-0.02054	0.00125	0.00145	0.00078
=					
-0.01900	**0.04444**	**-0.02816**	**-0.00116**	**0.00298**	**0.00096**

Thus,

$-0.030862x^5 + 0.073458x^4 - 0.048699x^3 + 0.000087x^2 + 0.004430x + 0.001742$ - There is a bracket here	
$-0.01900x^5 + 0.04444x^4 - 0.02816x^3 - 0.00116x^2 + 0.00298x + 0.00096$	$*\ (-0.0004925T^2 + 0.31709775T - 49.868421081)$

Or,

$$\eta\ (Pa.s) = (-0.030862x^5 + 0.073458x^4 - 0.048699x^3 + 0.000087x^2 + 0.004430x + 0.001742) - (-0.01900x^5 + 0.04444x^4 - 0.02816x^3 - 0.00116x^2 + 0.00298x + 0.00096) * (-0.0004925T^2 + 0.31709775T - 49.868421081) \quad (5)$$

To prove that this equation satisfactory represents the data, the Percentage Difference for values from correlation and actual values, $[(\eta_{actual} - \eta_{calculated})/\ \eta_{actual}]*100.0)$, is calculated. From these values, the average percentage difference (Sum of Percentage Difference/Number of Points) is calculated. The values are presented in table 6.

Table 6

Percentage difference for dynamic viscosity values from correlations and actual values

Mole Fraction of ammonia in Solution	**0**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**
273.15K	1.749E-03	2.122E-03	2.363E-03	2.301E-03	1.970E-03	1.500E-03	1.027E-03	6.492E-04	3.971E-04	2.478E-04	1.631E-04
Calculated value from Proportional Nodes Method 273.15	0.001741086	0.002143045	0.002352	0.002283	0.001975	0.001517	0.001032	0.000632	0.000383	0.000027	0.000156
Percentage Difference $[(\eta_{actual} - \eta_{calculated})/\ \eta_{actual}]*100.0$	0.452487	-0.99175	0.634786	0.782269	-0.25381	-1.13333	-0.48685	2.649415	3.550743	-8.95884	4.353158
Generated Equation 1 and R^2 from Excel	$\eta = -0.030862x^5 + 0.073458x^4 - 0.048699x^3 + 0.000087x^2 + 0.004430x + 0.001742$ $R^2 = 0.999663$										
Mole Fraction of Ammonia in Solution	**0**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**
283.15K	1.328E-03	1.596E-03	1.771E-03	1.728E-03	1.490E-03	1.147E-03	7.982E-04	5.152E-04	3.233E-04	2.073E-04	1.367E-04
Calculated value from Proportional Nodes Method 283.15K	0.001326272	0.001615056	0.001766	0.00172	0.001497	0.001162	0.000803	0.000504	0.000314	0.000223	0.000132
Percentage Difference $[(\eta_{actual} - \eta_{calculated})/\ \eta_{actual}]*100.0$	0.130112	-1.19398	0.282326	0.462963	-0.4698	-1.30776	-0.60135	2.173913	2.876585	-7.57356	3.438186
Generated Equation 2 and R^2 from Excel	$\eta = -0.02263x^5 + 0.05424x^4 - 0.03656x^3 + 0.00063x^2 + 0.00313x + 0.00132$ $R^2 = 0.99971$										
Mole Fraction of Ammonia in Solution	**0**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**
293.15K	1.012E-03	1.201E-03	1.326E-03	1.297E-03	1.128E-03	8.811E-04	6.258E-04	4.144E-04	2.678E-04	1.769E-04	1.168E-04
Calculated value from Proportional Nodes Method 293.15K	0.001006214	0.001207676	0.001316	0.001286	0.001128	0.000887	0.000627	0.000406	0.000261	0.000186	0.000113
Percentage Difference $[(\eta_{actual} - \eta_{calculated})/\ \eta_{actual}]*100.0$	0.571739	-0.55587	0.754148	0.848111	0	-0.66962	-0.19175	2.027027	2.539208	-3135.16	3.253425

Generated Equation 3 and R^2 from Excel	$\eta = -0.01638x^5 + 0.03958x^4 - 0.02723x^3 + 0.00097x^2 + 0.00216x + 0.00101$ $R^2 = 0.99977$										
Mole Fraction of Ammonia in Solution	**0**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**
303.15K	7.819E-04	9.134E-04	1.002E-03	9.834E-04	8.651E-04	6.878E-04	5.004E-04	3.411E-04	2.274E-04	1.547E-04	1.023E-04
Calculated value from Proportional Nodes Method 303.15K	0.000780914	0.000920907	0.001	0.000098	0.0000868	0.0000694	0.0000503	0.0000337	0.0000224	0.0000161	0.00001
Percentage Difference $[(\eta_{actual} - \eta_{calculated})/\eta_{actual}]*100.0$	0.126103	-0.82187	0.199601	0.345739	-0.33522	-0.90142	-0.51958	1.201994	1.495163	-4.0724	2.248289
Generated Equation 4 and R^2 from Excel	$\eta = -0.01186x^5 + 0.02902x^4 - 0.02054x^3 + 0.00125x^2 + 0.00145x + 0.00078$ $R^2 = 0.99985$										

The average percentage difference for the surface (Sum of percentage deviation/Number of points) is calculated from values in table 6 and presented in table 7.

Table 7

Values of percentage deviation for various temperatures and mole fractions

	Mole Fraction									
Temp (K)	**0**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**
273.15	0.45249	-0.99175	0.63479	0.78227	-0.25381	-1.13333	-0.48685	2.64942	3.55074	-8.95884	4.35316
283.15	0.13012	-1.19398	0.28233	0.46296	-0.4698	-1.30776	-0.60135	2.17391	2.87659	-7.57356	3.43819
293.15	0.57174	-0.55587	0.75415	0.84811	0	-0.66962	-0.19175	2.02703	2.53921	-5.14415	3.25343
303.15	0.12610	-0.82187	0.19960	0.34574	-0.33522	-0.90142	-0.51958	1.20199	1.49516	-4.0724	2.24829

Average percentage difference for the surface ±0.2614293

The very low average percentage difference for the surface proves that the equation (5) satisfactorily represents the final expression for calculating the dynamic viscosity of the ammonia-water solution at any given temperature and mole fraction for the selected temperature range.

Assuming to increase the temperature bounds (273.15 to 423.15K) and the procedure is repeated, the results are presented.

Table 8

Dynamic viscosity of ammonia-water solution for various temperatures and mole fraction

T (K)	Mole fraction (-)										
	0	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**
273.15	1.749E-03	2.122E-03	2.363E-03	2.301E-03	1.970E-03	1.500E-03	1.027E-03	6.492E-04	3.971E-04	2.478E-04	1.631E-04
283.15	1.328E-03	1.596E-03	1.771E-03	1.728E-03	1.490E-03	1.147E-03	7.982E-04	5.152E-04	3.233E-04	2.073E-04	1.367E-04
293.15	1.012E-03	1.201E-03	1.326E-03	1.297E-03	1.128E-03	8.811E-04	6.258E-04	4.144E-04	2.678E-04	1.769E-04	1.168E-04
303.15	7.819E-04	9.134E-04	1.002E-03	9.834E-04	8.651E-04	6.878E-04	5.004E-04	3.411E-04	2.274E-04	1.547E-04	1.023E-04
333.15	4.317E-04	4.758E-04	5.086E-04	5.062E-04	4.648E-04	3.938E-04	3.096E-04	2.295E-04	1.660E-04	1.210E-04	8.030E-05
343.15	3.950E-04	4.300E-04	4.569E-04	4.562E-04	4.229E-04	3.630E-04	2.896E-04	2.178E-04	1.596E-04	1.174E-04	7.800E-05
363.15	3.194E-04	3.331E-04	3.428E-04	3.379E-04	3.141E-04	2.735E-04	2.226E-04	1.705E-04	1.254E-04	9.009E-05	5.694E-05
383.15	2.681E-04	2.673E-04	2.654E-04	2.577E-04	2.404E-04	2.127E-04	1.771E-04	1.384E-04	1.022E-04	7.155E-05	4.265E-05
403.15	2.267E-04	2.141E-04	2.029E-04	1.928E-04	1.807E-04	1.636E-04	1.403E-04	1.125E-04	8.352E-05	5.656E-05	3.110E-05
423.15	1.940E-04	1.723E-04	1.536E-04	1.417E-04	1.338E-04	1.249E-04	1.114E-04	9.207E-05	6.876E-05	4.475E-05	2.200E-05

Once again, the data is depicted in graphical form as shown in figure 7, and the dynamic viscosity values at 0.2wt fraction are extracted as shown in table 9.

Figure 7

Variation of dynamic viscosity of ammonia-water solution for various mole fraction and temperatures

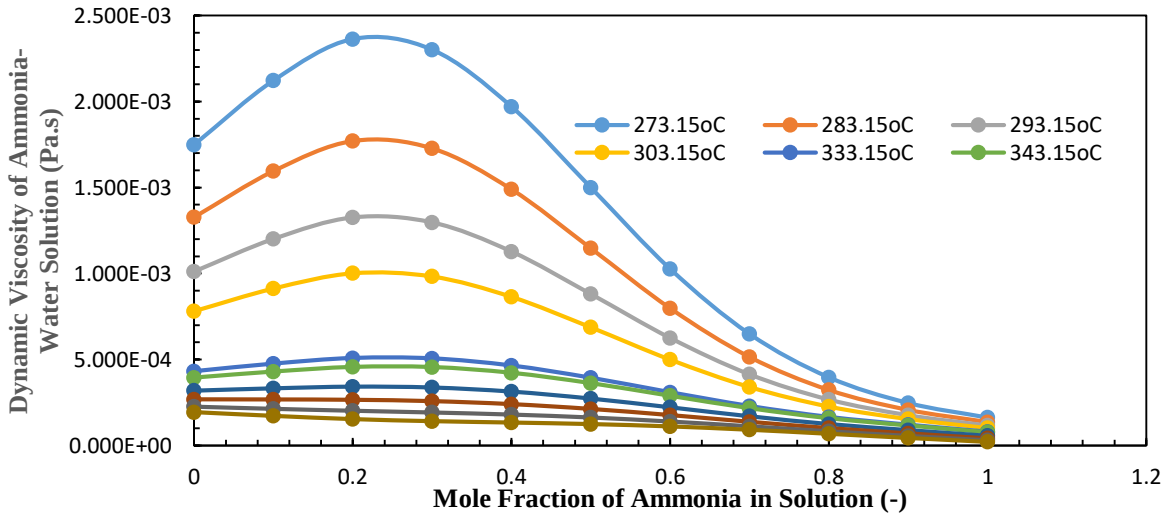


Table 9

Dynamic viscosity values of ammonia-water solution at 0.2 wt fraction for various temperatures

Temperature (K) (y -value)	Dynamic Viscosity (Pa.s) (x-value)
273.15	2.363E-03
283.15	1.771E-03
293.15	1.326E-03
303.15	1.002E-03
333.15	5.086E-04
343.15	4.569E-04
363.15	3.428E-04
383.15	2.654E-04
403.15	2.029E-04
423.15	1.536E-04

The procedure for calculating the new set of proportional nodes for each temperature is shown in table 10.

Table 10

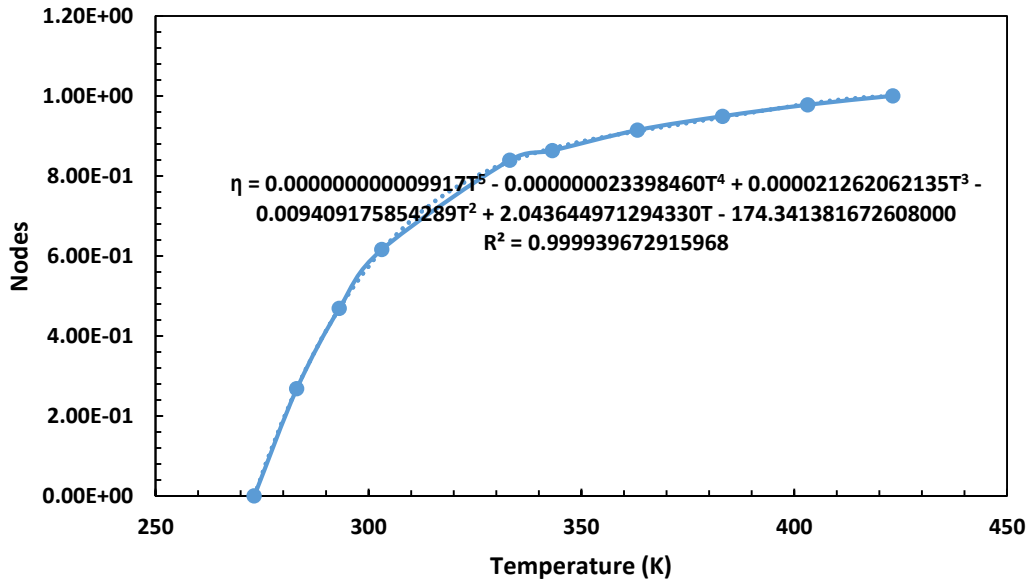
Procedure for calculating the proportional nodes

Temperature (K) (y value)	Dynamic viscosity (Pa.s) (X value)	Values of proportional nodes (x values)	
273.15	2.363E-03 =A	(A-A)/(A-J)	0.00E+00
283.15	1.771E-03 = B	(A-B)/(A-J)	2.68E-01
293.15	1.326E-03 = C	(A-C)/(A-J)	4.69E-01
303.15	1.002E-03 = D	(A-D)/A-J)	6.16E-01
333.15	5.086E-04 = E	(A-E)/(A-J)	8.39E-01
343.15	4.569E-04 =F	(A-F)/(A-J)	8.63E-01
363.15	3.428E-04= G	(A-G)/(A-J)	0.914366
383.15	2.654E-04=H	(A-H)/(A-J)	9.49E-01
403.15	2.029E-04=I	(A-I)/(A-J)	0.977686
423.15	1.536E-04=J	(A-J)/A-J)	1.00E+00

The Microsoft Excel plot of table 10 is shown in figure 8.

Figure 8

Plot of Nodes data



The dynamic viscosity of ammonia-water solution is calculated by following the same procedure earlier explained.

$\eta\ (Pa.s) = (-0.030862X^5 + 0.073458X^4 - 0.048699X^3 + 0.000087X^2 + 0.00443X + 0.001742)-((-0.030862X^5 + 0.073458X^4 - 0.048699X^3 + 0.000087X^2 + 0.00443X + 0.001742)-(\ 0.000737x^5 - 0.001389x^4 + 0.000493x^3 + 0.000246x^2 - 0.000259x + 0.000194))x\ Nodes$ (6)

or

$\eta\ (Pa.s)=(-0.030862X^5 + 0.073458X^4 - 0.048699X^3 + 0.000087X^2 + 0.00443X + 0.001742)-((-0.030862X^5 + 0.073458X^4 - 0.048699X^3 + 0.000087X^2 + 0.00443X + 0.001742)-(\ 0.000737x^5 - 0.001389x^4 + 0.000493x^3 + 0.000246x^2 - 0.000259x + 0.000194))\ (0.000000000009917T^5 - 0.000000023398460T^4 + 0.000021262062135T^3 - 0.009409175854289T^2 + 2.043644971294330T - 174.341381672608000)$ (7)

or

$\eta\ (Pa.s)= (-0.030862x^5 + 0.073458x^4 - 0.048699x^3 + 0.000087x^2 + 0.004430x + 0.001742)-(\ -0.0316x^5 + 0.074847x^4\ -0.04919x^3 -0.00016x^2 +0.004689x + 0.001548)*\ (0.000000000009917T^5 - 0.000000023398460T^4 + 0.000021262062135T^3 - 0.009409175854289T^2 + 2.043644971294330T - 174.341381672608000)$

(8) To authenticate the accuracy of the correlation, average percentage deviation is calculated as shown in table 11.

Table 11

Values of percentage deviation for various temperatures and mole fractions

T (K)		Mole fraction (-)										
		0	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**
2.73E+02	Actual	1.75E-03	2.12E-03	2.36E-03	2.30E-03	1.97E-03	1.50E-03	1.03E-03	6.49E-04	3.97E-04	2.48E-04	1.63E-04
	Calculated	1.74E-03	2.15E-03	2.35E-03	2.29E-03	1.98E-03	1.52E-03	1.03E-03	6.33E-04	3.84E-04	2.70E-04	1.56E-04
	% Deviation	-2.57E-01	1.20E+00	-4.19E-01	-5.91E-01	4.42E-01	1.35E+00	7.01E-01	-2.49E+00	-3.34E+00	9.10E+00	-4.22E+00
2.83E+02	Actual	1.33E-03	1.60E-03	1.77E-03	1.73E-03	1.49E-03	1.15E-03	7.98E-04	5.15E-04	3.23E-04	2.07E-04	1.37E-04
	Calculated	1.33E-03	1.61E-03	1.76E-03	1.71E-03	1.48E-03	1.14E-03	7.85E-04	4.87E-04	2.99E-04	2.09E-04	1.20E-04
	% Deviation	-1.73E-01	1.10E+00	-6.66E-01	-1.15E+00	-6.51E-01	-3.31E-01	-1.68E+00	-5.46E+00	-7.56E+00	8.44E-01	-1.22E+01
2.93E+02	Actual	1.01E-03	1.20E-03	1.33E-03	1.30E-03	1.13E-03	8.81E-04	6.26E-04	4.14E-04	2.68E-04	1.77E-04	1.17E-04
	Calculated	1.02E-03	1.22E-03	1.32E-03	1.28E-03	1.11E-03	8.65E-04	6.01E-04	3.79E-04	2.36E-04	1.64E-04	9.32E-05
	% Deviation	4.35E-01	1.52E+00	-4.22E-01	-1.30E+00	-1.41E+00	-1.88E+00	-4.02E+00	-8.47E+00	-1.18E+01	-7.42E+00	-2.02E+01
3.03E+02	Actual	7.82E-04	9.13E-04	1.00E-03	9.83E-04	8.65E-04	6.88E-04	5.00E-04	3.41E-04	2.27E-04	1.55E-04	1.02E-04
	Calculated	7.93E-04	9.35E-04	1.00E-03	9.71E-04	8.46E-04	6.63E-04	4.68E-04	3.01E-04	1.91E-04	1.31E-04	7.39E-05
	% Deviation	1.42E+00	2.31E+00	1.60E-01	-1.26E+00	-2.18E+00	-3.55E+00	-6.55E+00	-1.16E+01	-1.61E+01	-1.53E+01	-2.78E+01
3.33E+02	Actual	4.32E-04	4.76E-04	5.09E-04	5.06E-04	4.65E-04	3.94E-04	3.10E-04	2.30E-04	1.66E-04	1.21E-04	8.03E-05
	Calculated	4.52E-04	4.99E-04	5.20E-04	4.99E-04	4.40E-04	3.56E-04	2.64E-04	1.83E-04	1.21E-04	8.11E-05	4.43E-05
	% Deviation	4.64E+00	4.97E+00	2.15E+00	-1.44E+00	-5.32E+00	-9.60E+00	-1.46E+01	-2.05E+01	-2.68E+01	-3.30E+01	-4.48E+01
3.43E+02	Actual	3.95E-04	4.30E-04	4.57E-04	4.56E-04	4.23E-04	3.63E-04	2.90E-04	2.18E-04	1.60E-04	1.17E-04	7.80E-05
	Calculated	4.00E-04	4.34E-04	4.46E-04	4.28E-04	3.79E-04	3.10E-04	2.34E-04	1.65E-04	1.11E-04	7.36E-05	3.99E-05
	% Deviation	1.32E+00	8.79E-01	-2.28E+00	-6.27E+00	-1.04E+01	-1.47E+01	-1.93E+01	-2.45E+01	-3.04E+01	-3.73E+01	-4.89E+01
3.63E+02	Actual	3.19E-04	3.33E-04	3.43E-04	3.38E-04	3.14E-04	2.74E-04	2.23E-04	1.71E-04	1.25E-04	9.01E-05	5.69E-05
	Calculated	3.33E-04	3.48E-04	3.51E-04	3.35E-04	2.99E-04	2.49E-04	1.94E-04	1.41E-04	9.74E-05	6.37E-05	3.40E-05
	% Deviation	4.30E+00	4.56E+00	2.49E+00	-9.14E-01	-4.83E+00	-8.89E+00	-1.29E+01	-1.72E+01	-2.23E+01	-2.93E+01	-4.02E+01
3.83E+02	Actual	2.68E-04	2.67E-04	2.65E-04	2.58E-04	2.40E-04	2.13E-04	1.77E-04	1.38E-04	1.02E-04	7.16E-05	4.27E-05
	Calculated	2.81E-04	2.82E-04	2.78E-04	2.63E-04	2.37E-04	2.03E-04	1.63E-04	1.23E-04	8.69E-05	5.62E-05	2.96E-05
	% Deviation	4.98E+00	5.65E+00	4.76E+00	2.17E+00	-1.24E+00	-4.73E+00	-7.96E+00	-1.10E+01	-1.50E+01	-2.15E+01	-3.07E+01
4.03E+02	Actual	2.27E-04	2.14E-04	2.03E-04	1.93E-04	1.81E-04	1.64E-04	1.40E-04	1.13E-04	8.35E-05	5.66E-05	3.11E-05
	Calculated	2.34E-04	2.21E-04	2.10E-04	1.97E-04	1.80E-04	1.60E-04	1.35E-04	1.06E-04	7.72E-05	4.92E-05	2.54E-05
	% Deviation	3.02E+00	3.38E+00	3.56E+00	2.20E+00	-1.60E-01	-2.51E+00	-4.13E+00	-5.37E+00	-7.58E+00	-1.31E+01	-1.83E+01
4.23E+02	Actual	1.94E-04	1.72E-04	1.54E-04	1.42E-04	1.34E-04	1.25E-04	1.11E-04	9.21E-05	6.88E-05	4.48E-05	2.20E-05
	Calculated	2.04E-04	1.84E-04	1.68E-04	1.56E-04	1.45E-04	1.33E-04	1.17E-04	9.62E-05	7.12E-05	4.48E-05	2.29E-05
	% Deviation	5.16E+00	6.62E+00	9.53E+00	1.02E+01	8.57E+00	6.41E+00	4.96E+00	4.46E+00	3.55E+00	1.90E-01	3.95E+00

Average percentage deviation for the surface= ±08.65%

It can be seen that increasing the temperature range increases the average percentage deviation (±0.2614293 for 273.15K to 303.15K and ±08.65% for 273.15K to 423.15K). To achieve lower average percentage differences, the temperature range is divided into two, 273.15K to 303.15K and 303.15K to 423.15K. The correlation for dynamic viscosity for temperature range 273.15K to 303.15K is represented by equation (5). Following the same procedure outlined, the correlation for dynamic viscosity for temperature range, 303.15K to 423.15K, is represented by equation (9).

$$\eta = (-0.01186x^5 + 0.02902x^4 - 0.02054x^3 + 0.00125x^2 + 0.00145x + 0.00078) - ((-0.012597x^5 + 0.030409x^4 - 0.021033x^3 + 0.001004x^2 + 0.001709x + 0.000586)(-1.341883066421660E-11T^6 + 2.978411452541260E-08T^5 - 2.748924904648520E-05T^4 + 1.350381914949820E-02T^3 - 3.723844022456550E+00T^2 + 5.465803771537870E+02T - 3.336163181385320E+04)) \quad (9)$$

$$\text{Average percentage Deviation} = \pm 1.11 \quad (9)$$

5. Discussion

Equations (5) and (9) satisfactorily represent the correlations for calculating the dynamic viscosity of the ammonia-water solution at any given temperature and mole fraction for the selected temperature ranges. They incorporate the polynomial equations at the boundary temperatures (273.15K, 303.15K and 423.15K), as well as the proportional nodes equations. The resulting correlations are less complex and offer robust and highly accurate models for predicting the dynamic viscosity of an ammonia-water solution under varying conditions.

