JMSS Journal of Multidisciplinary in Social Sciences

Journal of Multidisciplinary in Social Sciences
Journal homepage : https://so03.tci-thaijo.org/index.php/sduhs

Designing an Artificial Intelligence using Fuzzy Logic for Assessing COVID-19 Risks in Higher Education Institutions during In-Person Class Resumption

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Article info

Article history:
Received: 12 March 2022
Revised: 19 July 2023
Accepted: 25 July 2023

Keywords:
Covid-19 risk assessment, School re-opening, Fuzzy logic model development, Face-to-face class

Abstract

The COVID-19 pandemic has had a significant impact on the education sector, leading to the closure of schools to prevent the spread of the virus. With the Philippine government approving the reopening of face-to-face classes in colleges and universities, there is a need to ensure that the academic community is protected from the risks associated with COVID-19. This study developed a Fuzzy Logic-based model to measure the risk associated with COVID-19 transmission in Northeastern Mindanao State University - Tagbina campus. The research design employed in this study involved the development of the Fuzzy Logic-based model, which was validated by experts in the field to assess COVID-19 risk transmission. The developed model produced satisfactory results after expert validation, and the campus had a 38.5% risk, classified as "Low," based on the developed model. Despite challenges in opinions of multiple experts, the model was able to draw conclusions to support campus management's decision-making pertaining to campus risk of COVID-19 transmission. The developed model can be used as a decision-support tool for campus administration to implement certain modalities and policies that do not pose a high COVID-19 risk to the academic community. Further studies can explore the applicability of the developed model to other higher education institutions and settings.

Introduction

The COVID-19 pandemic has had a profound impact on various sectors of society, including the education system. The rapid spread of the virus has forced authorities worldwide to implement lockdown or curfew orders, leading to school closures and difficulties in ensuring continuity of instruction or deciding when and how to reopen schools (NAS, 2020). Learners and parents have also faced various hurdles with the abrupt shift to homeschooling (Agaton et al., 2021). Despite this, the Philippine government has recently approved the phased rollout of limited face-to-face classes for colleges and universities starting in November 2021, which has placed tremendous responsibility on the university management to make informed decisions based on risk assessment. To ensure the safety of students, teachers, and staff during the reopening, it is crucial to develop a model that can accurately measure the risk of COVID-19 transmission on the campus.

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According to UNESCO (2020), more than 100 countries have closed their schools due to the COVID-19 pandemic, affecting millions of students. Thousands of universities and colleges worldwide have also closed their doors to encourage social distancing measures (Naciri, 2020). The decision to reopen schools is based on guidance documents provided by the Commission on Higher Education, and universities and colleges may apply to conduct limited face-to-face classes beginning December 2021 and onwards. However, the decision to reopen must be carefully deliberated to ensure that health protocols are in place and followed in accordance with national and international guidelines (Sarmiento et al., 2021).

To facilitate a safe reopening, universities and colleges must adhere to general health and safety protocols, such as the use and practice of respiratory etiquette and other preventive measures following the DOH guidelines on risk-based public health standards for COVID-19 mitigation (Singh-Vergeire, 2020). Disinfection supplies must also be readily available at all times. The World Health Organization has also issued a checklist to help reopen and prepare for COVID-19's resurgence.

Therefore, the North Eastern Mindanao State University has applied for authorization to conduct limited face-to-face classes and must closely adhere to school health regulations to guarantee the safety of students, teachers, and staff. To aid in the decision-making process, the development of a model that can measure the risk of COVID-19 transmission during the reopening of limited face-to-face classes is essential. The developed model will serve as a decision support tool and be the basis for maintaining a low risk of COVID-19 transmission during the reopening of limited face-to-face classes on the campus.

Objectives

The main objectives of this research project were two-fold. The first objective was to develop a model using fuzzy logic that can effectively measure the level of COVID-19 risk during the reopening of limited face-to-face classes. Fuzzy logic is a type of mathematical logic that deals with reasoning that is approximate or uncertain. By utilizing this approach, the research aims to develop a model that can take into account the complex and ever-changing factors that influence the spread of COVID-19 and accurately measure the risk involved in reopening limited face-to-face classes.