The R^2 values associated with each generated equation (as shown in table 6) are consistently very close to 1, ranging from 0.999663 to 0.99985. Also, the average percentage deviation (±0.2614293 for temperature range, 273.15K to 303.15K and $\pm$ 1.11 for temperature range, 303.15K to 423.15K) is indicative of the effectiveness of the model in predicting the dynamic viscosity of ammonia-water solution. The average percentage differences between the actual and calculated dynamic viscosity values for various mole fractions and temperatures are tabulated in table 7. These percentage differences are generally very low, affirming the strong correspondence between the model's predictions and the actual measured data. Notably, the deviations are not systematic and fluctuate around zero, indicating no apparent bias in the model's predictions. These R^2 values and low average

percentage deviation further substantiate the validity and reliability of the derived model, reflecting its strong alignment with actual observations (Motulsky & Ransnas, 1987). The inverse relationship between temperature and viscosity, as indicated in the results, is consistent with existing literature on fluid dynamics (Bergman et al., 2011). For example, it has been previously established that an increase in temperature generally corresponds to a decrease in viscosity due to the increased kinetic energy of the molecules, resulting in a reduced internal resistance to flow (Incropera & DeWitt, 2002).

6. Conclusion

This study provides a comprehensive and highly accurate model for predicting the dynamic viscosity of an ammonia-water solution under varying temperatures and mole fractions. The innovative concept of proportional nodes introduced in this study allows for temperature-adaptive predictions, a significant advantage over standard polynomial fitting techniques. The very low average percentage differences between actual and calculated values (±0.2614293 for temperature range, 273.15K to 303.15K and ±1.11 for temperature range, 303.15K to 423.15K), demonstrate the model's exceptional predictive capability and reliability. Overall, this study makes a noteworthy contribution to the understanding and calculation of the correlations for dynamic viscosity of ammonia-water mixtures, promising implications for various applications where such data arrangement for mixtures exist.

Future works on this subject are encourage to explore properties such as the density of aqueous organic and inorganic solutions, the specific heat of aqueous solutions, and other thermodynamic and engineering properties of working fluids.

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Influence of Thinking Style on the Critical Thinking Skills and Creativity in Mathematics

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Abstract

Two of the key talents that students need to possess in the twenty-first century are the ability to think critically and creatively, both of which can be nurtured through mathematics training. Teachers should take into account the various ways that each student thinks when using pedagogical strategies to help students develop their critical and creative thinking abilities in mathematics. Thus, the main goal of the study was to determine whether there were any significant differences in the critical thinking and creativity abilities in mathematics among the various thinking styles of Grade 10 students in a national high school in the Philippines. In order to compare the differences between the critical thinking skills and creativity of sixty respondents in mathematics depending on their thinking styles—inchworm and grasshopper—a comparative descriptive research design was used in the study. The results showed a significant difference in the critical thinking skills in mathematics as to interpreting information component only of critical thinking skills. Furthermore, thinking style is not a determinant in students' mathematical creativity due to non-existence of significant difference. The study recommends that teachers consider students' thinking styles when developing instructional materials and strategizing their instruction because this helps students interpret information and decide whether the evidence and conclusions obtained from mathematical problems can be generalized. To confirm the study's conclusions, a similar study with a high number of respondents for each thinking style is recommended.

Keywords: *thinking style, grasshopper, inchworm, critical thinking skills, mathematical creativity*

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1. Introduction

Current and prospective learners will be needed to meet a new set of requirements that are considered as quality indicators and key factors for future success as society goes further into the twenty-first century and focuses on becoming more globalized. According to the National Education Association (2014), these are the "Four Cs" of 21st-century abilities which stand for critical thinking, collaboration, communication, and creativity. Critical thinking and creativity are two of these skills that may be cultivated through problem-solving (Starko, 2017; Kholid et al., 2020), and students learn how to solve problems in mathematics (DepEd, 2016). Mathematical problem solving stimulates pupils' mental processes. Each student has a unique approach to acquiring their lessons, absorbing their teacher's knowledge, and then implementing what they have learned. This is related to cognitive thinking style since it relates to how pupils acquire and process information (Susandi & Widyawati, 2017).

Mathematical problem solving is inseparable from the capacity for critical thinking. whereas cognitive (thinking) style can influence critical thinking (Kholid et al., 2020). Each individual has a distinct personality, and this distinction motivates students to consider in a variety of ways when providing an idea or solution to a particular response. Mathematical problem-solving is the response in question (Susandi & Widyati, 2017). There are two styles of mathematical thinking labeled as "*inchworm*" thinking style and "*grasshopper*" thinking style. An inchworm-style of problem solving involves formulas and memorized step-by-step methods, but grasshopper-style takes a global approach by looking at the broader picture to arrive at the answer (Chinn, 2013). A learner's processing of information and mental reflection on concepts is characterized by their thinking styles. Hence, each thinking style plays an imperative role as this serves a students' preference in processing information (Soleh, 2017). It just implies that intervention should be considered depending on their thinking style, and intervention should be actively aware of how the learner thinks (Chinn, 2016).

Some of the factors that contribute to students' poor critical thinking abilities include a lack of pedagogy in critical thinking in the classroom (Rahayu, 2020), and the absence of learning innovations that aids students to think systematically (Rivers & Kinchin, 2019). As a result, the Philippines was ranked 57th out of 63 economies in the World Talent Ranking measured by the International Institute for Management Development (IMD) World

Competitiveness Center in 2021 and 54th in 2022, which the institute believes was due to poorer performance by other economies (IMD World Competitiveness Center, 2021; IMD World Competitiveness Center, 2021). In 2021 and 2022, it was placed 13th out of 14 Asia Pacific economies, with Singapore, Australia, and Hong Kong occupying the top three spots. Due to a serious lack of critical thinking skills among students, the Philippines has to improve its educational system to make its future workers more competitive on the global market (Ibanez, 2020).

As stated by Firdaus et al. (2015), it is mandatory for the teachers to gauge and foster students' critical thinking skills during classroom discussion. The development of students' capacities for critical thinking needs to be a central focus of education. However, students have not been able to effectively cultivate this gift. Currently, math educators play crucial responsibilities for this matter (Fong et al., 2017).

Creativity is also given emphasis as one of the top skills stated by World Economic Forum as this is essential for success in the workplace and highly sought after by employers (Whiting, 2020). Robinson (2015) perceives that only through creative experiences will our children be able to prepare for the ever-changing environment they must face. Learning activities that promote creativity position students in the roles of problem solvers and communicators rather than passive information acquirers (Starko, 2017). According to Walia and Walia (2017), the deductive approach of teaching is widely employed in most schools and does not allow students to think in a divergent manner. Students must solve problems using the formula as suggested by the teacher. When asked to uncover creativity in mathematics among pupils, mathematics teachers have no idea since they believe that just one answer exists for a specific question in mathematics. It is necessary to provide some issues and scenarios for pupils in order to stimulate their creativity (Walia & Walia, 2017). Since creative thinking is one of the 21st-century skills that gives motivation, drive, and strength in the face of the industrial revolution (Yuliati et al., 2018), schools need to prioritize it in order to solve the low level of creative thinking abilities among students (Ulfa, 2018).

The difficulties to think critically can make it difficult to think mathematically and creatively. Learning math requires the growth of creative thinking abilities. Hence, mathematics teacher must convey the need for applying creativity to mathematical activities before the development of mathematical creativity at school (Grégoire, 2016). According to

researchers, students' critical and creative thinking both grow as they learn (Chang et al., 2015). Thus, creative and critical thinking work best together in the establishment of quality innovations and the sustainability of education. These skills must be critically developed during the instructional design process in order to achieve global competitiveness (Birgili, 2015).

Meanwhile, multiple researches linked thinking style to critical thinking skills (Birgili, 2015; Kim & Song, 2013; Rifqiyana & Susilo, 2016; Siburian & Saptasari, 2019; Firdaus et al., 2015), as well as creativity (Purnomo et al., 2021; Tam et al., 2022; Wijaya, et al., 2016). Abdi (2012) asserts that there is a strong correlation between critical thinking and thinking style. There is evidence that certain thinking styles have a significant impact on critical thinking skills. However, the thinking style assessment used is not meant for mathematics education. Additionally, mathematical creativity is not taken into account in the previous investigations. On the other hand, Purnomo et al. (2021) concluded that a person's capacity for creative and critical thinking is not only impacted by their thinking style and that academic success in mathematics does not always indicate a person's capacity for these traits. On the other hand, Singer et al. (2017) confirmed that a specific thinking style is a good predictor of mathematical creativity while Piaw (2014) asserted that thinking style, along with gender, were important predictors of creative thinking abilities. Individuals with different cognitive styles used various strategies in creative mathematical tasks (Pitta-Pantazi et al., 2013).

These contradictory results from earlier studies imply the need for further studies. Hence, this study argues the need to find any significant difference on critical thinking and creativity in mathematics when students are classified according to their thinking styles. This research also looked into the following hypotheses:

Ho1: There is no significant difference that exists in the level of critical thinking skills of the students when they are grouped according to their thinking styles.

Ho2: There is no significant difference that exists in the level of mathematical creativity of the students when they are grouped according to their thinking styles.

2. Literature Review

2.1. Thinking styles and mathematical thinking styles

According to Chinn and Ashcroft (2016), a person's "cognitive style" (or thinking style) in mathematics refers to how they approach an issue. The majority of the time, teachers

may detect a student's thinking style by simply observing him as he works. The use of creative learning materials, art of questioning and flexible instruction can be employed to sustain students' interest in mathematics based on their thinking style. Furthermore, the use of thinking style can help students analyze word problems and strengthen links and interconnections between numerical facts and operations. Variation in the teaching strategies and approaches is beneficial for the students who demonstrate gaps in learning and the intervention must be actively cognizant of how the learner thinks (Chinn, 2016).

When a problem is presented by the teacher, a learner with an inchworm thinking style will demonstrate sequential thinking by developing one solution. On the other hand, a learner with a grasshopper thinking style exhibits holistic thinking, in which the learner concentrates on a deeper degree of understanding on a specific lesson and assimilates new concepts into past knowledge to further accomplish conceptual learning (Chinn, 2013). Students with an inchworm thinking style have an advantage in school because evaluation processes place a higher value on analytic thinking (Huincahue et al., 2021; Chinn, 2016). Thus, success is more favorable to inchworm than grasshopper because the former thinking style matches the demand of environment (Kovalcikiene et al., 2013). One reason for this is that successful sequential thinkers in mathematics have more working memory capacity than grasshoppers, especially for formulas and methods to be employed in specific items (Chinn, 2013). According to Batool and Saeed (2019), working memory capacity has a substantial link with student's mathematical performance, implying that higher working memory capacity leads to greater academic achievement in mathematics. Furthermore, working memory is a crucial predictor of academic learning and accomplishment (Friso-van den Bos & Van de Weijer-Bergsma, 2020). Meta-cognition, sometimes known as "knowing about how you know," is the process of comprehending and being aware of how you think. It is closely related to thinking style. By establishing learning objectives and monitoring students' advancement toward achieving them, a "metacognitive" approach to instruction will result to independent learning. In this sense, cognitive flexibility of learners should be given sufficient attention in creating instructional materials and implementing teaching pedagogies (Chinn, 2013, 2016).

The two teaching methods, behavioristic and constructivist, represent the ever-swinging pendulum of teaching ideas. These two cognitive styles appear to correspond to the inchworm and grasshopper cognitive styles. The behavioristic focuses on skill development,

develops a single algorithm, memorizes and follows a specific method, masters skills prior to application. Further, it is more advantageous in individualized drill and rehearsal activities for mastery. On the other hand, the constructivist focuses on a deeper level of comprehension, concentrates on the variety of resources and activities, interacts with materials for an increased conceptual learning, and assimilates new concepts into prior knowledge. The inchworm learner will benefit from the behaviorist learning style, whereas the grasshopper learner will benefit from the constructivist learning style. In the ideal scenario, appropriate and balanced applications of both thinking and teaching approaches would be made (Chinn, 2013).

According to Kovalcikiene et al. (2013), students perform better when the thinking patterns are compatible with the demands of the educational environment than the counterparts. According to Zakariya (2022), self-efficacy is one of the personality factors that affects how well students perform mathematically. Self-efficacy can be defined as a person's belief in their own ability to carry out a task or achieve a goal that they have set for themselves. It is the belief that a person has in their ability to manage their conduct, exercise control over their environment, and keep their motivation up during the process of working toward reaching a goal (Cherry, 2023). According to Komarraju and Nadler (2013), students who are capable of successfully regulate their feelings and remain resilient in the face of challenges are more likely to achieve academic achievement.

It is important to note that mathematics education prefers students to learn mathematics rather than how well they are at learning mathematics. In this connection, assessing the mathematical thinking styles of student is significant due to the negative impact it brings on students' self-efficacy particularly if the thinking styles do not match the style required by the educational environment (Honicke & Broadbent, 2016). Students' dread of inadvertently recalling inaccurate responses in a classroom context may set off a chain reaction of quick scorn from their classmates, discouraging many of them from engaging in future classroom discussions (Bowie, 2018).

2.2. Critical thinking skills

The skills essential to see beyond various things or concepts to find the common value that connects them are used by students who are trained to think critically (Yousefi & Mohammadi, 2016). The educational programs incorporate the critical thinking, creative thinking, and problem-solving skills that are necessary in today's environments (Gini-

Newman & Case, 2018; Gray, 2016). According to Muhlisin et al. (2016), lack of critical thinking skills is related to a traditional teaching method. Students are limited to using a single answer, which limits their ability to explore ideas and other solutions, resulting in poor critical thinking skills (Haber, 2020). Students' critical thinking will suffer in an uncritical learning environment. In order to develop thinking students rather than regurgitators of knowledge with a narrow perspective, class activities should promote students' cognitive ability and higher order thinking skills (Fadhlullah & Ahmad, 2017).

For students to succeed in the future, critical thinking skills are necessary (Firdaus et al., 2015). As the educational system aims to produce future leader who can think critically, these skills should be given emphasis in the entirety of the teaching and learning process. Exposure to several mathematics activities that challenge students may help to refine their critical thinking abilities. Lack of critical thinking skills hindered students' analytical abilities to make conclusions, adjust to higher-level thinking, and identify truths and facts (Taleb & Chadwick, 2016). Consequently, only a few pupils are able to interpret information and synthesize evidence from issues. Due to differences in perspectives, incomplete data leads to an incorrect conclusion (Chasanah, 2019).

2.3. Mathematical creativity and creative thinking

Mathematical creativity is undeniably an essential element in today’s generation (Barraza-Garcia et al., 2020; Isnani et al., 2020; Pitta-Pantazi et al., 2013). Students today frequently memorize shortcuts for solving mathematical puzzles without comprehending the underlying concepts (Tubb et al., 2020; Roslan et al., 2021). Every student may be creative when given the right conditions, and teachers expect them to solve arithmetic problems more effectively and creatively (Kozlowski et al., 2019). Enhancing mathematical creativity paves the path for the inspiration, encouragement, and motivation of all students.

According to math educators, fostering innovative thinking in children through a creative learning technique can increase their creativity for mathematics (Hamid & Kamarudin, 2021). In order to solve mathematical issues or generate new ideas, creative thinking is required (Hadar & Tirosh, 2019). This process comprises identifying and changing something's most recent regular traits (Perry & Karpova, 2017). As mentioned by Alismail and McGuire (2015), using creative thinking can also enable students to draw fresh and meaningful conclusions from their activities and experiences. Furthermore, creative thinking as a cognitive talent is critical for pupils to understand the outcomes of a novel

concept or solution (Sitorus, 2016). Students should be able to think creatively in math, which is typically based on an underlying process or something that has been produced. As a result, examinations to assess mathematical creative thinking abilities should be included in educational courses.

3. Methodology

3.1. Research design

The descriptive-comparative research design was used in this study. According to Cantrel (2011), the purpose of this study is to describe the differences between groups in a population without manipulating the independent variable. Therefore, in this study, the existence of significant differences in critical thinking and creativity in mathematics was examined when they were grouped based on their thinking styles.

3.2. Respondents of the study

The population of the study were Grade 10 students from 5 heterogeneously grouped sections. They were composed of 112 male students and 89 female students and the researcher classified the respondents through determining their thinking style through the cognitive (thinking) style test by Bath et al. (1896). They were classified as respondents with inchworm thinking style or grasshopper thinking style.

3.3. Sampling technique

The respondents for this study were chosen using the purposive sampling technique. This sort of non-probability sampling technique, according to Nikolopoulou (2022), picks respondents based on the attributes required in the sample. The researcher classified the population in this study based on their style of thinking as defined by Chinn (2013). The respondents of this study were those students who had the most dominant signs of inchworm and grasshopper thinking styles, thirty (30) students for each thinking style, among the population.

3.4. Research Instrument

The study adopted the cognitive (thinking) style test by Bath et al. (1986) to determine the thinking styles of the respondents from the population. Afterwards, the respondents answered a researcher-made mathematical creativity test. Subsequently, the respondents answered another researcher-made critical thinking test to measure their critical thinking skills. The acceptability of the mathematical creativity test was determined using a 4-point Likert scale to measure the appropriateness of the word problems in measuring

mathematical creativity in terms of fluency, flexibility, and originality. Five word problems were chosen with 'highly appropriate' rating in terms of content validity from the ratings, comments, and suggestions of the validators. Moreover, the acceptability of the critical thinking test was determined with a 4-point Likert scale to measure the appropriateness of the word problems in measuring critical thinking skills of the respondents in terms of inferences, recognition of assumptions, deductions, interpreting information, and evaluation of arguments. All of the word problems were given a 'highly appropriate' rating in terms of content validity.

3.5. Research procedure

The researcher prepared the necessary letters for the conduct the study and explained the purpose of the study to the administrators as well as the respondents. Ethical considerations were observed to ensure confidentiality and anonymity of respondents. After approval, the researcher identified the population with inchworm thinking style and grasshopper thinking style by answering the cognitive (thinking) style test. This test was divided into four days with three items per day in order to prevent the respondents from feeling anxious while answering the test. As part of the purposive samples, the top thirty respondents who had dominant percentage of inchworm thinking style as well as the grasshopper thinking style were qualified to answer the mathematical creativity test. In this phase, one-word problem per day was given to prevent anxiety from the respondents while answering the test. Afterwards, the respondents answered the critical thinking test to measure their critical thinking skills with one component of critical thinking test per session.

After implementation, the researcher compiled all the responses and gathered all the needed data. The data gathered from the test of cognitive style in mathematics was scored based on Chinn's (2016) rubric for scoring the test. Mathematical creativity was scored using the scoring rubric adapted from Andrade and Pasia (2020). The data gathered from the critical thinking test was scored based on correct responses through the researcher-made scoring rubric. After checking, the scores of the respondents were summarized and independent t-test was used as statistical treatment for the scores. To guarantee the normality of the distribution, the study used Shapiro Wilk Test which has a p-value of 0.583. The goal of Shapiro Wilk Test is to compare two distributions to determine if they are pulling from the same underlying distribution. With this, the parametric tests used were deemed suitable for the conduct of this research.

4. Findings and Discussions

Table 1

Test of difference in the critical thinking level

Critical Thinking	Inchworm		Grasshopper		T	Df	Sig. (2-tailed)
	Mean	SD	Mean	SD			
Inferences	3.67	0.81	3.67	0.98	.029	58	.977
Assumptions	3.45	0.82	3.13	0.73	1.594	58	.116
Deductions	3.40	0.84	3.30	0.99	.421	58	.675
Interpreting Information	2.30	0.49	2.03	0.47	2.189	58	.033
Arguments	2.53	1.14	2.60	0.97	-.244	58	.808

Table 1 compares the critical thinking levels of inchworm and grasshopper respondents. The table shows that both thinking styles have the same mean score for inferences (3.67), but the inchworms have a higher mean for critical thinking in terms of recognition of assumptions (3.45 for inchworms, 3.13 for grasshoppers), deductions (3.40 for inchworms, 3.30 for grasshoppers), and interpreting information (2.30 for inchworms, 2.03 for grasshoppers). In comparison to the inchworms, the grasshoppers had a better advantage in terms of evaluating arguments (2.53 mean for inchworms, 2.60 mean for grasshoppers) since they had a higher mean.

The inferences questions are made up of shapes and figures, and respondents must look for a specific pattern in order to draw a conclusion from the presupposed information on the specific shapes and figures. The inchworms had an advantage because of their adept focus on details and parts of the specific shapes and figures. On the other hand, the grasshoppers found it easier because they were able to understand the relationships of the figures to their corresponding numerical values because of their ability to 'trial and adjust' when deciphering the numerical values of the particular items to solve for the correct answer. Students with strong problem-solving skills tend to think more critically, which helps them achieve their goals in practically all areas of life (Bhat, 2016). This further substantiates Chukwuyenum's (2013) assertion that in order to arrive at a trustworthy and accurate conclusion, critical thinking requires the effort of information gathering, interpretation, analysis, and evaluation. Mathematical problem solving and critical thinking are intricately related.

The table also shows that there is no significant difference between the inchworm and grasshopper thinking styles and inferences, recognition of assumptions, deductions, and

argument evaluation. This suggests that the thinking style does not help the inchworm and grasshopper respondents' critical thinking skills in areas of making inferences, recognition of assumptions, deductions, and evaluation of arguments. According to Purnomo et al. (2021), if there is no substantial difference, someone's critical thinking capacity is influenced by factors other than cognitive style. Furthermore, good mathematics academic aptitude is not always an indication of high critical thinking ability (Purnomo et al., 2021), which suggests that students' thinking styles cannot be a key component in determining their critical thinking skills.

However, there is a significant difference in thinking styles and interpreting information between the inchworm and grasshopper, with a p-value of 0.033. It also revealed that the inchworms have a higher mean (2.30 mean) than the grasshoppers (2.03 mean). This suggests that there is a significant difference in the grasshopper and inchworm thinking styles and critical thinking when it comes to interpreting information. This also implies that thinking styles play an important role in determining whether the evidence and conclusions derived from word problems can be generalized and in examining how something will be done to reach a result. Cosku (2018) defines a learner's thinking style as their processing of knowledge and mental reflection on concepts. As a result, each thinking style is important since it serves a student's preference in processing information (Soleh, 2017), and cognitive (thinking) style can influence critical thinking (Kholid et al., 2020). This validates the most current study by Abdi (2012) that thinking style influences critical thinking; however, this study was released more than ten years ago, and no other studies have been published in recent years.

Consequently, despite the absence of significant differences between thinking styles and critical thinking skills, it is imperative for educators and prospective educators to undertake the responsibility of cultivating and evaluating the critical thinking aptitude of pupils during the course of instruction and acquisition. Firdaus et al. (2015) posit that the acquisition of critical thinking skills is imperative for students to achieve success in their future endeavors. The integration and cultivation of critical thinking abilities throughout the fundamental curriculum, pedagogy, and educational practices are imperative for the production of proficient and visionary students who can become future leaders. Hence, it is imperative to cultivate the critical thinking abilities of students across all academic disciplines, with a particular emphasis on mathematics. According to Aybek and Yolcu

(2018), the classroom is a crucial environment for promoting and instructing critical thinking in a systematic and structured manner, thereby fostering a lifelong skill.