The second objective of the study was to assess the COVID-19 risk of the NEMSU-Tagbina campus based on the developed model. This assessment involved applying the developed fuzzy logic model to the specific context of the NEMSU-Tagbina campus and analyzing the resulting risk level. By doing so, the research aims to provide valuable insights into the potential risks and challenges associated with reopening limited face-to-face classes in a real-world setting.

Conceptual Framework

The conceptual framework is presented in Figure 1, which comprises the input variables *(staffing, class size, social distancing, hygiene implementation, awareness, crowdedness, and facilities),* the model inference using Mamdani-Style Inference (Mamdani, 1975), and the output variable (*Risk*).

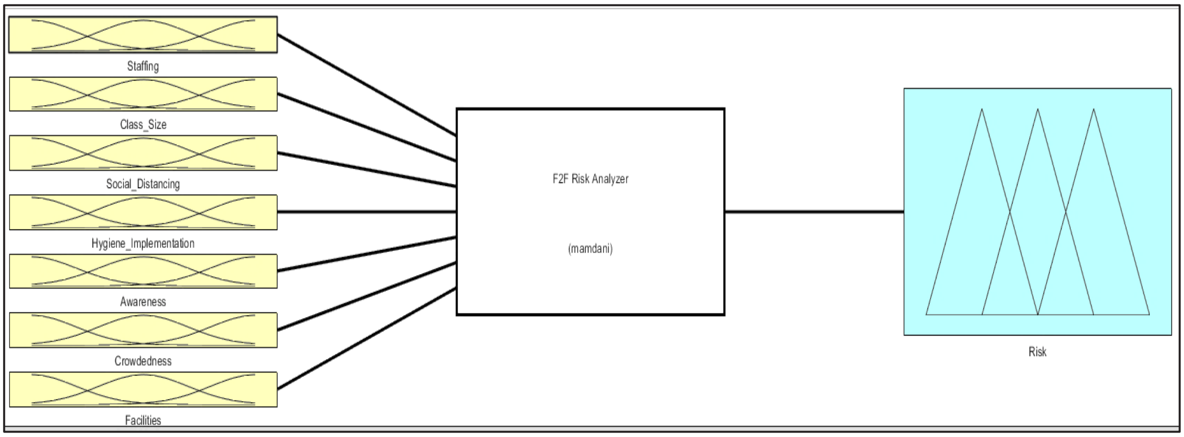

Figure 1. Conceptual Framework

Research Methodology

The researchers employed a structured algorithm research design utilizing the Fuzzy Logic model for risk assessment of limited face-to-face classes under the NEMSU-Tagbina campus condition. Fuzzy logic is a mathematical representation of fuzziness based on terms or logic that extends the range of truth values to all real numbers in the interval between zero (0) and one (1) (Lukasiewicz, 1930). It is a set of mathematical principles for knowledge representation based on degrees of membership rather than on crisp membership of classical binary logic (Zadeh, 1965).

To develop the COVID-19 pandemic risk assessment model, the following algorithm was utilized:

- Specify the problem and define linguistic variables
- Determine Fuzzy Sets
- Construct Fuzzy Rules
- Perform Fuzzy Inference using Mamdani Style Inference
- Defuzzification using Centroid Technique

The first step of the algorithm involved specifying the research problem and defining the linguistic variables related to COVID-19 risk assessment. In the second step, fuzzy sets were determined to represent the linguistic variables. In the third step, fuzzy rules were constructed to relate the input variables to the output variable, which is the COVID-19 risk level. In the fourth step, Mamdani Style Inference was performed to compute the output variable based on the fuzzy rules and input variables. Finally, defuzzification using Centroid Technique was employed to convert the fuzzy output variable into a crisp value representing the level of COVID-19 risk.