Table 2

Test of difference in the mathematical creativity level

Mathematical Creativity	Inchworm		Grasshopper		T	Df	Sig. (2-tailed)
	Mean	SD	Mean	SD			
Fluency	4.08	0.67	3.79	0.89	1.441	58	.155
Flexibility	2.84	0.36	2.59	0.65	1.867	58	.067
Originality	2.98	0.82	3.13	1.20	-.553	58	.582

Table 2 shows the difference in mathematical creativity levels between inchworm and grasshopper respondents. The inchworms (4.08 for fluency; 2.84 for flexibility) have a higher mean of mathematical creativity in terms of fluency and flexibility than the grasshoppers (3.79 for fluency; 2.59 for flexibility), but the grasshoppers (3.13 for originality) have a higher mean of mathematical creativity than the inchworms (2.98 for originality). This suggests that inchworms have a better level of mathematical creativity than grasshoppers. In terms of fluency and flexibility, inchworms are more mathematically creative than grasshoppers, who are more mathematically creative in terms of originality. According to Nami et al. (2014), higher levels of creativity for pupils boost their academic accomplishment, which explains why the inchworm respondents outperform the grasshopper respondents. Furthermore, Huincahue et al. (2021) verified that students with an analytical thinking style, such as inchworms, have an advantage in school because the evaluation systems place a larger value on analytic thinking. These successful sequential thinkers in mathematics have better working memory capacity than grasshoppers, notably for formulas and methods employed in the mathematical creativity test (Chinn, 2013). According to Batool and Saeed (2019), working memory capacity has a substantial link with student mathematical performance, implying that higher working memory capacity leads to greater academic achievement in mathematics. Another reason is that inchworm respondents outperform grasshopper respondents in terms of academic achievement. This supports the assertion of Huincahue et al. (2021) that inchworms (analytical thinkers) outperform grasshoppers (visual thinkers) in academic performance since mathematical references in schools are primarily formal-oriented and many teachers prefer the Inchworm thinking style. Furthermore, according to Friso-van den Bos and van de Weijer-Bergsma (2020), working

memory is a major predictor of academic learning and accomplishment, giving the inchworm a competitive advantage.

The results also demonstrate that there is no significant difference in mathematical creativity between inchworm and grasshopper thinking styles in terms of fluency, flexibility, and originality. This shows that the respondents' levels of mathematical creativity in terms of fluency, flexibility, and originality were unaffected by their thinking styles. This implies that pupils' thinking styles cannot significantly influence how creative they are with mathematics. This is in line with the findings of Purnomo et al. (2021) that a person's capacity for creative thinking is influenced by factors other than cognitive style and that strong academic aptitude in mathematics is not always a reliable indicator of creative ability.

Enhancing students' mathematical creativity should be one of the teachers' primary focuses in their students' learning. According to Walia and Walia (2017), most schools adopt the deductive method of teaching, which does not allow students to think creatively. When asked to uncover originality in mathematics among pupils, mathematics teachers have no notion since they believe that just one answer exists for a specific question in mathematics. With this, this study supports Walia and Walia's (2017) claim that it is necessary to set up some challenges and situations for pupils in order to encourage creativity. Teachers are urged to try out with several teaching approaches rather than being limited to one. According to Chinn (2013), the behavioristic teaching style benefits the inchworm learner while the constructivist teaching style benefits the grasshopper learner. Learners must have cognitive flexibility to access both types, and teachers must be aware of and teach both styles (Chinn, 2013; Chinn, 2016). Because thinking styles have a big impact on achieving learning objectives, students need to be aware of each other's thinking patterns in order to discover their own potential. The teacher must be aware of the student's thinking style in order to enhance learning. It is hoped that educators will be able to determine the most effective method and technique for overcoming different difficulties in the learning process, which will improve learning outcomes (Rohman, 2017).

5. Conclusion

This study found a significant difference between students' thinking styles and critical thinking skills in terms of the interpreting information component of critical thinking. However, there is no significant difference between the Inchworm and Grasshopper thinking styles and critical thinking skills of students in terms of making inferences, recognition

of assumptions, deductions, and evaluating arguments. Furthermore, there is no significant difference between the inchworm and grasshopper thinking styles and mathematical creativity of students in terms of fluency, flexibility, and originality.

The study recommends teachers to consider students' thinking styles when developing learning activities that promote critical thinking as to interpreting information, which involves analyzing how something will be done to draw a conclusion and reason to believe that it is the correct answer or solution. When planning learning activities and classes, it is also important to consider how to develop mathematical creativity. The study encourages teachers to be less confined by one sort of teaching style and to increase cognitive flexibility in subject instruction.

Future researchers may do a similar study on homogeneous classes and/or a different year level to validate the results with a larger sample size for each thinking style. This can pave the way for more effective teaching and learning that encourages students' critical thinking and mathematical creativity.

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Spatial Analysis on the Spread of Dengue Hemorrhagic Fever in Baubau, Southeast Sulawesi, Indonesia

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Abstract

We studied the spatial patterns of Dengue Hemorrhagic Fever (DHF) transmission in Baubau, a city in Southeast Sulawesi, Indonesia. DHF is a serious disease caused by the dengue virus and spread by Aedes mosquitoes. We used Moran's Index, a spatial analysis tool, to create a DHF spread map for Baubau's sub-districts. We found different patterns of DHF risk, such as: cold spots, Betoambari and Batupoaro had lower DHF cases, but they were vulnerable to infection from nearby areas; hot spot, Murhum had higher DHF cases and could transmit the disease to neighboring areas; and low risk, Bungi had the lowest DHF risk and was resilient to infection. Our findings suggest that preventive measures should be tailored to the specific risk level of each sub-district. Our study also provides useful guidance for controlling DHF transmission in Baubau and beyond. Our research is a beacon of hope for a safer and healthier future.

Keywords: *dengue hemorrhagic fever, thematic map, Moran's I, spatial analysis, Aedes mosquitos*

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1. Introduction

Dengue Hemorrhagic Fever (DHF) is a severe illness resulting from the dengue virus, and its transmission occurs through Aedes aegypti and Aedes albopictus mosquitoes. It typically manifests as a sudden fever lasting two to seven days, accompanied by symptoms such as headaches, nausea, and various bleeding manifestations. According to the World Health Organization (2023), it is now endemic to more than 100 countries with Americas, South-East Asia and Western Pacific regions as seriously affected. In fact, Asia represents 70% of the serious cases globally.

In Indonesia, Aedes mosquitoes are prevalent throughout most regions of the country. Hence, dengue fever remains a persistent public health concern, particularly in densely populated urban areas (Halide & Ridd, 2008). The study of Harapan et al. (2019) showed an increasing trend of DHF in the country over the past 50 years while fatality decrease by half every decade. The incidence rates (IR) of DHF from 2018 to 2020 were 65,602, 138,127, and 108,303, respectively (Badan Pusat Statistik, 2021). However, Triastuti (2022) found a decrease in both IR and number of deaths due to DHF in 2022 as compared to the recorded cases in 2021. Majority of the conducted studies in various regions of the country exhibited an increasing trend of DHF cases (i.e. Mochamad Rizal Maulana et al., 2023; Faridah et al., 2023; Dewi et al., 2021; Pasaribu et al., 2021; Nainggolan et al., 2023; Fuadzy et al., 2020; Suryadi et al., 2021; Hasana & Susanna, 2019; Rakhmani et al., 2018; Setiawati, 2019; Utama et al., 2019; Sasmono et al., 2020; Haryanto, 2018; O'Reilly et al., 2019; Harapan et al., 2019; Maula et al., 2018; Wahyono et al., 2017). Hence, it remains a serious social issue not only by the medical practitioners but by different sectors of the society.

Numerous authors have proposed various approaches to address the challenges posed by Dengue Hemorrhagic Fever (DHF). While it is given that the majority of the strategies are medical in nature (i.e. Cavany et al., 2023; Smith, 2021; Saputra & Oktaviannoor, 2017; Indriani et al., 2023; Sulistyawati, 2020; Sulistyawati et al., 2023; Utama et al., 2019; Kurniawan et al., 2021; Sulistyawati et al., 2019; Utarini et al., 2021; Brady et al., 2020; Suwantika et al., 2020), there are breakthrough studies to control the spread of the disease through modeling techniques (i.e. Ramadona et al., 2023; Bannister-Tyrrell et al., 2023; Eryando et al., 2013; Nirwantono et al., 2022), profiling (Chew et al., 2019; Indriani et al., 2018; Adrizain et al., 2018) and spatial analysis (Dhewantara et al., 2019; Syukri &

Wardiah, 2023). For instance, Halide and Ridd (2008) developed a statistical model capable of forecasting DHF outbreaks up to six months in advance, utilizing current DHF cases, climate variables, and weather conditions. Similarly, Camargo et al. (2022) devised a mathematical model that illustrates how infants born to mothers with immunity to certain dengue serotypes can still contract DHF, particularly during periods of elevated monocyte infection and dengue virus levels. In addition to these contributions, Nuraini and Tasman (2012), Gonçalves et al. (2012), Bente and Rico-Hesse (2006), Tolinggi and Dengo (2019), Derouich et al. (2003), and Esteva and Vargas (1999), have also explored modeling dengue transmission within the human population. Despite the substantial number of studies on this field, the cases of DHF continues to pose challenges and evolve.

Several factors have been implicated in the persistence of DHF cases, including the lack of comprehensive information regarding the timing, location, and total number of incidents in an integrated manner. According to Kusairi and Yulia (2020), the use of Geographic Information Systems (GIS) helps facilitate the reduction of cases. The use of map as proposed by Mukhsar at al. (2021), Sani et al. (2023), and Mukhsar at al. (2023) could provide information on the spread of DHF among neighboring areas. However, there is still no specific study or published research on the distribution and vulnerability mapping (spatial aspects) of dengue cases in Baubau, a prominent city in Southeast Sulawesi Province situated on Buton Island, which was consistently been labeled as an endemic area for DHF. This is substantiated by the annual detection of a relatively high number of cases. For instance, in the years 2018, 2019, and 2020, there were 98, 160, and 74 recorded cases, respectively (Badan Pusat Statistik, 2021). With the population of 159,248 people based on 2020 census, the IR were 62, 100, and 46 cases in every 100,000 people, while the global IR is 50. The fatality rates were 0%, 1.27%, and 1.20%, respectively. These statistics underline the ongoing challenge in effectively curtailing DHF within Baubau City.

Understanding the regional dynamics is crucial, as each area varies in population behavior, density, and type. A geographic distribution map would be invaluable in empirically investigating the relationship between geographic factors and the disease, aiding in prevention efforts. Hence, this article aims to analyze the pattern of spatial distribution of DHF using spatial autocorrelation and to create a map of DHF vulnerability in Baubau City in 2018-2020.

2. Theoretical Background

2.1. Spatial autocorrelation

Spatial data refers to georeferenced information wherein different attributes are associated with distinct spatial units. In the context of GIS, the data can be categorized into two primary types: spatial data and attribute data. Spatial data pertains to information intrinsically linked to spatial locations, whereas attribute data encompasses non-spatial details designed to elucidate the characteristics of various objects within the spatial dataset (Smith, 2020; Griffith, 2020). According to Lee and Wong (2001), it is a method for identifying spatial patterns by considering the values of locations and their attributes. Spatial patterns can be described into three parts, namely *clustered*, *dispersed*, and *random.* Spatial autocorrelation has positive value if the spatial data pattern tends to be clustered, it has a negative value if the pattern tends to spread out, and it is said to have no spatial autocorrelation if the pattern is random (Anselin, 1995; Lee & Wong, 2001; Griffith, 2020).

2.2. Spatial weights matrix

A spatial weights matrix serves as a mathematical construct designed to capture and quantify the inherent spatial connections within a dataset. This matrix operates as a tool for quantifying the geographical relationships among different geographical regions present in the data. These values within the matrix are assigned in accordance with predetermined criteria that delineate the spatial associations among these locations, ultimately influencing the calculation of spatial autocorrelation statistics (Xu & Lee, 2019). The foundation for these spatial relationships is rooted in concepts like Queen, Rook, and Bishop contiguities, each of which prescribes specific rules to determine how neighboring areas are connected. Specifically, areas in close proximity are assigned a value of 1, while those farther apart receive a value of 0 (Anselin, 1995; Rey & Anselin, 2010).

2.3. Moran's index

Moran's index (Moran's I) is an indicator of spatial autocorrelation and is commonly used to determine spatial autocorrelation coefficients. Moran's index can be used to determine local spatial patterns (LISA). Moran's index is used to determine the correlation of a variable in all observed data sets (Lee & Wong, 2001; Vogl & Mikula, 2021). Moran's index can be calculated by the following equation:

$$I = \frac{n \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}(X_i - \bar{X})(X_j - \bar{X})}{W \sum_{i=1}^{n} (X_i - \bar{X})^2} \quad (1)$$

where n is the number of observations, W is the number of weights, X_i is the observed variable at the i-th location, i = 1, 2, …, n, X_j is the variable observed at the j-th location, j = 1, 2, …, n, w_{ij} is the ij element of the spatial weights matrix W (which has been standardized), and $\bar{X}$ is the average of X on n locations (Chen, 2009; Bivand, 2009).

The Moran's Index value falls within the range of -1 to 1, and both negative and positive values indicate a spatial association with the surrounding area (Ren et al, 2016; Yu & Chang, 2021). The expected value of the Moran Index is shown in the following equation:

$$E(I) = \frac{-1}{n-1} \quad (2)$$

Moran scatterplot can be constructed by plotting the variable of interest on both the x-axis and y-axis. Each point on the scatterplot represents a specific location on the map. The position of the point is determined by the value of the variable at that location. Different symbols or colors can also be used to indicate the direction of spatial autocorrelation (Negreiros et al., 2010).

On the other hand, the Local Indicators of Spatial Association (LISA) is a valuable tool for examining spatial associations within a research area. The LISA method serves as an effective means to identify areas of contraction or outliers in spatial phenomena within a given region. LISA is defined by the equation:

$$I_i = \frac{(x_i - \bar{x})}{[\sum_{i=1}^{n} (x_i - \bar{x})]} \sum_j w_{ij} \left(x_j - \bar{x}\right) \quad (3)$$

where x_i is the observed value at location i, x_j is the observed value at location j, $\bar{x}$ is the average value of the observed variables, and w_{ij} is the weighted measure between region i and region j (Anselin, 1995).

To test the parameter I_i, we can use statistic Z in which the null hypothesis (H_0): $I_i = 0$ (indicating no spatial autocorrelation) versus the alternative (H_1): $I_i \neq 0$ (indicating the presence of spatial autocorrelation).

The calculation of statistic Z is as follows: $Z_{calc} = \frac{I_i - E(I_i)}{\sqrt{var\ (I_i)}}$

Here, Z_{calc} stands for the LISA Index test statistic, I_i represents the LISA Index, $E(I_i)$ represents the expected value of the LISA Index, and var (I_i) represents the variance of the LISA Index. The null hypothesis H_0 will be rejected if the absolute value of $Z(I) > Z(\alpha/2)$, indicating the presence of spatial autocorrelation.

LISA Index measures the degree of a particular location to its adjacent counterparts by contrasting the value of a chosen variable at a given site with those of neighboring locations. LISA analysis assigns local indicators to each dataset location, categorizing them into one of four distinct groups (Negreiros et al., 2010):

1. High-High (HH): Indicates locations with high values enclosed by other high-value locations, signifying the presence of clusters with elevated values.
2. Low-Low (LL): Identifies sites with low values encompassed by neighboring low-value locations, suggesting the existence of clusters with diminished values.
3. High-Low (HL): Recognizes locations with high values bordered by low-value sites, implying spatial outliers.
4. Low-High (LH): Pinpoints sites with low values surrounded by high-value areas, also indicating spatial outliers.

The application of LISA analysis is advantageous across various domains such as geography, urban planning, economics, and more. By delineating local spatial associations, it facilitates the comprehension of the presence and extent of spatial clustering or spatial outliers within datasets, thereby unveiling the underlying spatial structure (Anselin, 1995).

2.4. Thematic map

A thematic map serves as a geographic representation that conveys specific information related to a designated theme, encompassing both surface and subsurface data pertaining to that theme. These maps are alternatively known as statistical maps or special purpose maps, and they offer a concise depiction of spatial patterns or characteristics within a particular area, as per the chosen thematic focus (Kettani & Moulin, 1999).

Thematic maps fulfill the role of conveying information of a specific theme, accommodating both qualitative and quantitative data. They share a profound connection with GIS, as thematic maps frequently constitute the output of GIS projects. Such maps are available in both digital formats and traditional paper map forms, serving as valuable tools

for visualizing and communicating thematic data in geographical contexts (Slocum et al., 2005).

3. Research Methods

The data used are the reported number of DHF cases in Baubau City in 2018 – 2020 obtained from the City Health Office of Baubau. The research procedures for this study are outlined as follows.

Preparation of geographical description. This step involves describing the location, area, population, climate, and other relevant features of Baubau City, which is the study area for this research. The geographical description helps to provide the background and context for the analysis of DHF cases in the city. We used secondary data sources, such as census reports, maps, and official websites, to prepare the geographical description of Baubau City.

Descriptive statistics of DHF cases. This step involves summarizing the number, frequency, and distribution of DHF cases in Baubau City from 2018 to 2020. The descriptive statistics help to provide an overview of the magnitude and trend of DHF cases in the city. We used primary data sources, such as health records, surveillance reports, and laboratory tests, to obtain the data on DHF cases in Baubau City.

Spatial distribution of DHF cases. This step involves analyzing the spatial pattern of DHF cases in Baubau City across its sub-districts. The spatial distribution helps to identify the areas that have higher or lower incidence of DHF cases than expected by chance. We used the following analytical steps to investigate the spatial distribution of DHF cases in Baubau City: (a) compute the spatial weights matrix, which measures the spatial proximity and connectivity of the sub-districts, (b) determine the statistics related to Moran's Index, which measures the global spatial autocorrelation of DHF cases, generate and identify Moran's scatterplot, which visualizes the local spatial autocorrelation of DHF cases.

Hotspots and coldspots of DHF cases. This step involves identifying the areas that have significantly high or low incidence of DHF cases compared to the average of Baubau City. The hotspots and coldspots help to detect the spatial clusters or outliers of DHF cases in the city. We used the LISA index, which stands for Local Indicators of Spatial Association, to test the hypothesis of spatial dependence of DHF cases in Baubau City.

Thematic map of DHF cases. This step involves creating a thematic map that depicts the vulnerability of enclave areas to DHF cases in Baubau City. The thematic map helps to communicate the results and implications of the spatial analysis of DHF cases in the city. We used ArcView GIS 3.3, which is a geographic information system software, to produce the thematic map of DHF cases in Baubau City.

4. Results and Discussion

4.1. Description of DHF cases in Baubau City

Baubau City, situated within Southeast Sulawesi Province, is comprised of eight sub-districts: Betoambari, Wolio, Murhum, Batupuaro, Sorawolio, Kokalukona, Lea-lea, and Bungi, covering a total area of 294.99 square kilometers. In the year 2018, the city reported 98 cases of DHF, with the highest incidence recorded in Wolio (31 cases), followed by Murhum (29 cases) and Batupuaro (26 cases), while the remaining sub-districts reported an average of 5 to 6 cases each. Notably, there was a significant surge in DHF cases in the subsequent year, 2019, with a total of 160 cases, of which 80 cases were concentrated in the Wolio sub-district and 29 in the Murhum sub-district. However, in 2020, efforts to combat the disease proved effective, resulting in a reduction of DHF cases to 74.

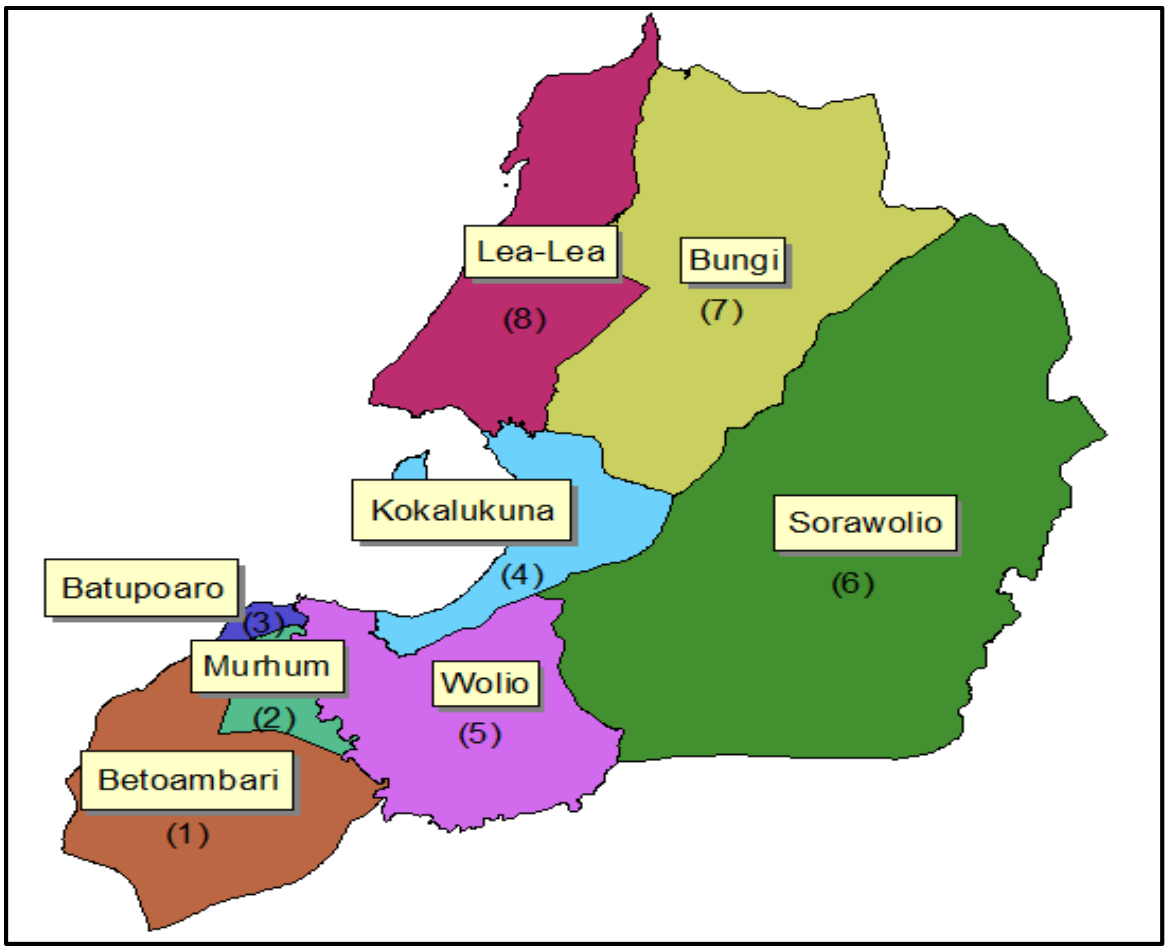
4.2 Spatial Pattern of DHF Cases in Baubau City

The contiguity matrix is formed based on the location of each sub-district as depicted on the administrative map of Baubau City shown in figure 1.

The legends for each district and its adjacent districts is generated based on the Queen's Move principle. To illustrate, consider the Betoambari sub-district, which shares its borders with three nearby neighbors: Murhum, Batupoaro, and Wolio sub-districts. Similarly, the Murhum sub-district is in proximity to Betoambari, Batupoaro, and Wolio sub-districts. This same rationale holds for determining the number of neighbors for the remaining districts.