1. Population and Samples

The population for this study included experts in the field of COVID-19 risk assessment and management in the higher education context. This included twelve (12) members of the local Inter-Agency Task Force (IATF) for Covid-19 Pandemic Response and thirty-six (36) task force counterpart of the university's management and administration. The sample for this study was selected using purposive sampling. The researchers purposefully selected individuals based on selection criteria such as knowledge and expertise related to COVID-19 risk assessment and management in the higher education context.

2. Research Instrument

The research instrument used in this study followed the Fuzzy Logic model, utilizing two qualitative instruments for data acquisition. The first instrument was a structured interview guide used to interview members of the Inter-Agency Task Force (IATF). The interview aimed to determine whether certain values belong to a certain set, which enabled the researchers to produce fuzzy sets and rules. The interview questions were developed based on the specific research objectives and the linguistic variables identified in the Fuzzy Logic model. The second instrument was an initial assessment of the independent variables under the university condition using observed behavior and literature. This assessment involved a review of existing literature related to COVID-19 risk assessment and management in the higher education context, as well as observation of behaviors and practices related to COVID-19 risk mitigation on the NEMSU-Tagbina campus. This data was used to identify and refine the linguistic variables and fuzzy sets used in the Fuzzy Logic model.

Both instruments were designed to provide valuable insights into the linguistic variables and fuzzy sets used in the Fuzzy Logic model, as well as the specific risks and challenges associated with reopening limited face-to-face classes in the higher education context. The instruments were tested and refined to ensure that they were valid and reliable measures of the constructs of interest.

3. Collection of Data

The researchers utilized an individual interview method to collect data from the members of the Inter-Agency Task Force (IATF). The interview questions were developed based on the specific research objectives and aimed to elicit the expert opinion of the IATF members on various elements related to COVID-19 risk assessment and management in the higher education context. During the interview, the experts were asked whether various elements belong to a given set, such as excellent, moderate, or poor ventilation. The expert's opinion was then recorded and used to produce fuzzy sets and rules in the Fuzzy Logic model. To ensure the validity and reliability of the data collected, the researchers ensured that the interviews were conducted in a consistent and standardized manner. The same interview questions were used for all IATF members, and the interviews were conducted in a one-on-one setting to minimize the influence of other participants' opinions.

4. Data Analysis

The researchers used the Fuzzy Logic Designer of Matlab software to analyze the expert opinion data collected through individual interviews with members of the Inter-Agency Task Force (IATF). Using this modeling software, fuzzy sets were generated using triangle and trapezoid functions. The researchers ensured that there was sufficient overlap in adjacent fuzzy sets for the fuzzy system to respond smoothly. The next step was to generate fuzzy rules using the fuzzy sets. The researchers used the expert opinion data collected during the interviews to determine the relationships between the linguistic variables and the corresponding fuzzy sets.

The MATLAB Fuzzy Logic Toolbox has two built-in OR methods: max and the probabilistic OR method, probor. The probabilistic OR, also known as the algebraic sum, is calculated as:

$$\mu_{A \cup B}(x) = probor\,[\mu_A(x), \mu_B(x)] = \mu_A(x) + \mu_B(x) - \mu_A(x) \times \mu_B(x)$$

Similarly, in order to evaluate the conjunction of the rule antecedents, we apply the AND fuzzy operation intersection:

$$\mu_{A \cap B}(x) = min\,[\mu_A(x), \mu_B(x)]$$

Once the fuzzy rules were completed, they were encoded into the fuzzy inference, which in this case was the Mamdani-style inference.

Finally, the defuzzification process was used to complete the model development. The centroid technique was used to defuzzify the output of the fuzzy inference and generate a crisp output value for the level of COVID-19 risk associated with the reopening of limited face-to-face classes in the higher education context. Mathematically this centre of gravity (COG) can be expressed as:

$$\text{COG} = \frac{\int_a^b \mu_A(x)x\,dx}{\int_a^b \mu_A(x)\,dx} \quad \text{or} \quad \text{COG} = \frac{\sum_{x=a}^{b} \mu_A(x)x}{\sum_{x=a}^{b} \mu_A(x)}$$

This output was then used to assess the COVID-19 risk of the NEMSU-Tagbina campus based on the developed model, which was one of the main objectives of the study.