Figure 1

Baubau City map with its sub-districts



The outcomes of the Moran's *I* analysis conducted for annual DHF cases in Baubau City via Rstudio are presented in table 1.

Table 1

Moran index values for Baubau City in 2018-2020

Year	Moran's Index (*I*)	Moran's Expectations Index (E(*I*))	Spatial Pattern
2018	0.26569479	-0.14285714	Clustered
2019	-0.03491325		Dispersed
2020	-0.06539569		Dispersed

By referring to table 1, we can imply that the Moran Index value for 2018 manifests as positive, denoted by $I > E(I)$, showing the significance of a clustered spatial pattern. This

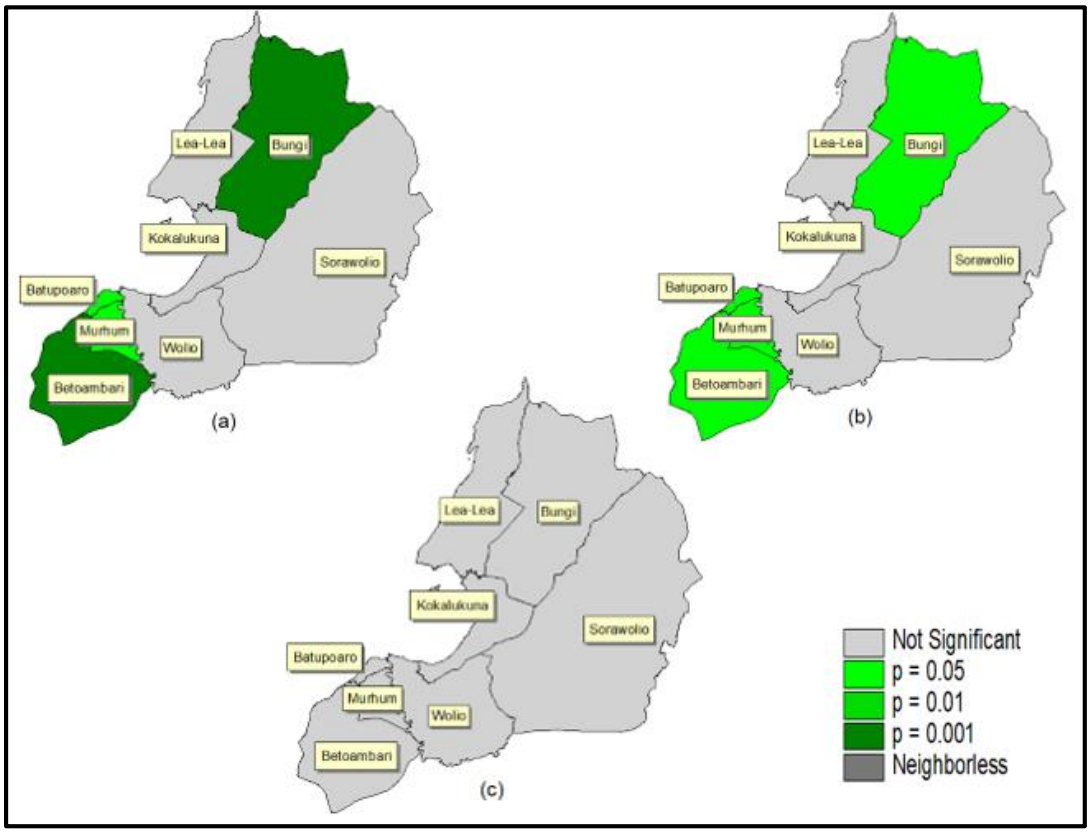
suggests that in neighboring areas or sub-districts, occurrences of DHF cases tend to exhibit a similar or identical count. Conversely, there is a negative Moran Index value for 2019 and 2020, as indicated by $I < E(I)$, which means dispersed spatial patterns, where neighboring areas or sub-districts tend to display varying and dissimilar numbers of DHF incidents.

4.3. LISA index of DHF cases in Baubau City

The outcomes of the LISA index test for the year 2018 reveal that there were two sub-districts with statistically significant results at a significance level of α=5%, namely Murhum and Batupoaro. Additionally, two other sub-districts, Bungi and Betoambari, exhibited statistical significance at a more stringent α=0.1%. These findings indicate a spatial relationship among these sub-districts, particularly with their immediate neighbors. Conversely, there were four districts that did not yield statistically significant results, namely Wolio, Sorawolio, Lea-Lea, and Kokalukuna. The results of the 2018 DHF LISA analysis are shown in figure 2.

Figure 2

DHF cases in Baubau City using LISA Index



Legend: (a) 2018; (b) 2019; (c) 2020

In 2019, there were four sub-districts to have significant results at α= 5%, namely Betoambari, Batupoaro, Bungi and Murhum. These indicate that the sub-districts have spatial relationship with their neighboring sub-districts or their direct adjacent. There are four sub-districts to have no significant results, namely Wolio, Sorawolio, Lea-Lea and Kokalukuna. The map shows the results of the 2019 DHF data using LISA index.

In 2020, there were eight sub-districts to have no significant results, namely Murhum, Betoambari, Wolio, Sorawolio, Lea-Lea, Kokalukuna, Batupoaro and Bungi. The map provides the results of the 2020 DHF case using LISA index.

4.4. Map of the spread of dengue fever in Baubau City

Summary of the results of Moran's scatterplot is presented in table 2 and the thematic map of the results of Moran's scatterplot is presented in figure 3.

Table 2

Position of each sub-district in Moran's scatterplot for 2018-2020

Year	HH	LH	HL	LL
2018	Murhum Batupoaro	Betoambari Sorawolio	Wolio	Lea-lea Bungi Kokalukuna
2019	Murhum	Betoambari Batupoaro Kokalukuna Sorawolio	Wolio	Bungi Lea-lea
2020	Murhum Kokalukana	Betoambari Sorawolio Batupoaro	Wolio	Bungi Lea-Lea

In 2018 as shown in table 2, there were two sub-districts located in quadrant I (High-High), namely Murhum and Batupoaro. This indicates that these two sub-districts have high number of DHF cases and the surrounding sub-districts also have high DHF cases. There are two sub-districts in quadrant II (Low-High), namely Betoambari and Sorawolio. These two sub-districts have low number of DHF incidents while the surrounding districts have high DHF cases. Quadrant III (Low-Low) indicates an area that is safe from DHF cases, namely

Kokalukuna, Lea-Lea and Bungi sub-districts. Wolio is the one and only sub-district in Quadrant IV (High-Low) with high incidence while the surrounding districts are low.

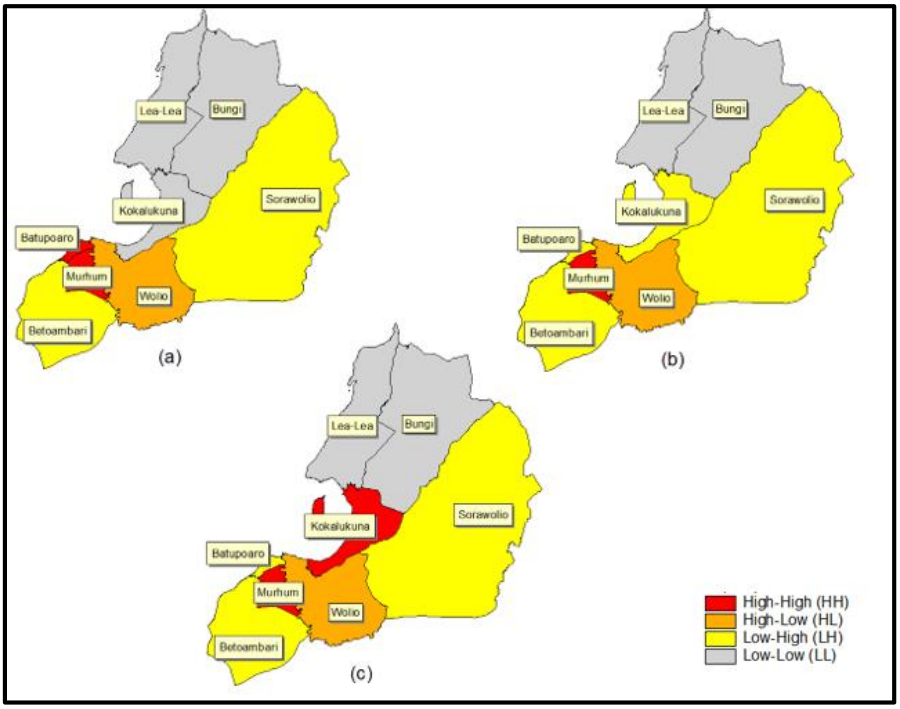
The composition of quadrant changed in 2019. In Quadrant I, there is only one district, Murhum, where there is a high number of DHF cases in the sub-district and in the surroundings. In Quadrant II, where the incidences are low while the surroundings are high, there are four districts, namely Sorawolio, Kokalukuna, Batupoaro and Betoambari. In Quadrant III, there are two districts, namely Lea-lea and Bungi, which are considered safe areas from dengue. In Quadrant IV, there is also only one district, Wolio, where the sub-district itself has high number of incidences while the surroundings are low.

In 2020, the constellation of sub-districts in the quadrants changed again. In Quadrant I, where the area and the surroundings have high number of incidences, there are two districts, namely Kokalukuna and Murhum. Betoambari, Sorawolio and Batupoaro sub-districts are in Quadrant II. In this quadrant, the number of DHF incidents is low while the surroundings are high. In quadrant III, there are two districts, namely Bungi and Lea-Lea. This quadrant is a safe area from dengue. Quadrant IV, where the number of DHF incidences is high while the surroundings are low, consists only of one sub-district, Wolio.

4.5. DHF thematic map of Baubau City

Figure 3

Thematic map of Moran's scatterplot



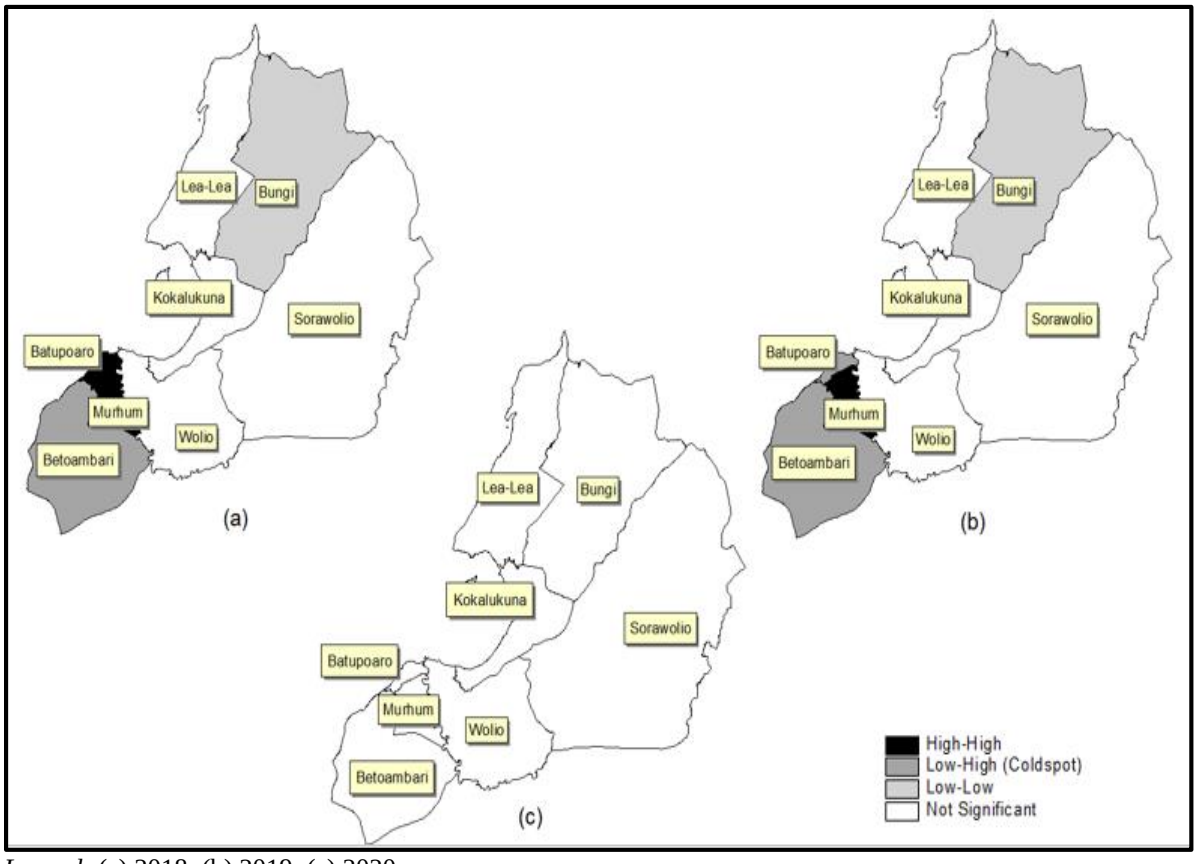
Legend: (a) 2018; (b) 2019; (c) 2020

In figure 3, it can be seen that Murhum and Wolio sub-districts are both with high DHF IR during three years of observation (2018-2020), while for Lea-lea, Betoambari, Sorawolio and Bungi sub-districts have low DHF IR. It also can be seen that the DHF incidences in Kokalukuna sub-district increased annually. Being in Low-Low quadrant in 2018 and Low-High in 2019, it became High-High in 2020. This is due to the lack of local people in carrying out mosquito-nest eradication activities. There are still many local people who collect rainwater which can result in providing breeding sites for Aedes aegypti and Aedes albopictus mosquitoes.

4.6. Map of dengue fever cases in Baubau City

Figure 4

Dengue disease vulnerability map in Baubau City



Legend: (a) 2018; (b) 2019; (c) 2020

The results of the LISA Index test during the three-year period of observation showed four significant sub-districts, namely Murhum, Betoambari, Bungi and Batupoaro. Batupoaro, categorized as cold-spot area in 2019. Meanwhile, in 2018 and 2019, Betoambari is considered as cold-spot area. The cold-spot area has negative autocorrelation or outlier

pattern with low number of DHF incidences while the surroundings are high. However, this area has the potential to be prone to the spread of dengue fever, which is probably transmitted by the high number of surrounding areas. Meanwhile, the LISA test for 2018 and 2019 showed that the Murhum sub-district is classified as an area with high DHF incidence rate and the surrounding areas are also high. These areas should be monitored by all stakeholders to prevent the spread of dengue to the neighboring sub-districts. LISA test for Bungi shows that the sub-district is categorized as low incidence of DHF while the surrounding areas are also low. This area is safe from DHF incidences.

5. Conclusions and Recommendations

Our analysis reveals significant fluctuations in the number of DHF cases in Baubau City between 2018 and 2020. Notably, there was a substantial spike in DHF cases in 2019. Throughout this period, Wolio consistently reported the highest number of DHF cases among the sub-districts. Moreover, our examination employing the Moran Index demonstrates varying spatial patterns. In 2018, the Moran Index registered a positive value of 0.2, indicating a clustered spatial pattern in DHF distribution across Baubau City. In contrast, 2019 exhibited a negative Moran Index of -0.03, signifying a dispersed spatial pattern. A similar dispersed pattern was observed in 2020, with a Moran Index of -0.06. Positive Moran's Index values indicate a uniform DHF distribution across sub-districts, while negative values suggest variation in DHF distribution among sub-districts.

A closer look through LISA analysis highlights that in 2018, both Murhum and Batupoaro sub-districts experienced high DHF incidence. However, in 2019, only Murhum exhibited a notable increase in DHF cases. Consequently, targeting interventions for DHF reduction and prevention should prioritize the Murhum sub-district. Additionally, the data from 2019 indicates that Betoambari and Batupoaro sub-districts are potential areas at risk for DHF transmission from their neighboring sub-districts while the Bungi sub-district appears to be a safer zone with a lower risk of DHF transmission.

It is essential to note that this research exclusively focuses on spatial patterns and does not account for other contributing factors. Hence, future research endeavors should aim to incorporate other factors to comprehensively model the influences on the number of DHF cases in Baubau City.

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Development of an Offline Computer-Based Assessment Tool in Statistics and Probability Utilizing MS PowerPoint and MS Excel

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Abstract

This capstone project aimed to develop an offline computer-based assessment (CBA) tool that uses a computer instead of a traditional paper test in evaluating student learning. This addresses the difficulties faced by teachers in administering quarterly assessments. Incorporating technology into student assessment can increase student interest because of the immediate feedback generated automatically and can help teachers improve their work performance. This capstone project employed a developmental approach and utilized a modified ADDIE (Analysis, Design, and Development) model to design the tool using Microsoft PowerPoint and Excel. Ten experts in mathematics, ICT, and assessment validated the face and content validity of the developed CBA tool. Based on the panel's evaluation, the developed offline CBA tool in Statistics and Probability has passed all the assigned criteria, such as functionality, usability, efficiency, technicality, and accessibility. Overall, the developed CBA tool is suitable for use to address assessment-related issues.

Keywords: *ADDIE model, assessment in learning, ICT integration, Microsoft office applications*

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1. Introduction

Assessment is integral to the teaching and learning process that determines whether the learner has learned what has been taught. It also provides teachers with immediate feedback, allowing them to modify their teaching approaches to the diverse learning styles of their students. There are various types of assessments used in the classrooms (Sarmiento et al., 2020; Gonzales & Callueng, 2014) but the public schools in the Philippines generally use the paper and pen tests (PPT), which several researchers argued the need for technology-based assessment techniques (Neumann et al., 2018; Danniels et al., 2020; Jurāne-Brēmane, 2023; Nye, 2022; Elmahdi et al., 2018). While majority of the studies showed no significant difference in the performance of the students in PPT and computer-aided tests (i.e. Bayazit & Aşkar, 2012; Darr, 2014; Grapin & Sayac, 2022; Laurie et al., 2015; Wang et al., 2008; Smolinsky et al., 2020; Akdemir & Oguz, 2008; DiCarlo et al., 2023; Moon, 2013) and some still prefer PPT (Wang et al., 2021; Wagner et al., 2022; Alabi et al., 2023), the PPT has three-fold tasks for teachers involving preparation, administration and post-evaluation of results. In fact, Jomuad et al. (2021) describe this as additional teachers' workload with a significant impact on their stress levels as well as on their performance. Similarly, Hundani and Toquero (2021) supposed that teachers' work-related paperwork contributes to their level of occupational stress.

Researchers and educators alike urge teachers to become innovative in assessing students' learning (Looney, 2009; Serdyukov, 2017; Zacharis, 2010) and one of the most effective strategies is to employ technology through computer-based assessment (CBA). A CBA is a method of evaluating student learning that uses a computer instead of a traditional paper test, also known as onscreen testing and e-testing. CBA has become essential to teaching and learning over the last two decades and is viewed as a solution for assessment implementation for learning and providing real-time feedback on students' performance (Burgmanis et al., 2023). It also reduces test durations while increasing students' motivation to take tests (AlAdl, 2020). While implementing computer-based tests can give teachers a new challenge in the digital era, they need to be creative to keep up with the advancement of science and technology. Aside from created opportunities to raise the status and accreditation of the school (Lesly, 2021), it follows the Department of Education (DepEd) order no. 78, s. 2010, on the computerization program to equip public schools with the necessary

technologies to improve the quality of education and address the challenges of the 21st century. Students nowadays prefer to use technological devices in every aspect of their daily activities (Cha et al., 2020; Pentang, 2021). Hence, the use of technology, particularly for assessment, is highly beneficial. It can help the country's educational system by allowing students to showcase their skills in ways that traditional methods would not allow (Das, 2019).

The use of CBA tool to assess students' performance increases teachers' productivity (Terzis & Economides, 2011) by reducing laborious tasks due to the automated results generated. In terms of the assessment administration, the main argument with the CBA is the availability of reliable internet connection (Sibberns, 2020; Csapó et al., 2012; Thurlow et al., 2010; Tomasik et al., 2018) specially in countries like the Philippines where the internet has been a constant challenge in online education (Asio et al., 2021; Gocotano et al., 2021; Barrot et al., 2021). Hence, offline CBA, a method of assessment that uses a computer without an internet connection, is highly recommended in the Philippines. If locally developed, an offline CBA is less expensive than an online CBA since it can be administered in school computer laboratories without a need for strong internet connection. Moreover, it can also reduce students' cheating chances since they cannot look for answers online and waste time when answering questions during the test (Alek, 2020). Through ICT, the content can be presented engagingly, capturing students' interest and perception through text, color, and visual displays (Mirsharapovna et al., 2022). Students and educators may benefit from such an approach regarding quality, efficiency, and quantity. Since many students use computers, tablets, and smartphones outside the classroom, utilizing these same devices for testing may help students connect what they learn in class and what happens in real-world situations.

Given the advantages of using CBA to the teachers through efficiency and ease (Nikou & Economides, 2019; Maqableh et al., 2015; Sirianni et al., 2017; Bloom et al., 2018; Ceka & O'Geen, 2019; Zheng & Bender, 2019; Sullivan, 2020; Efendi et al., 2021; Dembitzer et al., 2017; Terzis & Economides, 2011) and the immediate feedback given to the students (Shute & Rahimi, 2017; Debuse & Lawley, 2016), this capstone project developed an offline CBA tool in Statistics and Probability. In addition, to address the common issue on internet connectivity in the research locale, the CBA has been developed using easily

available built-in software Microsoft PowerPoint and Excel. This allows maximum benefit for teachers for the ease of use with minimum training required.

2. Methodology

2.1. Research design

This project used developmental research design to develop an offline CBA tool in Statistics and Probability. Based on Richey and Klein (2005), developmental research focuses on designing, producing, and assessing instructional materials and processes that can provide educators with valuable data. The instructional system design method was the modified ADDIE model, which only includes the analysis, design, and development processes. The implementation and evaluation stages were excluded from this project since the material needs to be validated by experts before implementation. According to Campbell (2014), ADDIE can be modified to meet almost any educational need or purpose. Given the dynamic nature of current education, this paradigm for instructional design is ideally equipped to address future issues associated with the design.

2.2. Participants

This project was evaluated by ten experts with the following criteria: Master's or Doctorate degree holder, an expert in teaching Mathematics, an experienced teacher in the field of Mathematics, an expert in ICT, and an Assessment expert. Purposive sampling was employed since the project requires specialized experts who can assist the study in achieving its objectives. This type of sampling is used to increase the study's rigor and the accuracy of the data and results by better matching the participants to the study's goals and objectives (Campbell et al., 2020). Purposive sampling helps the researcher to eliminate irrelevant feedback that is unnecessary in the study's context and it reduces the data collection margin of error (Obilor, 2023).

2.3. Instruments

As part of the analysis phase of the modified ADDIE model, the third and fourth quarterly assessment issues and concerns and other essential reports were used in developing the offline CBA tool. Teachers' experiences during the administration of assessments served

as the basis for developing the tool. Microsoft applications such as PowerPoint and Excel were used as the platforms for designing and developing the tool.

Moreover, the instrument used to validate the CBA tool was adapted from ISO 9126, an international standard for software quality. The validation form has the following criteria: functionality, usability, efficiency, technicality, and accessibility. Since the validation was limited to the CBA tool and not the assessment itself, the criteria only focus on software validation. Functionality refers to the usefulness and appropriateness for its intended use. Usability is a means of determining how easy it is to use. Efficiency is the ability to deliver desired and accurate outcomes with minimal resources. Technicality refers to the set of information and specifications regarding the utilization, and the accessibility is concerned with how easily the tool may be accessed or operated by anyone. Each criterion may be scored on a scale of 1 to 5, with 5 representing the highest rating. The validation rating sheet follows Pentang (2023) with the following: (1) strongly disagree, (2) disagree, (3) neutral, (4) agree, and (5) strongly agree.

2.4. Data gathering procedures

The research used the modified ADDIE model development process. This method is the most appropriate since it offers an integrated approach that can be employed in developing the offline CBA tool.

Analysis phase. During this phase, it was found that evaluating student's learning involves various tasks, such as preparing test materials, administering tests, checking test papers, recording scores, and analyzing the test results. It is challenging for teachers because the various tasks require much time and effort. Similarly, during the conduct of the Regional-Mid-Year Assessment, there were necessary reports that teachers needed to submit following the administration of the assessment. Teachers struggle to keep up with the deadlines, especially during the 3rd and 4th quarter assessments, because of the other school forms and year-end activities needed. Additionally, students do not find traditional tests especially interesting or engaging based on the issues and concerns reported by the teachers specially in Statistics and Probability, a core subject in grade 11 senior high school.

During the fourth quarterly assessment at a particular school in Central Luzon, Philippines, 50 students underwent CBA for core subjects, and based on the report of

teachers who facilitated the CBA, one major problem is the internet connectivity since the platform used was Google Forms. Online CBA can be highly beneficial to schools, but since a strong internet connection is required, it is relatively expensive. Based on the analysis, innovative approaches to assessment are needed to help teachers prepare assessment-related reports, fulfill deadlines, and stimulate students' interest in assessments without using excessive resources.

Design phase. Using the data acquired during the analysis phase, the issues and concerns reported during the conduct of quarterly assessments were considered in designing the CBA tool, particularly for the preparation of assessment-related reports such as the grading sheets, Mean Percentage Scores (MPS), number of students who achieved or exceeded the minimum proficiency level and the most and least learned competencies. An offline CBA was designed considering the type of test and what platform to create the project, considering the functionality, usability, efficiency, technicality, and accessibility.

The tool was designed following the 50-item multiple-choice type of test and utilized the following software.

PowerPoint - a complete graphical presentation program with tools for word editing, outlining, sketching, and presentation management. This served as the central platform for creating the assessment tool; all the programming codes were done through this software.

PowerPoint macro-enabled Show – It enables users to integrate small programs known as macros into the slides. This is the medium through which test takers respond to the assessment.

Excel - a program used to arrange data, perform computations and perform data analysis. This stores all data about the assessment takers and is linked to the PowerPoint.

***Development phase*.** In this phase, the tool was created with help from comments and suggestions of ICT experts including techniques in designing the background design, adding navigation buttons for the tool's usability, and incorporating the following features and functionalities.

Offline setting. This tool does not require internet connectivity. This can also prevent students from cheating since this will be administered in computer labs, and students cannot open search engines to look for answers online.

Shuffling of choices. This feature can discourage students from copying their seatmates' answers.

Changing of answers. Students can change their answers if they accidentally click the wrong button.

An *Exit Assessment* button that leads to results if the test taker decides to terminate the exam early.

A *display of the taker's total score*, *number of missed questions*, and *percentage* after the assessment. The immediate results will attract students' interest and help teachers harvest scores and prepare grading sheets easily.

A button that *generates a certificate* if the test taker scored 60% or more.

An *Excel file* that stores all the student data, such as the student's name, section, score, percentage, and questions with corresponding labels (correct or wrong). This saves time for teachers to complete other tasks by making it simple for them to record and analyze test results and generate automated assessment-related reports on time.

Validation. Ten experts acted as the validation panel chosen based on their years of experience in teaching and their knowledge of Mathematics, ICT, and Assessments. They provided comments and suggestions to ensure the CBA tool is efficient and valuable.

2.5. Data analysis

To analyze the data in validating the CBA tool based on experts' ratings, the Content Validity Ratio (CVR) and the Content Validity Index (CVI) were employed. Ratings of "strongly agree" were considered. Given a panel of size of ten, a value greater than or equal to 0.62 is interpreted as valid (Lawshe, 1975). Tilden et al. (1990) suggested that a value must exceed 0.70 for the item to be considered valid. On the other hand, Lynn (1986) said that a value of 0.80 or more is preferred to be considered valid. Table 1 shows the formula to calculate the CVR and CVI used to analyze the experts' rating data.

Table 1

The formula for calculating the CVR and CVI

CVR values	**CVI values**
$\text{CVR} = \frac{Ne - \frac{N}{2}}{\frac{N}{2}}$ Where: *Ne* = the number of experts indicating "strongly agree" *N* = total number of experts	$\text{CVI} = \frac{\Sigma CVR}{n}$ Where: ΣCVR = total CVR scores *n* = total number of items

3. Findings and Discussions

3.1. Analysis phase

The data clearly show the experiences of the teachers on the laborious process of preparing assessment-related reports due to manual checking. Hence, an innovative approach is needed to assist teachers in assessing the students' learning, preparing quality assessment-related reports, and performing better. As Perryman and Calvert (2020) argue, teachers are disappointed with their jobs because they look to be made up of low-quality assignments that do not assist students. The biggest impediment to improving teacher performance is the high volume and low-quality workloads generated (Brady & Wilson, 2021). Teachers are experiencing high levels of stress and burnout due to the increased pressure from test-based accountability procedures (von der Embse et al., 2019). Ancho and Bongco (2019) stated that although it is good that teachers face challenges with a positive attitude, it would still be ideal to look for ways to complete the task without risking the teachers' physical well-being.

3.2. Design phase

The CBA tool used the 50-item multiple-choice type of test following the guidelines on test construction of the Department of Education. Multiple Choice Questions (MCQs) have been widely utilized as an educational assessment technique (Kumar et al., 2023). Kaipa (2021) revealed that students believe that MCQs will adequately assess their content knowledge and understanding.

Microsoft Office applications such as PowerPoint and Excel were used to design the offline CBA tool in Statistics and Probability. PowerPoint is a complete graphical presentation program with tools for word editing, outlining, sketching, and presentation management. Excel is a program used to arrange data and perform computations on it. It can perform data analysis and statistics computation. Because of the powerful tools available, such as PowerPoint Master Slide that is used for creating background designs, which allow users to create standards for the layout and visual appearance of every slide, and the built-in tools in PowerPoint, such as Visual Basic Application (VBA) and Macros, which are used to create programming codes to integrate interactive functions, PowerPoint and Excel are ideal platforms for designing assessment tools. As Abdulrahman et al. (2020) mentioned, using a suitable tool is crucial. Adopting multimedia in education demands a complete understanding of the technology and the components required to represent concepts or ideas accurately.

3.3. Development phase

3.3.1. The layout and features of the CBA tool using PowerPoint and Excel

Figure 1

Front-end view of the CBA tool

Figure 2

General Instructions for Assessment Takers

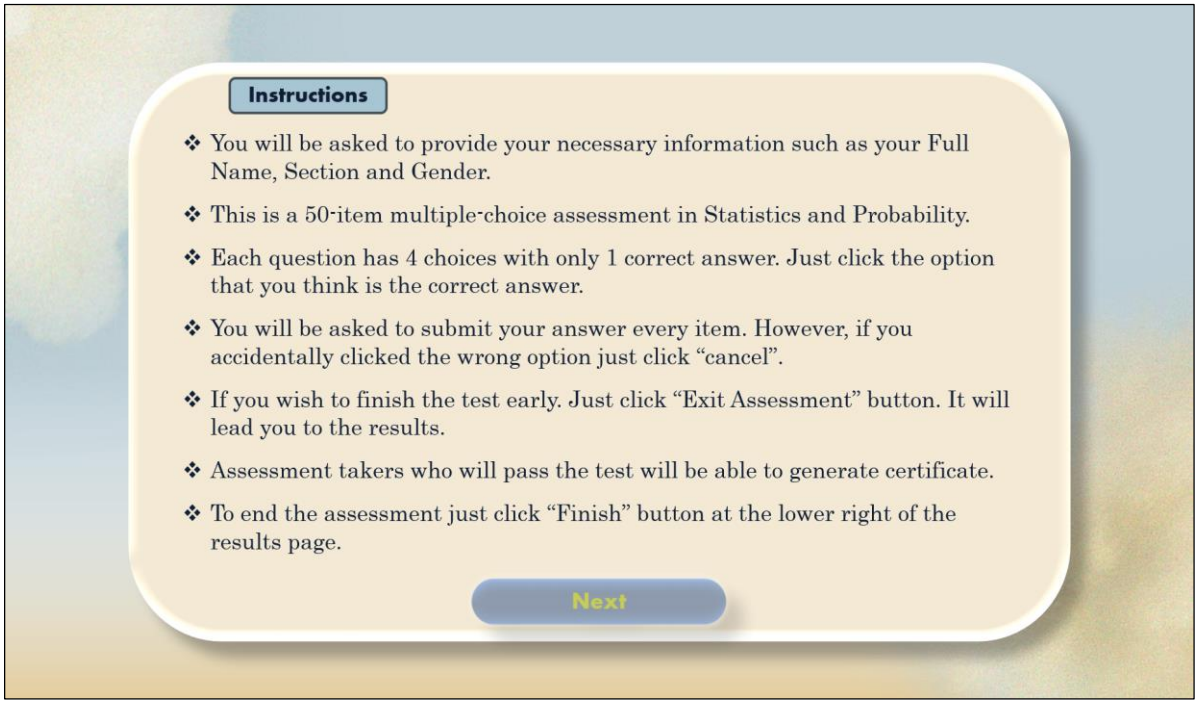
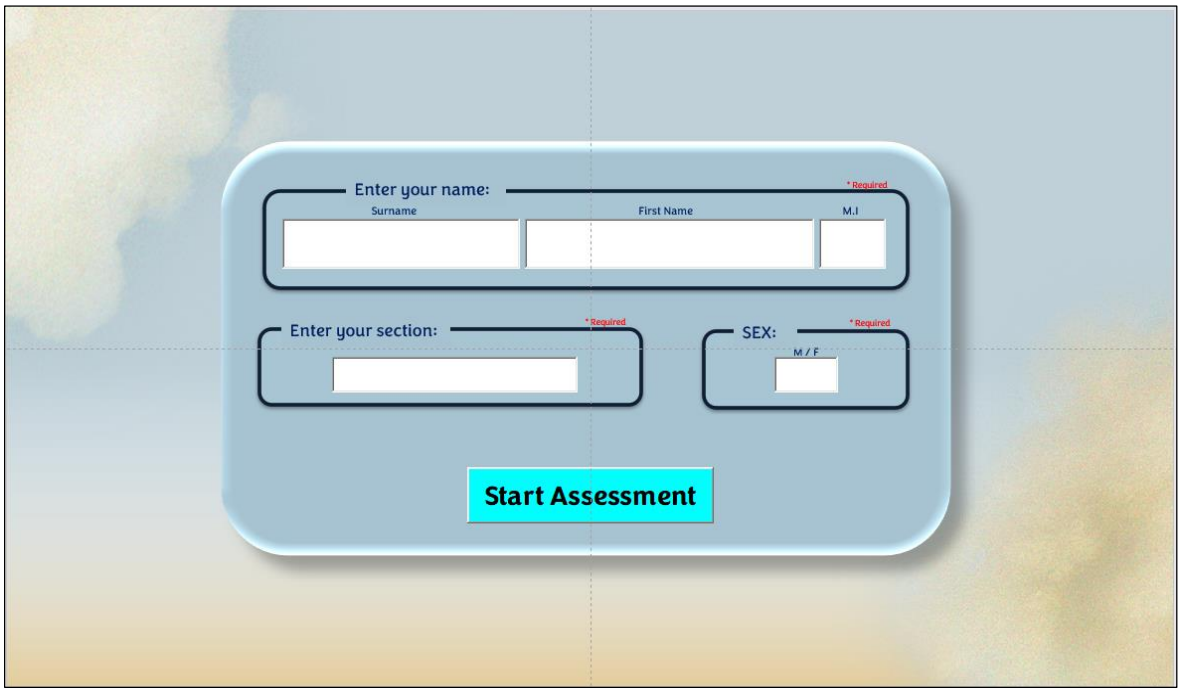


Figure 3

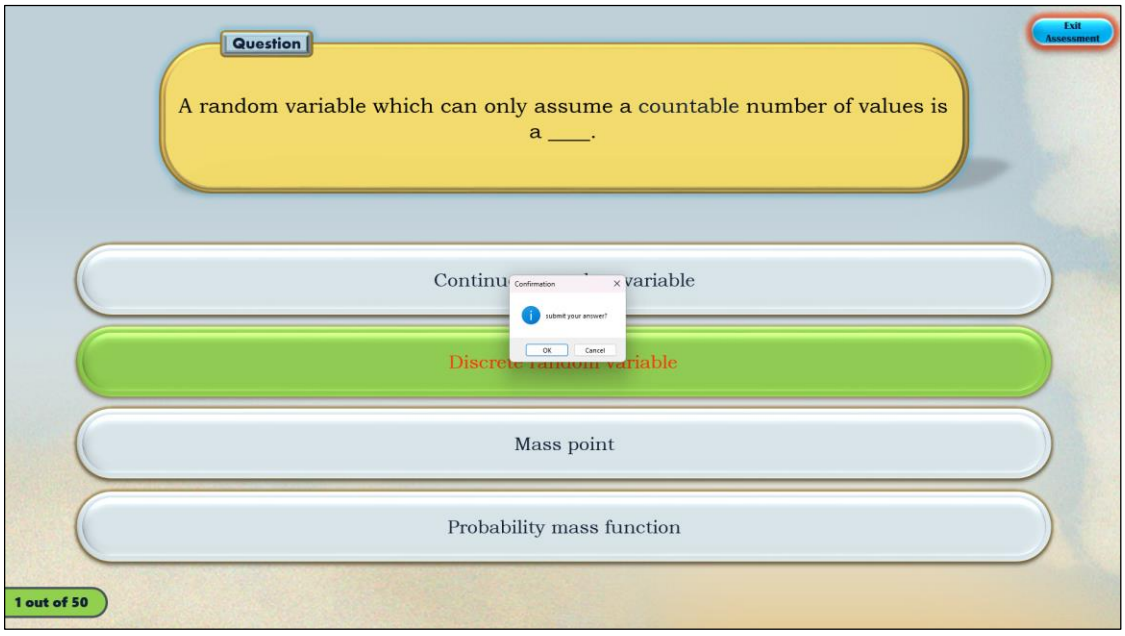
Data entry of necessary information for assessment takers



The tool does not require an internet connection. This can help prevent students from cheating. Because this will be administered through computer labs, teachers will have complete control and may restrict internet access so students cannot search for answers online.

Figure 4

Assessment question layout



Shuffling of choices. This feature can discourage students from copying their seatmates' answers.

Changing of answers. Students can change the answer if they accidentally click the wrong button. Teachers can easily give instructions to students because of the dialogue box that pops up whenever a user mistakenly clicks a wrong button.

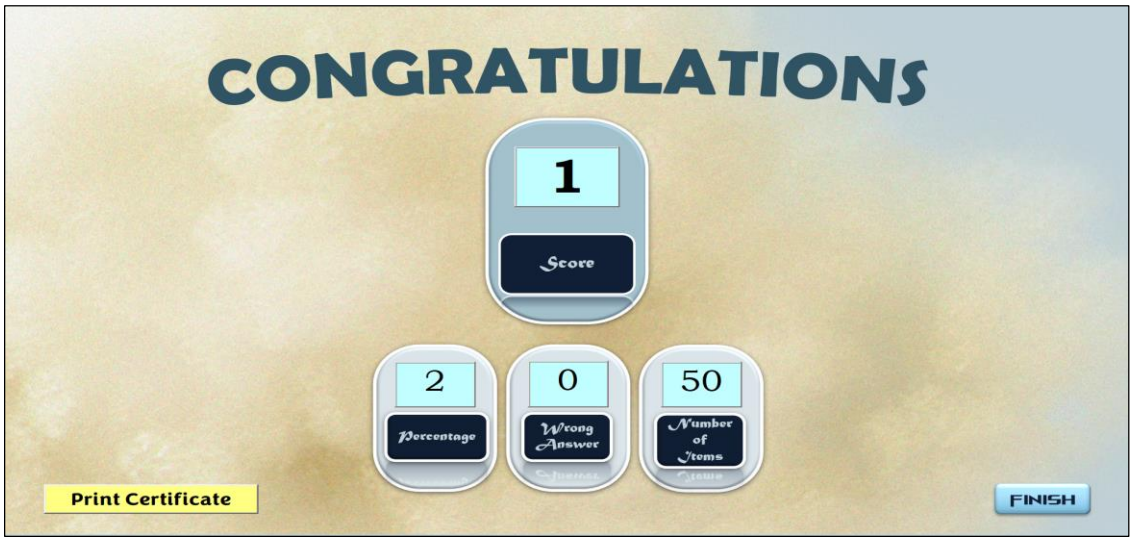
Exit assessment button. A button that leads to results if the test taker decides to terminate the exam early. Teachers can quickly provide directions to students since there are command buttons that are easy to understand.

Figure 5

View results layout

Figure 6

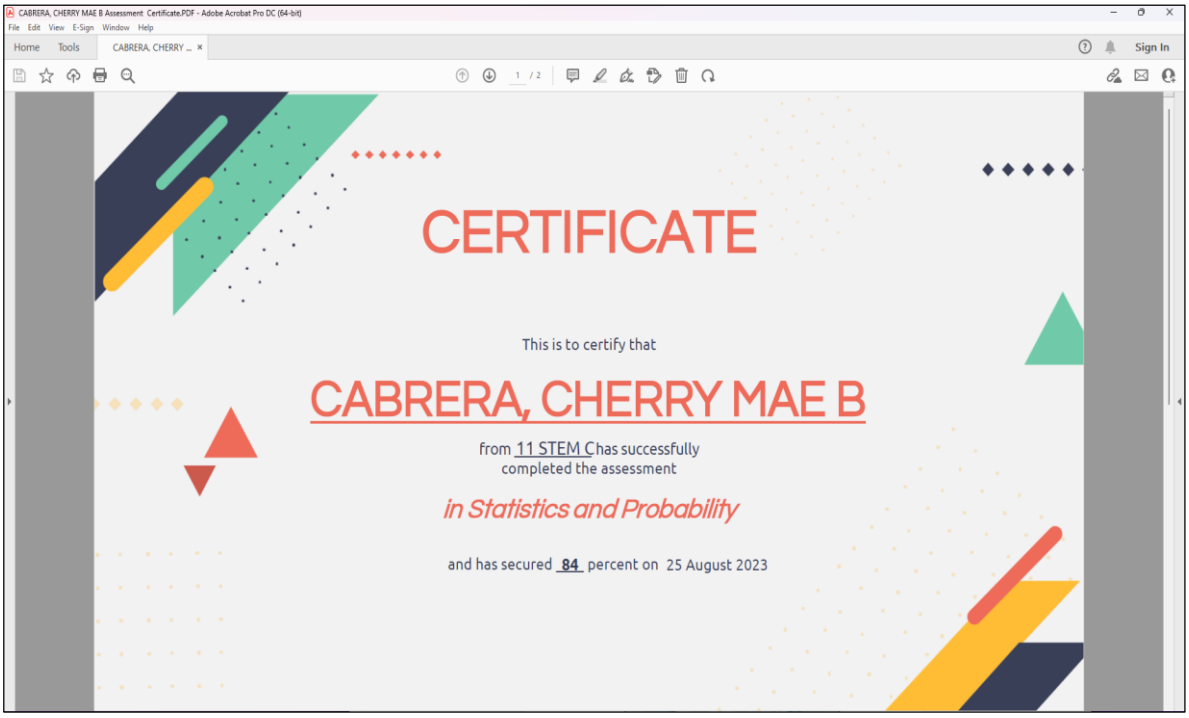
Results layout for assessment takers



It displays the taker's total score, number of missed questions, and percentage after the assessment. The immediate results will attract students' interest. Teachers can quickly harvest scores and prepare grading sheets on time.

Figure 7

Certificate of assessment passers layout



There is a button that generates a certificate if the test taker scored 60% or more.

Figure 8

Excel's data collection layout

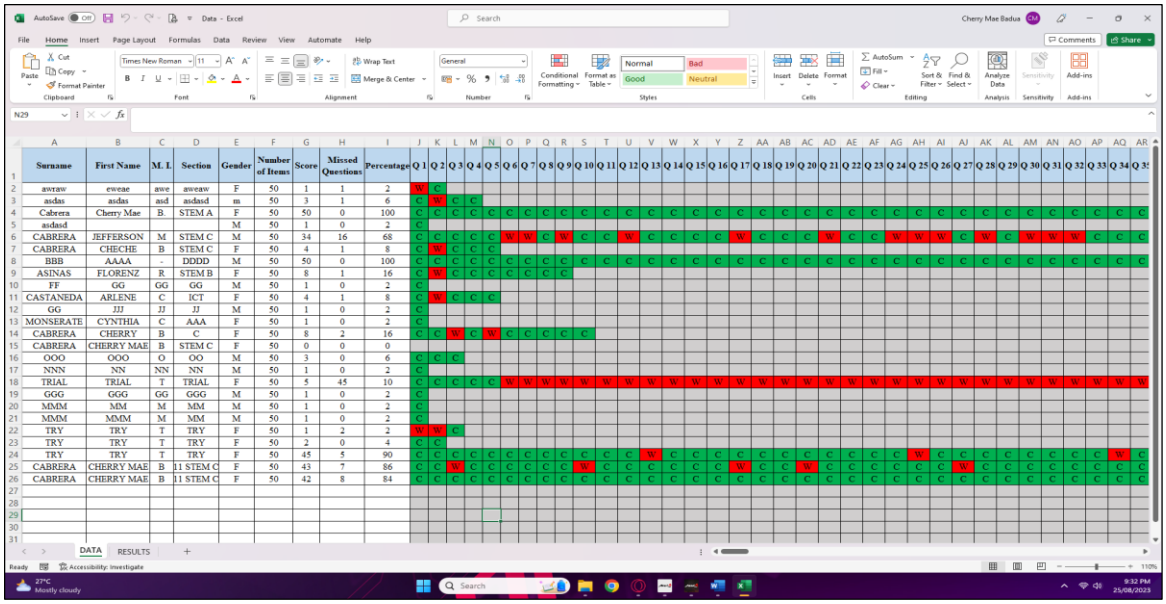
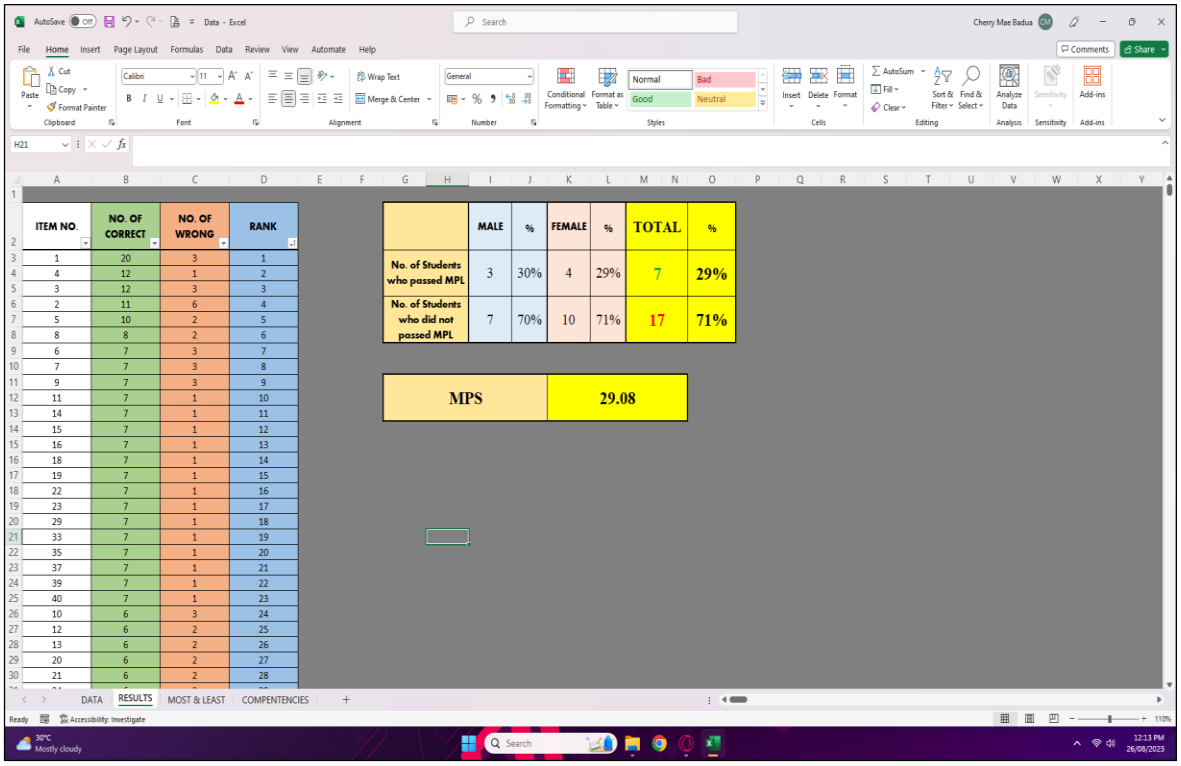


Figure 9

MPL and MPS results layout using Excel



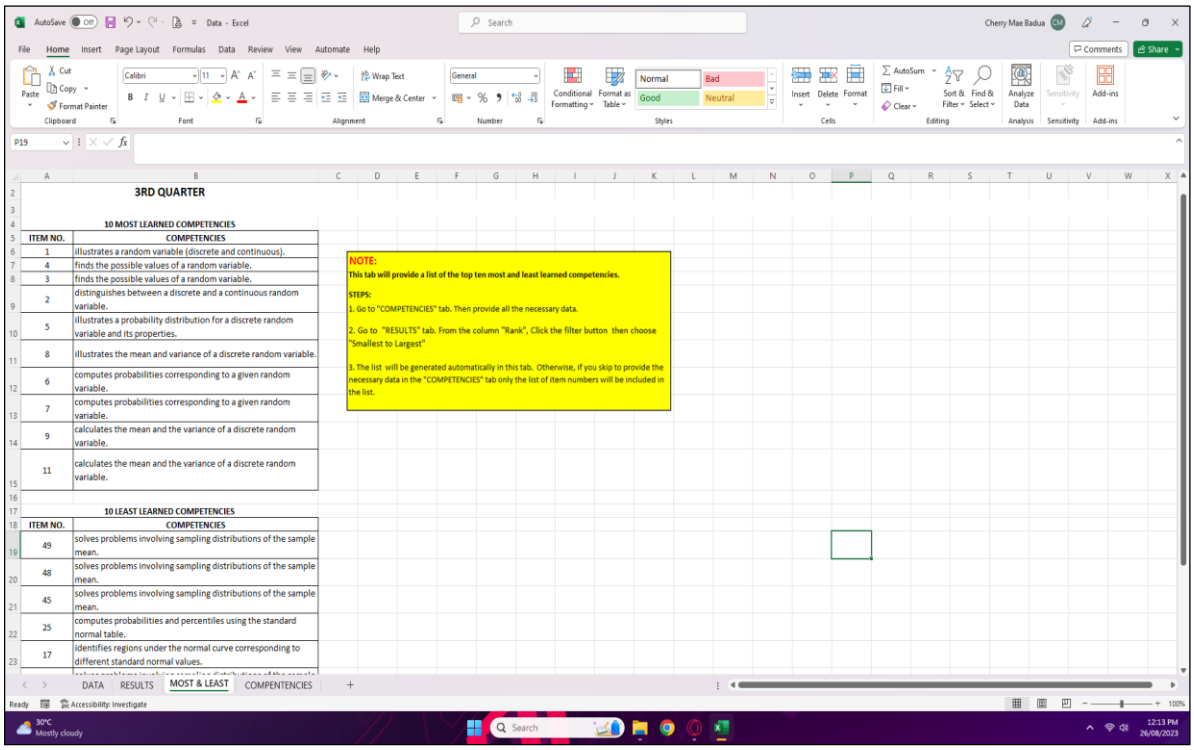
ITEM NO.	NO. OF CORRECT	NO. OF WRONG	RANK
1	20	3	1
4	12	1	2
3	12	3	3
2	11	6	4
5	10	2	5
8	8	2	6
6	7	3	7
7	7	3	8
9	7	3	9
11	7	1	10
14	7	1	11
15	7	1	12
16	7	1	13
18	7	1	14
19	7	1	15
22	7	1	16
23	7	1	17
29	7	1	18
33	7	1	19
35	7	1	20
37	7	1	21
39	7	1	22
40	7	1	23
10	6	3	24
12	6	2	25
13	6	2	26
20	6	2	27
21	6	2	28

	MALE	%	FEMALE	%	TOTAL	%
No. of Students who passed MPL	3	30%	4	29%	7	29%
No. of Students who did not passed MPL	7	70%	10	71%	17	71%

MPS	29.08

Figure 10

List of Most and Least Learned Competencies layout using Excel



3RD QUARTER

10 MOST LEARNED COMPETENCIES

ITEM NO.	COMPETENCIES
1	illustrates a random variable (discrete and continuous).
4	finds the possible values of a random variable.
3	finds the possible values of a random variable.
2	distinguishes between a discrete and a continuous random variable.
5	illustrates a probability distribution for a discrete random variable and its properties.
8	illustrates the mean and variance of a discrete random variable.
6	computes probabilities corresponding to a given random variable.
7	computes probabilities corresponding to a given random variable.
9	calculates the mean and the variance of a discrete random variable.
11	calculates the mean and the variance of a discrete random variable.

NOTE:
This tab will provide a list of the top ten most and least learned competencies.

STEPS:
1. Go to "COMPETENCIES" tab. Then provide all the necessary data.

2. Go to "RESULTS" tab. From the column "Rank", Click the filter button then choose "Smallest to Largest"

3. The list will be generated automatically in this tab. Otherwise, if you skip to provide the necessary data in the "COMPETENCIES" tab only the list of item numbers will be included in the list.

10 LEAST LEARNED COMPETENCIES

ITEM NO.	COMPETENCIES
49	solves problems involving sampling distributions of the sample mean.
48	solves problems involving sampling distributions of the sample mean.
45	solves problems involving sampling distributions of the sample mean.
25	computes probabilities and percentiles using the standard normal table.
17	identifies regions under the normal curve corresponding to different standard normal values.

There is an Excel file that stores all the data of the assessment takers, such as the name of the student, section, score, and percentage, and questions with corresponding labels (correct or wrong). This also includes the MPS result and the number of students correctly answering each item. This saves time for teachers to complete other tasks by making it simple for them to record and analyze test results and generate assessment-related reports on time.

3.3.2. Programming the codes using VBA and Macros

All the functionalities and features of the CBA tool were incorporated by allowing all the macros to run and using the VBA as a programming language. The codes are programmed by customizing the ribbon and adding the developer tool where all the codes are created. Each functionality was carefully programmed to make it easy for the user to navigate and understand each command button in the assessment tool.

Figure 11

Codes for collecting the test takers' information

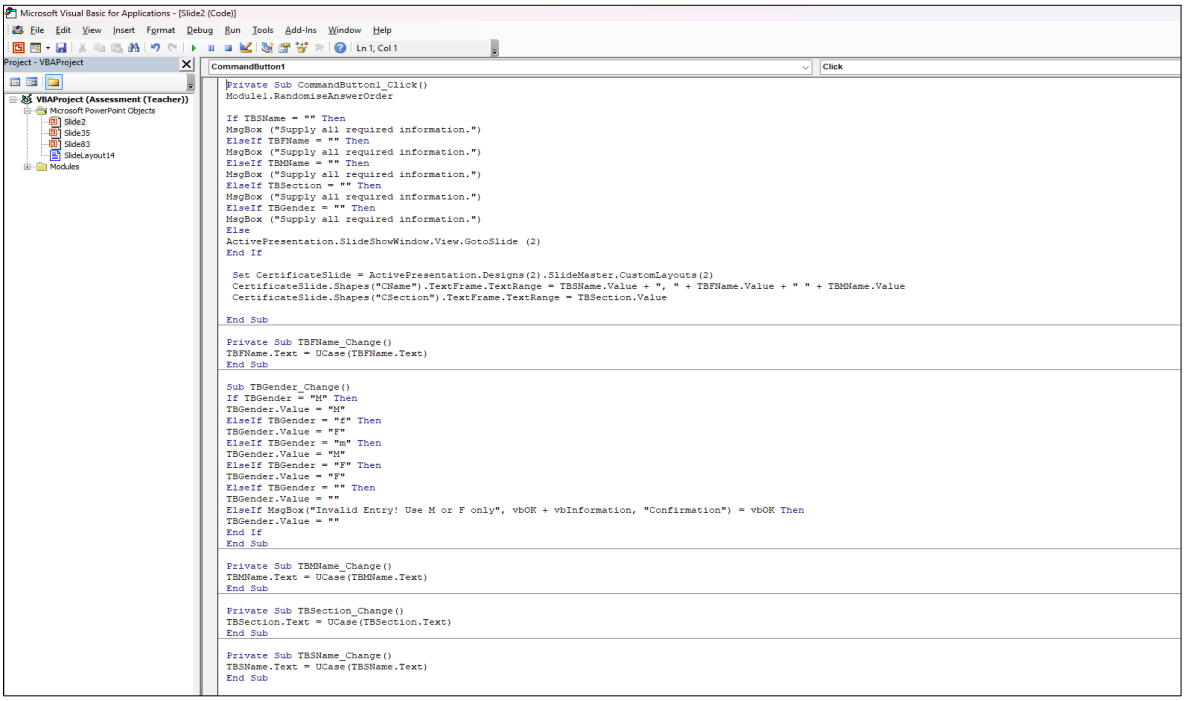


Figure 12

Codes for generating certificates for test takers

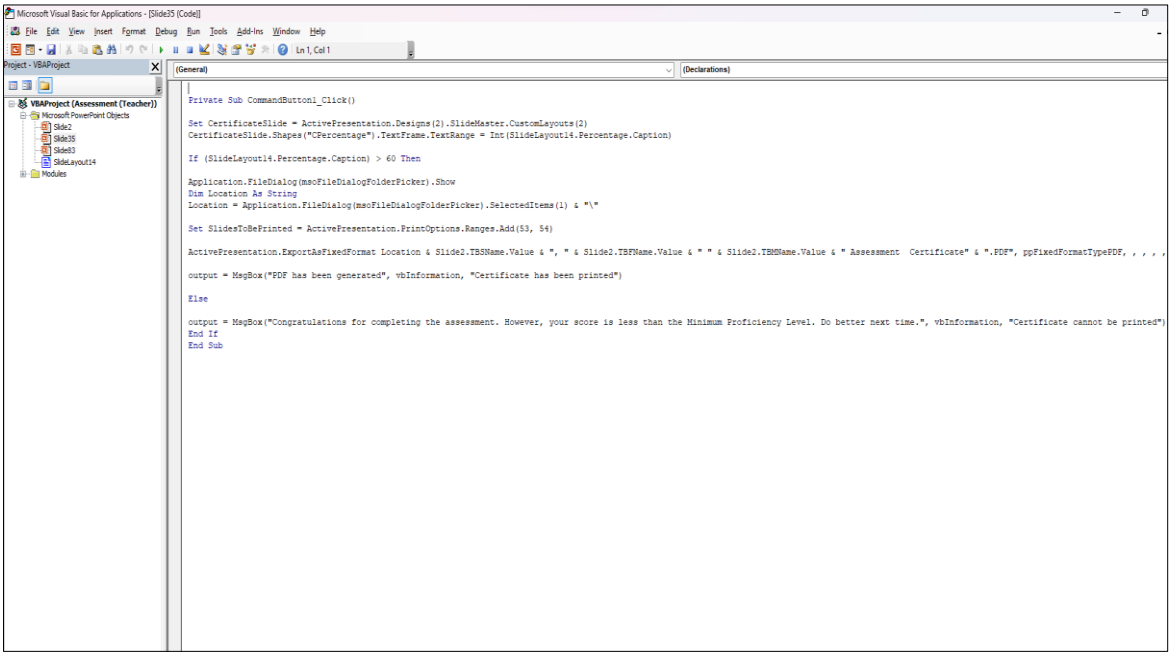


Figure 13

Codes for linking the results to the Excel file

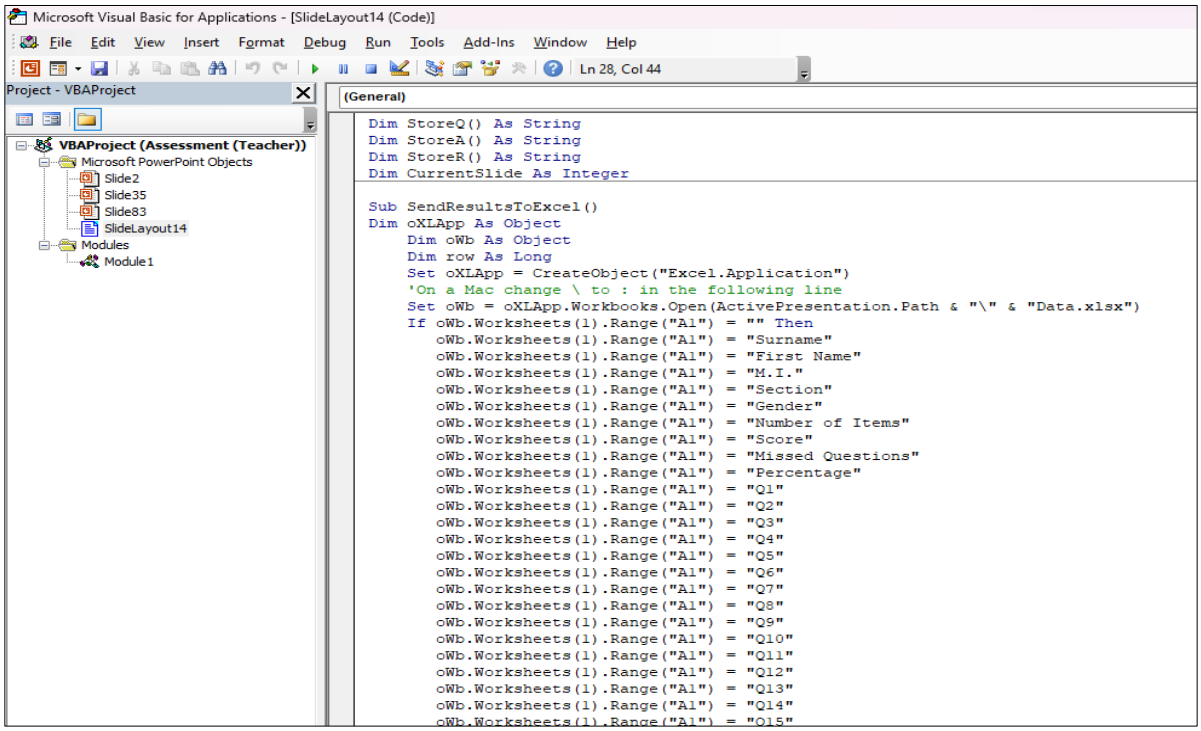


Figure 14

Codes for calculating the score of the test taker

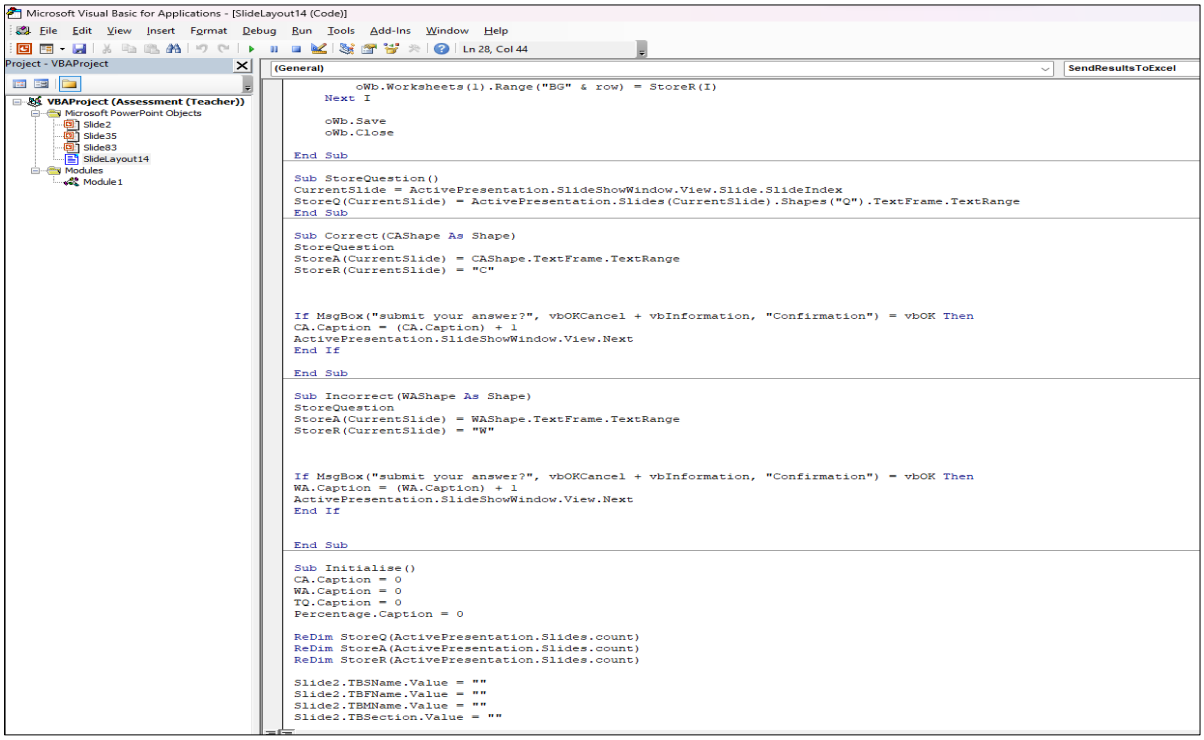


Figure 15

Codes for the shuffling of choices

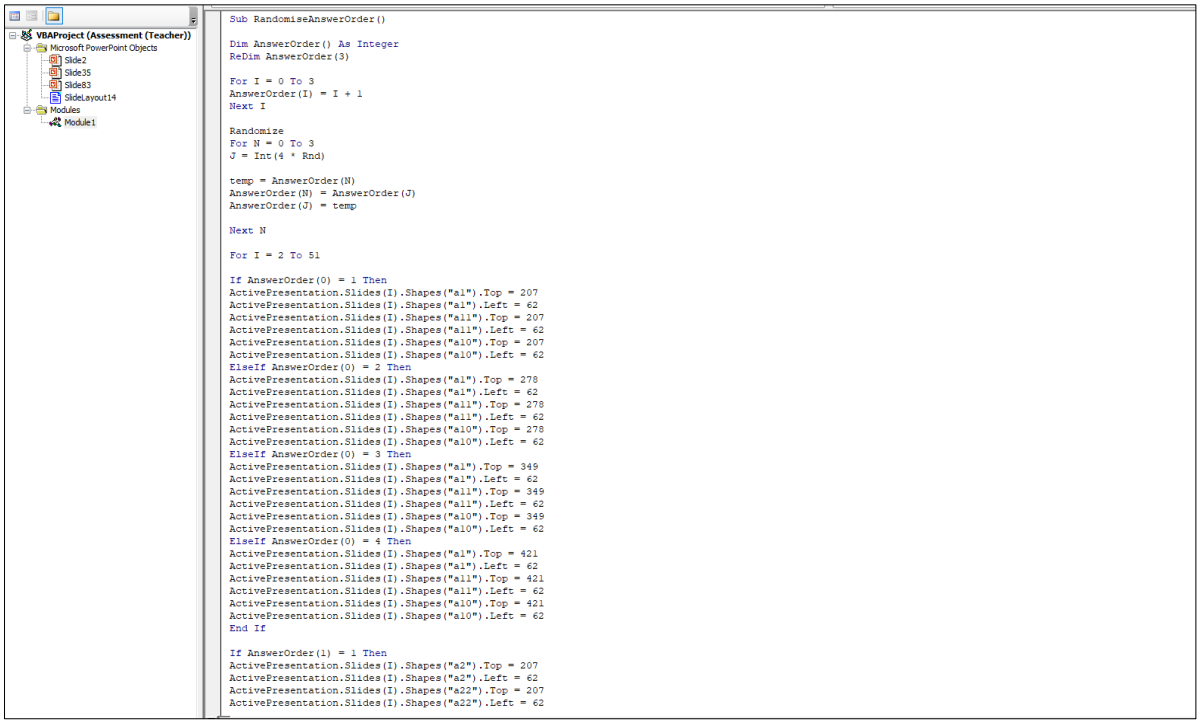


Figure 16

Codes for the navigation and functionalities of buttons of the CBA tool

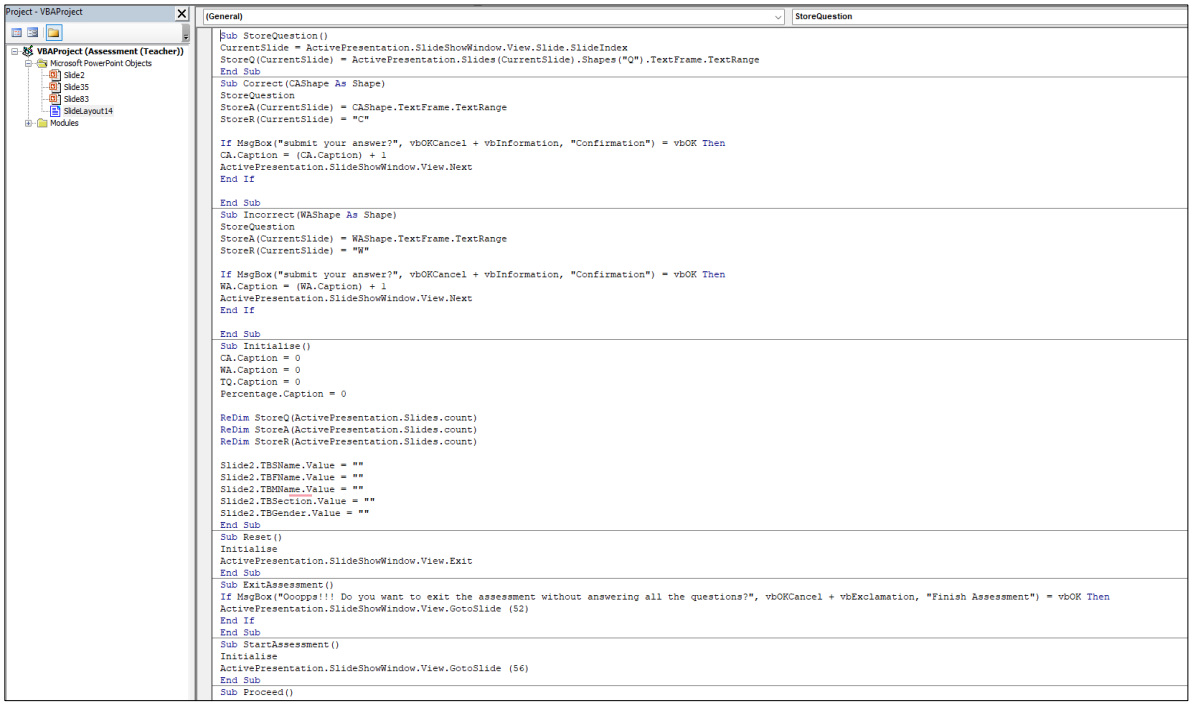
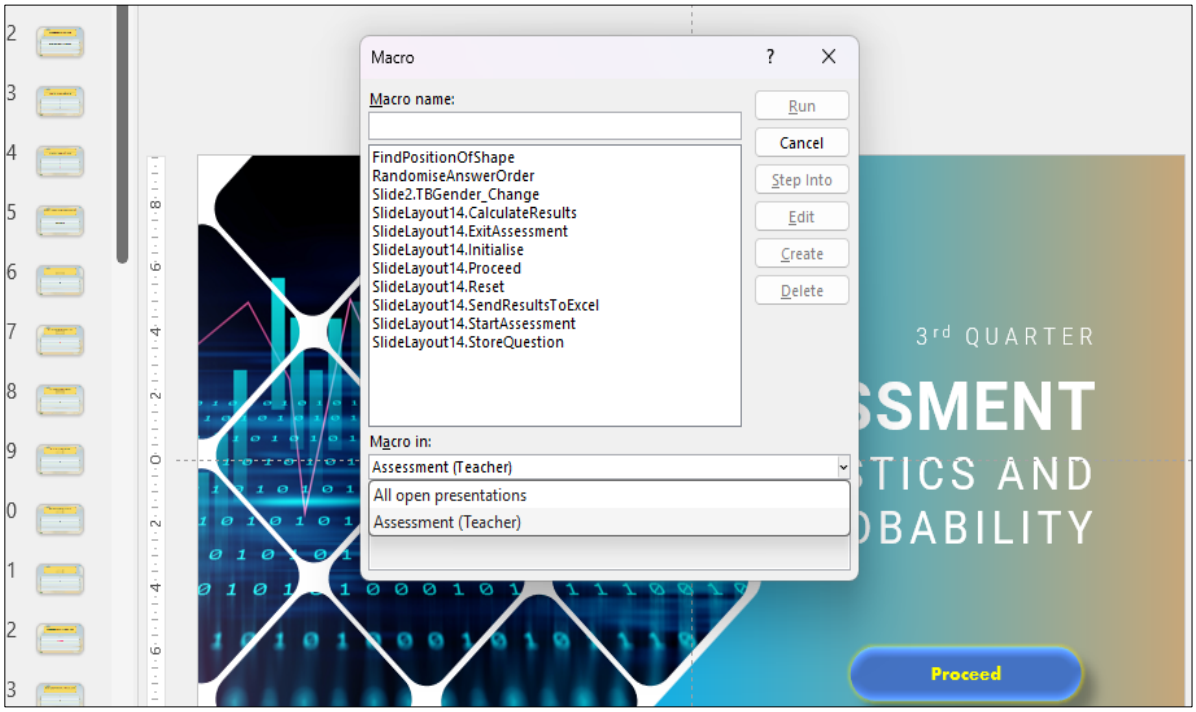


Figure 17

Macros setting of the CBA tool



3.4. Offline Computer-Based Assessment tool validation

Table 2

Validators' assessment of the CBA tool

Criteria	CVI	Interpretation
Functionality	1.00	Valid
Usability	0.90	Valid
Efficiency	1.00	Valid
Technicality	0.95	Valid
Accessibility	0.85	Valid
Overall CVI	**0.94**	**Valid**

Results indicate that the developed CBA tool is valuable and can help teachers to perform better. Parallel to the results found by Shute and Rahimi (2017) with CBA, teachers will have more time to perform other teaching-related tasks and be able to offer individualized learning opportunities to students. In addition, Joy (2023) concluded that computer-based tests save administration time and resources by creating easy-to-transfer digital records of student progress and development while Blundell (2021) explained that using digital technology in school-based assessments has a promising future. There is more opportunity to do so with the rising use of digital devices in schools. This demonstrates that the CBA can present many opportunities for the teaching and learning process in raising the quality of education. Overall, the offline CBA tool in Statistics and Probability received positive feedback from the validators regarding its usefulness in helping teachers prepare assessment-related reports. As a result, educational institutions should consider adopting the tool.

4. Conclusion and Recommendation

An innovative approach using offline CBA tools can assist teachers in addressing the issues on the difficulties in conducting quarterly assessments and preparing assessment-related reports. The CBA tool was designed following the 50-item, multiple-choice test utilizing MS PowerPoint and MS Excel with the following features: offline setting, shuffling of choices, changing of answers, exit assessment button, immediate results display, passers certificate, and data collection. Based on the experts' assessment, the developed CBA tool is

valid regarding functionality, usability, efficiency, technicality, and accessibility. Using CBA can help educators generate accurate and timely assessment results. However, one of the primary challenges is computer availability and the ICT knowledge of teachers and students.

Schools with a number of students should consider adopting innovative approaches like CBA to prevent assessment issues. However, they should provide students and teachers with basic ICT knowledge through training and workshops to successfully utilize CBA. Furthermore, the school administration may plan strategies to schedule and assign the students who will participate in CBA if there are not enough computers available.

Implementing the developed CBA tool can help establish further the validity of the tool and the reliability of the results. The tool can be further enhanced by exploring different types of tests and modifying the program settings, like adding a time limit and shuffling questions that may be incorporated according to the type of test. Similarly, future developers may utilize Microsoft Excel in encoding the questions and choices to avoid the deformation of the design in PowerPoint in creating CBA tools.

Acknowledgment/Declaration

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ChatGPT: Towards Educational Technology Micro-Level Framework

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Abstract

The study explores the role of ChatGPT in the development of a micro-level framework for Educational Technology (EdTech). This study employed an inductive research design particularly a Constructivist Grounded Theory (CGT) approach from thirty-four private secondary high school teachers in the Philippines. To gather insights from specific participants, a semi-structured interview format was utilized. The instrument went through face validation from two experts well-versed in education research, instrumentation, and three-stage prompts. In addition, using JAMOVI software, *Fleiss' Kappa* was used with a value of 0.715 indicating a substantial agreement among the expert validators. The interviews were designed to be open-ended, allowing for a flexible exploration of the research topic then subjected for data analysis with the aid of QDA Miner lite software. The findings revealed three (3) distinct milieux: pedagogical support, professional development, and ethical sense. In the (a) pedagogical support milieu, ChatGPT emerges as a virtual compass, offering real-time assistance, explanations, and guidance for teachers. It demonstrates the capability to answer questions, clarify concepts, and provide step-by-step support, crafted to individual students' needs and learning styles; within the (b) redesigning milieu, it serves as a catalyst for adapting and recalibrating assessment and teaching strategies to suit learning purpose; and (c) ethical sense milieu highlights various implications, including data privacy, plagiarism, transparency, accountability, and overly reliant to the AI tool. Thus, this paper offers a micro-level framework anchored to the ChatGPT's role in EdTech and aims to stimulate further scholarly discourse in the field.

Keywords: *ChatGPT, artificial intelligence, qualitative, constructivist grounded theory, educational technology, framework*

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1. Introduction

Educational technology (EdTech) today is not merely confined to chalk and board method, but it represents technology-based spectrum of digitization with educational theory designed for enhancing the 21st century skills. More than the tools with theoretical foundations that underpin design and implementation where it meets with pedagogies (Andriole, 2020; Mirrlees & Alvi, 2019), the premise is that a theory provides the framework through which educators comprehend, evaluate, and optimize any technological interventions in education. Concurrently, ChatGPT aims to improve the educational landscape by reinventing interactive support. ChatGPT is a pervasive Artificial Intelligence (AI) tool, its acronym derived from "Chat Generative Pre-trained Transformer," symbolizes a groundbreaking language model by Open AI. From an argumentative perspective, the advent of ChatGPT has changed natural language generation. A quick history drop tells that it is a sophisticated computer program that utilizes the transformer architecture (Montenegro-Rueda et al., 2023; Vaswani et al., 2017). In layman's term, it is designed to mimic and generate human-like conversation, enabling it to engage with users and perform processing tasks like translation, answering questions, and generating sentences based on user inputs and prompts.

Undeniably, ChatGPT emerges as a versatile tool with significant potential for supporting open education by providing feedback for self-directed learners. As such, its ability to recommend fueled learning materials and resources for teachers assists learners in accessing the most suitable information to enhance their knowledge acquisition (Cain et al., 2023). It is worth noting that while ChatGPT already offers valuable educational uses, there are further untapped possibilities for its integration in the future. However, as EdTech continues to expand and redefine how teachers utilize ChatGPT for learning, a noticeable void emerges – the absence of comprehensive theoretical framework that can guide its implementation at the micro-level of education.

A theoretical framework is essential at the micro-level of education as it provides a systematic approach to addressing the complexities of diverse learning environments. It offers guidance, promotes consistency, and helps educators navigate the challenges associated with individualized instruction, classroom management, assessment, and cultural sensitivity. The absence of such a framework can lead to adhoc practices and a lack of coherence in educational strategies, potentially hindering the quality of education at the

micro-level. This prompted the researchers to embark on contributing a framework covering ChatGPT's role in EdTech. This contribution is rooted in the recognition that, while the potential of AI in education is abundant, the lack of well-defined theories serves as an impediment to its realization. Hence, this study provides an overview of the growing significance of ChatGPT as part of EdTech and highlights the need for research exploring the perspectives of high school teachers and introduces constructivist grounded theory as suitable research design.

This study examines the timeliness and relevance of utilizing grounded theory as a research design to investigate the educational applications of ChatGPT in the context of high school education. Consequently, providing a theoretical framework from a grounded theory to educational research focused on ChatGPT, with a specific focused on the perspectives of high school teachers.

2. Literature Review

2.1. ChatGPT as a Subset Useful Tool in Education

The topic of AI is broad; it covers automation, data analytics, changing technological tools, and a variety of applications. The development of AI systems has been aided in part by what are known as large language models (LLMs), which are essentially language-based power chatbots like Google's Bard and Microsoft's Bing Chat. On the other fence, ChatGPT has become famous integral part of various industries, and the field of education is no exception. It can be employed in diverse tasks, from personalized learning and tutoring to language acquisition, research assistance, and even mental health support. Its adaptability and accessibility make it a valuable resource, enabling students and educators to access information and assistance 24/7, regardless of their location or time zone. Furthermore, Haluza and Jungwirth (2023) predict that these megatrends will persist as the twenty-first century advances.

In the field of education, ChatGPT is a useful tool for teachers in a variety of micro tasks and effective research and instructions. For tasks like essays, literatures, and even computational problems, it can be utilized to develop lesson plans. To assist teachers in providing their students with better instruction, ChatGPT offers topic-specific graphics, activities, and exercises. Teachers can use ChatGPT to offer their students individualized learning support. Depending on the needs and learning preferences of a student, ChatGPT

can also provide specific resources and procedural instructional activities. The ChatGPT model's strength can also be used by teachers to grade quizzes and assignments given to students (Rahman & Watanobe, 2023).

2.2. ChatGPT in Relation to Educational Landscape

According to Zhai (2023), the rise of AI has catapulted upheaval in the educational scene directly to the use of ChatGPT in education and opened new possibilities for interactive learning, allowing users to engage in dynamic conversations *vis-à-vis* the AI-powered system. This change is anticipated to have a systemic impact on educational objectives, curricula planning and methods, assessment and learning articulation. The world's educational agenda have changed dramatically over the past ten years, mostly as a result of technological improvements (Grassini, 2023; Neumann et al., 2023). The convergence of AI and education has provided revolutionary possibilities, and ChatGPT stands out as a major participant in this ever-changing field. Because of AI's versatility, accessibility, and responsiveness to individual needs, students and teachers can use it in a varied and inclusive educational context. Mhlanga (2023) claims that integrating ChatGPT when decided by teachers, can aid through providing them with helpful resources and enlightening knowledge that can help them enhance their teaching efficiency. This is in contrast to the argument of Hofer and Grandgenett (2012) that primary obstacles to the effective integration of EdTech in the classroom are external factors that lie beyond the decision of teachers. These external barriers necessitate institutional-level attention and often entail gradual changes.

In macro stance, it is opining that students' learning outcomes and experiences could be enhanced by the use of ChatGPT in educational settings, particularly in developing countries where access to high-quality education is limited (Peres et al., 2023; Qasem, 2023). ChatGPT serves as more than just a mentor or tutor; it becomes a constant source of support and guidance during the learning process and instructional preparations aid (Hwang & Chen, 2023; Ibrahim et al., 2023; Javaid et al., 2023; Seaba, 2023).

2.3. Challenges and Opportunities: Academic Integrity Is at Stake?

Offering promise of enhanced learning experiences, personalized instruction, and access to vast amounts of information, EdTech has undoubtedly opened new horizons in the surface of education. However, the use of AI in education is not without its challenges, one

of which is the educational polarization. One side may strongly support the advancement, and the other end spectrum strongly inhibits. However, from bibliometric analysis, it also presents challenges related to depersonalization, potential loss of pedagogical expertise, ethical concerns, and the need to balance standardization and creativity within the educational framework especially when assessment of work is on the line (Montenegro-Rueda, 2023).

ChatGPT poses to more established forms of evaluating written work, like essays, still it is one of the main arguments against using it to grade written assignments. The plagiarism detection tool and paraphrasing tests offered by ChatGPT have good matching rates (Aydn & Karaarslan, 2022). This makes it rather evident that ChatGPT plagiarizes and then writes original content. All of this may constitute "paraphrasing plagiarism," as it is called. Due to the difficulty in identifying instances of plagiarism, some educators are worried (Duha, 2023; Rudolph et al., 2023). Additionally, Lo (2023) advises that teachers be given upskilling on how to use ChatGPT efficiently to distinguish plagiarism in student work. Students are encouraged to determine or balance of ChatGPT's capabilities, limitations, and potential negative consequences on academic integrity.

Educational institutions prioritize the development of critical thinking, research skills, and original thought. According to Mhlanga (2023), the ability of ChatGPT to write essays opens the door for the employment of novel and cutting-edge techniques in educational contexts. Despite of the applaud, AI models can produce biased or unfair results due to the biases present in their training data. This is of great concern in sectors where decisions must be just and equitable. In finance, for instance, AI models can inadvertently perpetuate existing financial disparities. The potential for biases raises questions about accountability and transparency, and it can be difficult to pinpoint responsibility for AI-driven decisions. Also, putting into context, the foremost concern in academia is maintaining academic integrity. ChatGPT can be used to generate essays, answer test questions, or complete assignments, raising concerns about plagiarism and eroding the fundamental values of academia. Nonetheless, some institutions have thus opted to restrict the use of AI models in student work to preserve academic integrity (Greitemeyer & Kastenmüller, 2023).

2.4. ChatGPT: Future Trends in Education

As ChatGPT rise rapidly for wide audience, it opens a flexible conversational AI model, leading the way to inevitably transform education (Neumann et al., 2023). This can be said that the future of education is set to be shaped by this transformative technology, with a host of emerging trends poised to redefine how students learn, teachers instruct, and educational institutions operate. According to Zhai (2023), AI and ChatGPT are key components of the modern education revolution, with significant ramifications for both talent development and national competitiveness. With the use of these technologies, education will undergo a radical change that would produce future engineers, scientists, and citizens more equipped to satisfy the demands of society (Garcia-Penalvo, 2023; Rummel et al., 2016). Additionally, utilizing AI tools like ChatGPT can promote multi-perspective understanding, recalibrating curricula, and endless talk of discussions in the academe (Seaba, 2023).

The teachers' utilization of technology in the classroom can vary, either encompassing its comprehensive integration into the curriculum or its application to enhance specific lessons. These differences in technology adoption reflect underlying disparities in educators' perceptions of technology's relevance in the educational process. Ertmer et al. (2012) emphasize the alignment between teachers' technology integration practices and their beliefs, indicating that teachers tend to implement technology in accordance with their convictions. These convictions are substantially shaped by educators' philosophies concerning student learning. If a teacher subscribes to the notion that student learning predominantly hinges on direct teacher-led instruction, their classroom practices are likely to be guided by conventional teaching methods.

According to Zhai and Pellegrino (2023), educational objectives are set based on societal demands and must anticipate and educate students for citizenship in the future. AI has become a part of every aspect of society with the introduction of AI technology and programs like ChatGPT. As a result, it is noteworthy education address and provide a solution for the pressing problem of raising future citizens who can adapt to future societal evolution and are skilled in comprehending and utilizing AI technology.

2.5. ChatGPT on the Cusp of Information Generation for Learning

Based on the study of Lund and Wang (2023), the integration of ChatGPT in education has brought about substantial improvements in creative aspect, leading to increased

effectiveness and efficiency in educational management particularly preparing for different ancillaries. This application has not only facilitated global learning but also enabled personalized learning experiences, development of more intelligent educational content, and streamlined overall educational process. ChatGPT stands out as a pioneering example of AI technology, particularly free access making door to enhance creative skills within the educational landscape.

Despite an eerie stance for ChatGPT capacities, Garcia (2023) echoes the growing interest surrounding ChatGPT's role in education. It is lauded for its ability to enhance students' learning by providing immediate feedback, responsiveness to student needs, and offering timely assistance to grasp challenging subjects. Consequently, ChatGPT has evolved into a valuable educational tool not a direct producer of creative content but more on the active repository of information, actively engaging students, offering continuous support in their quest for knowledge.

At the outset, much research has attempted to investigate the possible effects of AI at large, particularly in relation to education and the well-known ChatGPT tool for students (Garcia-Penalvo, 2023; Hwang & Chen, 2023). Numerous applications were examined, including chatbots, adaptive testing, tailored learning experiences, and predictive analytics. A number of studies have looked into the use of chatbots in education, highlighting their ability to improve learning experiences, provide tailored help, and improve services (Okonkwo, 2021; Peres et al., 2023). These researches identified and evaluated numerous forms of educational chatbots, including those that serve as service assistants or instructional agents (Smutny, 2020; Pérez, 2020). As a result, it may demonstrate perceived increase learning effectiveness and provide direct personalized educational support. It is discussed to take into account the risks and restrictions as well (Atlas, 2023; Ibrahim et al., 2023; El-Seoud et al., 2023; Lund & Wang, 2023).

2.6. Bridging Existing Micro-Level Theories: A Modicum

A theory espouses a crucial role in providing researchers with a comprehensive grasp of the underlying principles and serves as the foundational framework for any research endeavor across diverse fields of study. However, Rivard (2021) argues that the common idealized view of theory in research as a complete and flawless explanation of a phenomenon

is unrealistic. Instead, he advocates for a more practical and iterative approach to theory building, emphasizing the pragmatic and evolving nature of theory construction in research.

As part of epistemological basis, micro-level frameworks in education indicate construct boundary among other broad scale theories which limit its parameter to the classroom and teaching learning processes (Bereiter, 2017). Borrowing from Bernstein's analytical framework, which emphasizes the presence of a curriculum and recognizing knowledge models, offers a valuable perspective for examining non-linear uncovering of educational technologies such as ChatGPT at the micro-level. Albeit this research enables how knowledge is conveyed and explored within educational interactions, it highlights the necessity of developing a timely micro-level theory in the field of EdTech, facilitating a more detailed analysis of how technology influences individual educational relationships and how teachers optimize instructions. Also, it sets the stage for a refined thought process and a robust belief in the research outcomes. This micro-level theory creation process is akin to paving grounded in sound principles and insights. To enrich this article prior to the theory building process, here are existing micro-level frameworks, not exhaustive list on EdTech:

Technological Pedagogical Content Knowledge (TPACK). The TPACK framework focuses on the intersection of the importance of educators efficiently incorporating technology into their instructional methods. While considering subject matter and pedagogical strategies, TPACK can help analyze how teachers' understanding of AI and educational technology influences their instructional decisions and student outcomes.

Unified Theory of Acceptance and Use of Technology (UTAUT). The UTAUT framework explores elements impacting people's acceptance and utilization of technology. It recognizes crucial factors including anticipated performance, ease of use, and supportive conditions. Applying UTAUT can help understand teachers' attitudes, intentions, and behaviors regarding the adoption and use of AI-based educational technologies.

Community of Inquiry (CoI). The CoI framework focuses on the collaborative development of knowledge in online different contextual environments.

The T3 framework. In education, it refers to the Technology, Pedagogy, and Content Knowledge framework. It is a model that guides educators in integrating technology effectively into their teaching practices. The T3 framework emphasizes the interplay between

technology, pedagogy, and content knowledge, highlighting the need for educators to have a balanced understanding and integration of these three components (Magana, 2020).

These frameworks offer theoretical lenses to investigate various aspects of educational technology in AI, including teacher knowledge and integration practices, technology acceptance and adoption, and online collaborative learning. But as a new horizon arises, new theory may be formed as the Education 4.0 is on the verge of AI, particularly with the pervasive use of ChatGPT in the teaching instruction.

3. Methodology

A grounded theory approach was employed in this research because the researchers systematically uncover the complexities and generate insights into the educational uses of ChatGPT, contributing to the field of educational technology and fostering evidence-based practices. Grounded theory has faced criticism for its perceived lack of quantitative elements in comparison to other research methodologies (Corbin & Strauss, 2008). However, critique overlooks the rigorous foundations of this approach, which position it not solely as qualitative research but as an inductive process. In the context of this study on educational technology using ChatGPT 3.0 or the latest models, grounded theory serves as a valuable approach for exploring and understanding the complex phenomena associated with the integration technologies.

This paper is motivated by the need for an emerging theory which prompted the researchers to follow Constructivist Grounded Theory (CGT) method, which allows to follow the data refinement and trace the events throughout the research process. This method emphasized the significance of social context, fostering a reciprocal relationship between researchers and participants, positioning researchers as active contributors to the data construction process ensuring a deep understanding of the studied phenomena patterned to several procedures (Chong & Yeo, 2015; Crotty, 1998; Karpouza & Emvalotis, 2019). To track the data in CGT, encoding and categorizing techniques were utilized. Employing constant comparison techniques, the researchers meticulously collected and analyzed data. Memo-writing was utilized to construct coding, analyses, and theoretical sampling emerging theoretical concepts, thus, offering flexibility in data collection. Overall, the study design aligned with the constructivist notion that knowledge is constructed through interaction.

Initially, the data for this study were collected from thirty-four (34) teachers associated with four private high schools in Candelaria, Quezon, Philippines who have at least five years teaching experiences either in the Junior or Senior High School level and identified to utilize ChatGPT versions 3.0, 3.5 or with premium subscriptions, in some capacity. Since Grounded theory does not emphasize having a predefined sampling process (Cronholm, 2002; Amir & Beaudry, 2023), still the researchers exercised rigorous theoretical sensitivity to obtain saturation.

To gather insights from specific participants, a semi-structured interview format was utilized. For the interview protocol, a crafted interview guide through a thorough collaboration with an instrumentation specialist was made, aimed to extract perceptions regarding the utilization of ChatGPT. The interview questions were designed to be open-ended to gain more detailed and reflective answers. The "what is/can?", “so what?” and "so what now?" prompts were utilized since these probing questions helped the interviewee's thoughts and encourage them to elaborate on their responses.

Establish connections and reflection. The prompt “*What is/can…?*” encourage interviewees to think more critically about their responses and consider connections of ChatGPT about their professions.

Clarify and elaborate. The "*So, what?*" prompts were injected clarify vague or general statements. This is to provide specific examples or details to support participants’ points.

Explore future actions or preflections. The *"So, what now?"* prompts can be particularly useful for exploring what actions or steps interviewees believe should be taken in light of their responses. This can be valuable for understanding potential solutions or constructing recommendations.

The instrument went through validation from two experts well-versed in education research, instrumentation, and qualitative grounded inquiry. In addition, using JAMOVI software, *Fleiss’ Kappa* was used in this process to assess the level of agreement among multiple expert validators when evaluating the interview protocol. *Fleiss Kappa* is a statistical measure used to quantify inter-rater or inter-observer agreement when multiple

raters or judges are involved in evaluating an interview protocol in this case. For this study, the *Fleiss Kappa* value is 0.715 indicated substantial agreement among the expert validators.

Each interview had a duration of approximately 30 to 40 minutes. To ensure accuracy and thorough analysis, the interviews were recorded using audio recording equipment and subsequently transcribed. In accordance with research ethics, the researchers provide detailed information about the study's objectives, procedures, and potential risks prior to the interview, and the voluntary and informed consent of participants be obtained. Confidentiality is strictly maintained, and participants are assured that they have the right to withdraw from the study at any point without facing any adverse consequences.

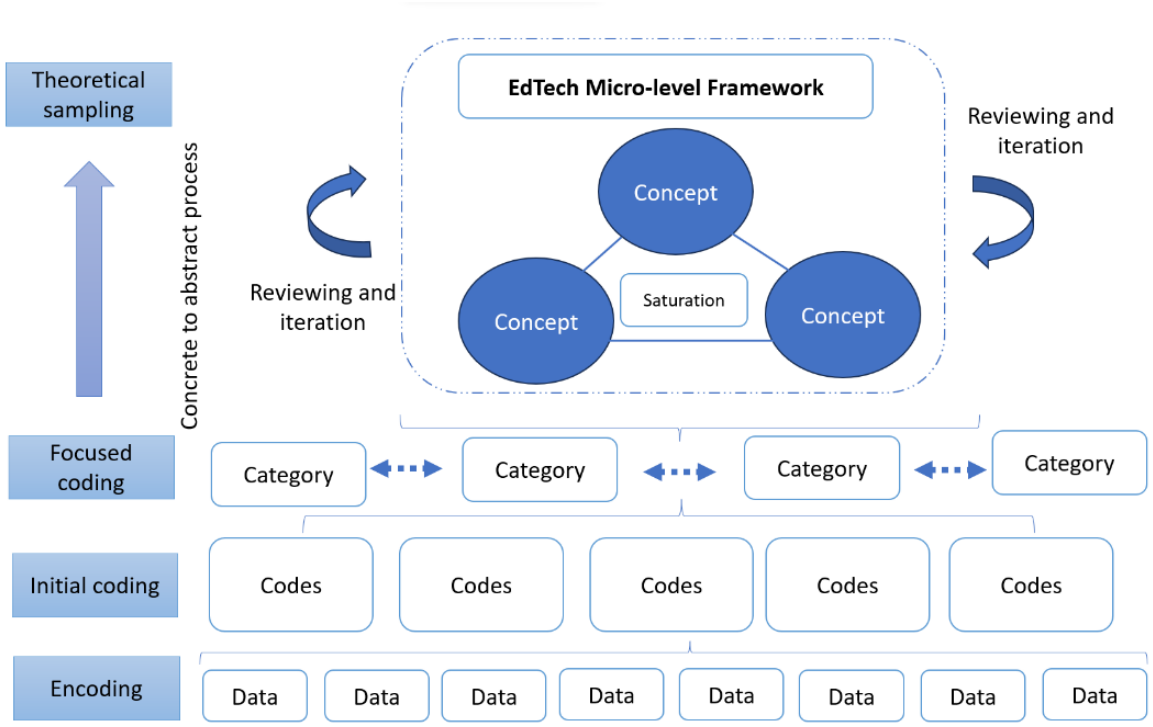
Table 1

Coding phases of CGT

Coding Phase	Focus	Steps
Encoding	Input of data	1. Retrieving, importing, and scanning of data. 2. Removing unnecessary elements (e.g., filler words, false starts, personally identifiable information)
Initial	Identify the expressions and experiences from the verbatim texts	1. Examine the data line by line to understand the actions or events described. 2. Generate codes by capturing the participants' responses and expressions as they appear in the data. 3. Generate process codes by describing "what's taking place?" in the data.
Focused	Identify the initial codes that appear frequently and then employing clustering before analyzing data in detail.	1. Identifying the meaningful or commonly occurring codes within the data. 2. Apply these focused codes comprehensively across the entire dataset and use them as organizing categories for grouping related data segments. 3. Analyze through appraising the data within each group associated with the focused codes. 4. Further refinement of the focused codes into initial concept that encapsulate the common themes or concept as emerging from the data. 5. Develop the properties and characteristics of each category, continuing the process until the data reaches a state of saturation, indicating that no new significant insights are emerging.

Figure 1

Visualization process of CGT



The coding process found in figure 1 was anchored to the Charmaz and Keller (2016) non-linear cohesive model. The study maintained an open-minded approach, remaining receptive to exploring various theoretical directions while there is a continuous refinement on the process since the coding system remains open and is not preconceived. As a result, the development of codes was achieved with the aid of QDA Miner lite application. This collaborative process results in an interpretive representation of reality within the research framework.

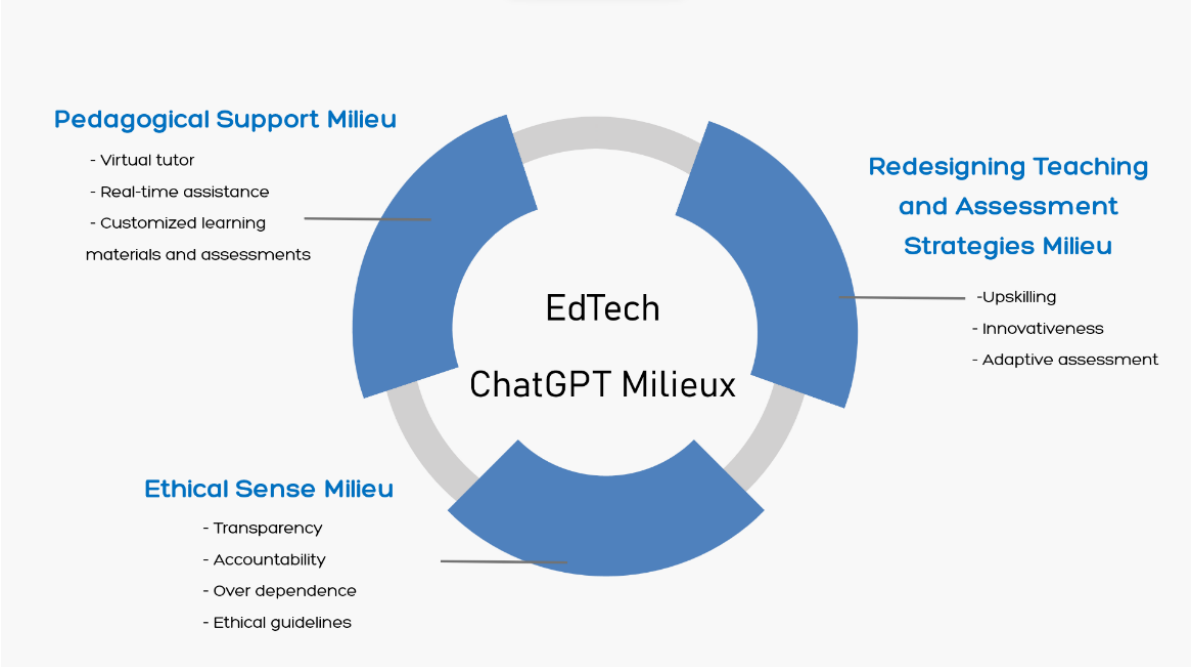
To support iterative and comparative analysis, subsequent round of interviews was delivered with a subset of ten informants selected from the initial participant pool. This simultaneous use of interviews and observations served to reinforce theoretical sampling that took one month to accomplish. The purpose of theoretical sampling is to gather sufficient and comprehensive data to establish theory(es) that pertain to the phenomena being investigated (Thornberg & Charmaz, 2014).

4. Findings and Discussions

Based on existing converging iteration with the participants, this section presents salient findings and emerging themes that arise from a CGT analysis of high school teachers' perspectives on ChatGPT. This study provides a suggested model from the findings.

Figure 2

Proposed model of micro-level framework



At the micro-level, a framework in educational technology refers to a specialized approach or model employed to comprehensively analyze and comprehend the utilization of technology within the educational sphere between how teachers confront ChatGPT onto the learning process. Unlike broader institutional or systemic perspectives, the framework is a non-sequential and non-linear paradigm which points general learning environment, such as a classroom, technological exposure, processes, and outcomes that transpire among learners, high school teachers, and other stakeholders. In granular level of examination, the micro-level framework, when taken together, provides insightful and in-depth understanding of how technology is effectively employed within educational contexts, enabling informed decision-making and impactful implementations as conceptualized by the secondary private school teachers.

The teachers have seen AI technologies from broad context, such as ChatGPT, offering unique opportunities for adaptive learning. They can provide tailored support, guidance, and immediate feedback to students' outputs, allowing for a more individualized approach to education. Through the analysis of user interactions, AI systems can understand learners' needs, preferences, and progress, and adjust their responses and recommendations accordingly. But from the coded responses in the context of educational technology, three milieux have emerged:

Pedagogical support milieu. Due to tumultuous workloads of teachers, ChatGPT act as a virtual guide, providing real-time assistance and explanations. It can answer questions, clarify concepts, and offer step-by-step guidance to support student learning. ChatGPT is seen to adapt its responses and resources to match the learning styles like offering customized exercises and learning materials based on the learners' needs. Primarily, teachers are using the technology for creating formative quizzes and grammar checking of materials. Thus, making feel teachers efficient in their works.

Redesigning teaching and assessment strategies milieu. This allows teachers to adapt their pedagogical approaches to individual student needs. Assessment techniques have been adaptive, with a departure from traditional standardized methods in favor of innovative, AI-enhanced assessments that focus on evaluating students' critical thinking and problem-solving skills. Also, continuous professional development has become essential, ensuring educators remain proficient in utilizing technologies.

Concern on ethical sense milieu. This sense comes to the looking glass self-process referring to the ethical considerations and concerns that arise with the use of AI in educational technology. These ethical implications encompass plagiarism, transparency, accountability.

3.1. Pedagogical support milieu

The theme of "pedagogical support milieu" emerged from the constant initial prompt of "*What is/can…?*" as a significant aspect in this paper. In the context of education technology and ChatGPT, this theme can be related to the role of educational technology in

providing pedagogical support within the learning environment. Through memo-sorting, here are some selected responses of the participants,

> *As a teacher, sobrang laking tulong ng ChatGPT. Para siyang kaibigan na laging handang tumulong. Sumasagot ito sa mga tanong, naglilinaw ng mga komplikadong problem, at nagpapaliwanag ng mga simpleng proseso. Parang kaibigan na kilala ka nang mabuti […] may personal na tutor sa math na kasama mo*. [As a teacher, ChatGPT is a huge help. It's like a friend always ready to assist. It answers questions, clarifies complicated problems, and explains simple processes. It is like a friend who knows you well [...] like having a personal math tutor with you.] *(Participant 04)*
>
> *Mabilis mag-simplify ng learning materials, lalo kapag ayos ang prompts.* [It quickly simplifies learning materials, especially when the prompts are clear.] *(Participant 13)*
>
> *Nakakatipid sa oras na puwede pa i-allot sa ibang productive tasks. Basta may internet connections.* [It saves time that can be allocated to other productive tasks, as long as there is an internet connection.] *(Participant 06)*
>
> *Hindi hassle ang paggawa ng learning materials lalo sa part ng assessment.* [Creating learning materials, especially in the assessment part, is not a hassle.] *(Participant 17)*

The transcribed interviews with teachers reveal the significant benefits of ChatGPT in instructional process, especially in simplifying and expediting the creation of learning materials, assessments, and providing personalized support to students. This aligns with the study's findings, demonstrating that ChatGPT serves as an efficient and effective tool for educators, allowing them to save time and resources while enhancing the learning experience through personalized assistance and resource generation.

ChatGPT, as an educational technology tool, can contribute to the pedagogical support milieu by offering various forms of assistance to students and educators. It can serve as a virtual tutor or mentor, providing personalized guidance and feedback to students. Through interactive conversations, ChatGPT can help clarify concepts, answer questions, and assist with problem-solving. This pedagogical support can be particularly beneficial in scenarios where individualized attention may be limited.

Furthermore, ChatGPT is perceived to guide the facilitations of educational resources and materials through selective suggestions. It can recommend an itemized learning material, provide explanations, and offer supplemental resources to supplement classroom instruction. This enhances the pedagogical support among teachers (Baidoo-Anu, 2023). Another, noteworthy category of ChatGPT is that it can foster collaborative learning environments by facilitating communication and discussion among students (Atlas, 2023). It is believed that it can be utilized as a platform for group interactions, allowing students to share ideas, engage in debates, and collaborate on projects. This social aspect of the pedagogical support milieu promotes active learning and knowledge construction.

Whilst ChatGPT can provide pedagogical support, its role reinstated to be complementary to human teachers. The generated responses do not provide cultural sensitivity and real-life applications but a generalized tone of suggestions. Wherefore, the presence of teachers is crucial to guide and contextualize the use of educational technology effectively. The pedagogical support milieu targets balance between the benefits of technology and maintaining the essential human element in education. Within the context of education, the "pedagogical support milieu" theme in the grounded theory framework highlights ChatGPT in facilitating access to resources, and collaborative learning environments.

3.2. Redesigning teaching and assessment strategies milieu

From the first theme, after participants contemplated their initial statements, this brought to uncover the second theme focused on the "*So what…*" prompt. Prior to this, three categories generated from the initial and focused coding are:

Adaptive teaching approaches. Teachers have embraced adaptive teaching approaches with the integration of ChatGPT. They have redesigned their instructional methods to align with the capabilities of AI, enabling personalized support and tailored content delivery. This adaptability has proven effective in addressing diverse learning needs among their students.

Dynamic assessment methods. The introduction of ChatGPT has prompted a shift in assessment paradigms. Teachers have moved away from traditional, uniform assessment methods and transitioned to more dynamic and personalized evaluation techniques.

Upskilling. Teachers have proactively engaged in upskilling, directly and indirectly, acquiring new skills and strategies to enhance their teaching as they acknowledge the value of different emerging EdTech.

Some testaments obtained are:

> *[…] to get authentic answers, teaching strategies ay dapat ding i-improve para makasabay tayo sa competencies.* [to obtain authentic answers, teaching strategies should also be improved to keep up with competencies.] *(Participant 19)*

> *Challenge ang pag-deliver ng lessons, kaya differentiated ang atake sa pagtuturo at hindi puro "the know lang" ang mga tanong kailangan may critical thinking kasi ang facts given at established sa online.* [Delivering lessons poses a challenge, so the teaching approach needs to be differentiated, and the questions should not solely focus on "the known." Critical thinking is essential because the facts provided are established online. *(Participant 27)*

The responses from the participants accentuate the teaching and assessment strategies as they grapple with the challenge of delivering authentic and engaging lessons; it becomes evident that a shift away from rote memorization towards more critical thinking and competency-based approaches is essential. This resonates with current educational research, emphasizing the need for pedagogical strategies that foster higher-order thinking skills, as outlined by Revised Bloom's taxonomy. The shift toward competencies and critical thinking aligns with the broader academic discourse on active learning and student-centered approaches, where the focus is on knowledge application and problem-solving rather than mere retention of facts (Elsayed, 2023; El-Seoud et al., 2023; Rudolph et al., 2023). It is clear that in the redesigning of teaching and assessment strategies, educators are moving toward a more dynamic and engaging milieu, confronting the demands of the digital age.

> *Need ayusin ang paggawa ng quiz at kung paano i-a-assess nang maayos ang learning outputs ng mga bata.* [There is a need to organize the creation of quizzes and establish a proper method for assessing the learning outputs of the children.] *(Participant 01)*

> *Kapag tama ang prompts or tanong, maganda rin sagot niya [ChatGPT], kaso general ang sagot lagi, kaya mahahalata na galing sa AI.* [When the prompts or questions are precise, ChatGPT provides excellent answers. However, its responses tend to be general, revealing that they come from an AI.] *(Participant 11)*

As supported by Baidoo-Anu and Ansah (2023), the revamp of academic instructions addressing the substantial concerns related to AI, approach to ChatGPT and its future iterations, should promote open and interdisciplinary discussions as paralleled to the participants' view, albeit ChatGPT is a valuable tool, it lacks the deep understanding and context that teachers provide. Still teachers play a critical role in adapting AI-generated content to suit the specific needs and curriculum of their students, reinforcing the importance of their expertise in delivering effective and meaningful deliverables of instructions (Duha, 2023; Elsayed, 2023). Moreover, ChatGPT not only compels review outdated teaching methods but also compels to break out traditional individualized domains and collaborate with colleagues from diverse fields and disciplines. Thus, making informed decisions for learners.

3.3. Ethical sense milieu

The theme "ethical sense milieu" is an overarching concerns arising from the prompt "*So, what now?; Quo Vadis* (Where will it lead us?)" in the context of using ChatGPT. This milieu resulted from the sense of doubt of teachers regarding the harnessing of AI. This theme encompasses several key ethical aspects, including plagiarism, transparency, accountability of teachers *per se* and its implicit impact on their students. As stated by the participants,

> *ChatGPT is here to stay na… it has become an essential support, 'yun nga lang tingin ko ay hindi gaanon [sic] makakatulong ito para lalong mag-isip at maging creative ang tao.* [ChatGPT is here to stay; it has become an essential support. However, I think it may not contribute significantly to stimulating deeper thinking and enhancing human creativity.] *(Participant 05).*

> *It [ChatGPT] will serve a good avenue for creating instructional plans, but needs to revisit at i-counter check lahat ng information generated ng ganitong tool…* It [ChatGPT] will serve as a good avenue for creating instructional plans but needs to be revisited and cross-checked for all information generated by this tool.] *(Participant 07)*

While ChatGPT can assist in content creation, it may not always produce high-quality educational materials. If teachers do not critically evaluate and edit the AI-generated content, it may contain inaccuracies or biases, negatively impacting the learning experience. Another argued,

> *No one can deny naman that it [ChatGPT] helps but in short-term case. Tampulan ito ng plagiarism at mag-evoke ng katamaran sa mga bata.* [No one can deny that it (ChatGPT) helps, but only in the short term. It can be a source of plagiarism and may evoke a sense of laziness in children.] *(Participant 14)*

> *ChatGPT offers several advantages, like development of learning assessments, improvements in pedagogical techniques, but there is [a] main concern […] first and foremost is that anyone can use it. Malaking problema ang assessment bilang factor […] also the quality of content ng bata ay puwedeng doubtful.* [ChatGPT offers several advantages, such as the development of learning assessments and improvements in pedagogical techniques. However, a main concern is that anyone can use it. Assessment is a significant problem as a factor, and the quality of a child's content may be doubtful.] *(Participant 23)*

In a short-term context, ChatGPT can be beneficial but has the potential to encourage plagiarism and student apathy. While it offers advantages like enhancing learning assessments and pedagogical techniques, a significant concern is its widespread accessibility, leading to challenges in assessment reliability and potential doubts regarding the quality of student-generated content. Another paper contends that while ChatGPT as a fait accompli, one can provide the provision of virtual personalized tutoring, assistance in generating outlines, and facilitating idea generation, highlighting potential concerns tied to academic integrity, the potential for unfair learning assessments, the accuracy of information (Memarian & Doleck, 2023; Sok & Heng, 2023).

Furthermore, the looking glass self for this milieu is a feedback loop, which means that teachers' perceptions of themselves and their role can affect their behavior. It is observed that teachers perceive themselves as innovative and technology-forward, they may be more likely to continue exploring and adopting new educational technologies, including ChatGPT. Teachers' perception of themselves as educators are opined to balance technology and human interaction which can influence their ethical considerations. Despite speculations that ChatGPT will be abused by students and over dependence of teachers for support still they are more inclined to ensure that AI tools like ChatGPT are used to enhance, not replace, human engagement in the learning process. Concomitantly, one of the primary ethical concerns is over reliance. Also, schools and educators must adhere to data privacy regulations and implement appropriate measures to safeguard student information from unauthorized access or misuse (Qasem, 2023).

Transparency and accountability are crucial ethical dimensions when using ChatGPT in education (Mhlanga, 2023; Reiss, 2021; Srinivasa et al., 2022; Tiwari et al., 2023). Since not all teachers are well-versed with the AI language, it is opined to initiate school discussions about any ethical issues. Hence, the central category for this lies on the ethical consideration primarily plagiarism which catapults for institutional ethical guidelines. Even Noam Chomsky, a luminary of modern linguistics, expressed his predicament statement that AI is *"high-tech plagiarism"* prompting everyone to address the potential misuse of these tools for plagiarism.

5. Conclusion

ChatGPT is a relevant and on par supplement for EdTech and navigating the implications associated with AI in education as it continuously penetrates educational landscapes is crucial. In an argumentative sense, private school teachers are believed to be proactive in using ChatGPT particularly in preparing for instructional materials without compromising responsible and ethical sense. This sense ensures that the integration of AI in education upholds ethical standards, respects data privacy, discourages plagiarism, promotes transparency and accountability, and strives for equitable access to AI tools through responsive adapting to challenges posed by advancement in technology. This study also advances the argument that ChatGPT holds immense promise in transforming the field of education and reshaping how students must be taught. But not all are breath of fresh air, by counting AI, the fear inquiries are on the rise, too. In particular, the utilization of ChatGPT is an AI ubiquity for enhancing the overall learning experience and preparing instructional materials of teachers – balancing the students' needs. It also identifies and seek policy formulations for schools discussing implications vis-à-vis ethical use of AI in education while maintaining the fruits being seek from the large language models.

6. Limitations

This study has acknowledged its limitations. Firstly, it exclusively employs an interpretative approach for theory building, prioritizing textual analysis over quantitative data. Secondly, it relies on textual context and personal experiences and proceeded refinement phases due to the nature of research design, making comparisons and generalizations less applicable. Finally, the participant pool is relatively small, which may

limit the broader applicability and replicability of findings. Nevertheless, these limitations do not diminish the value of the research, as it adheres to a well-established Standards for Reporting Qualitative Research (SRQR), and rigorous methodology.

7. Reflexivity

The authors' journey in developing the micro-level framework for EdTech mirrors the iterative process described. Early on, the authors engage in constant reading, reflecting, and writing activities that evolve with the research phases. At the outset, introspection about the motivation for EdTech framework development take precedence. The process then advances to reading literatures, reflecting, and rereading, with the aim of identifying trends, gaps, or challenging assumptions within the EdTech domain. As the research deepens, reflection blends with practical experimentation and dry runs, enriching the framework with hands-on insights. Throughout, writing remains intermittent, capturing the evolving EdTech micro-level framework, from jotting down initial ideas to documenting findings, modeling the framework, and verbalizing the emerging theory. This reflexivity declares the evolving nature of the authors' thought process yielding EdTech micro-level framework.

8. Conflict of interest

The authors assert that this qualitative study was carried out due to research enthusiasm, without any financial interests and organizational attachments that might be seen as a possible source of conflicts of interest.

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