Results

1. The Developed COVID-19 Risk Model

The fuzzy logic model developed in this study consisted of three-hundred eighty-seven (387) rules. To evaluate and tune the model, a three-dimensional plot for a two-input and one-output system was used. Since the study had multiple input variables, the researchers generated 3-dimensional output surfaces by varying any of two input variables and keeping the other input constant.

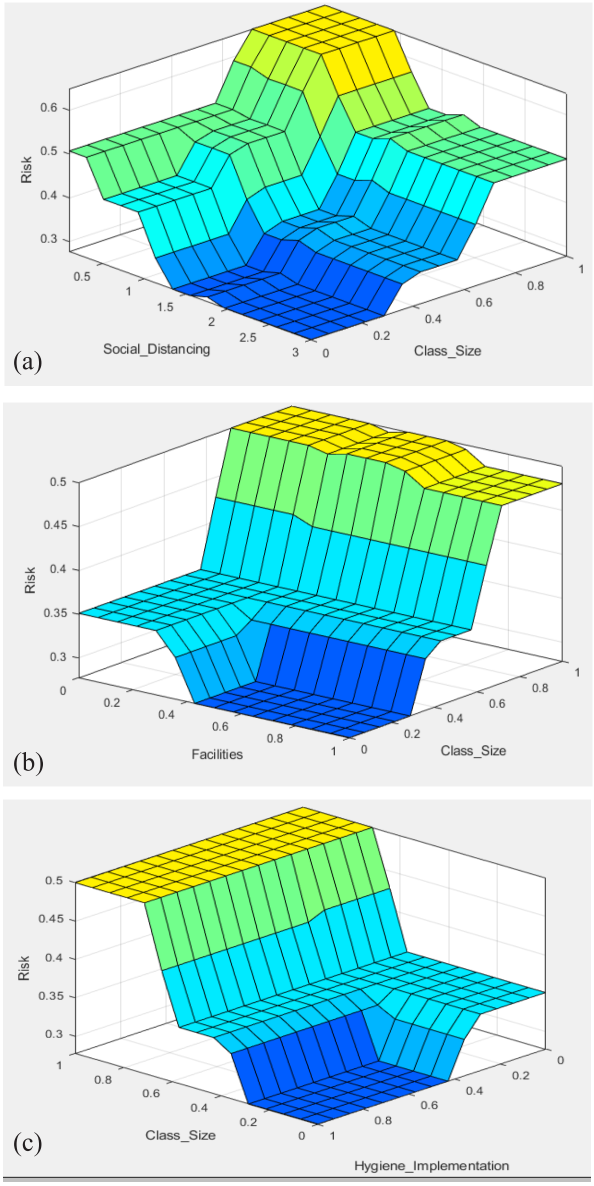

Figure 2. Three-Dimensional Plots of 2-Input 1-Output System

Figure 2 depicts the three varying 3-dimensional plots of COVID-19 risks associated with the constant input variable class size and the varying input variables social distancing, facilities, and hygiene implementation. Figure 2 (a) shows that when social distancing is maintained at an excellent level and the class size is kept small, there is a very low risk of COVID-19 transmission. In contrast, Figure 2 (b) shows that larger class sizes, regardless of the quality of facilities, result in high or very high risk of COVID-19 transmission. Similarly, Figure 2 (c) shows that when the class size is large despite strict hygiene implementation, there is also high or very high risk of COVID-19 transmission.

These findings highlight the importance of maintaining excellent social distancing and small class sizes to reduce the risk of COVID-19 transmission in the higher education context. It also suggests that strict hygiene implementation alone may not be sufficient to mitigate the risk of COVID-19 transmission in the classroom setting, particularly in the context of larger class sizes. These insights can be used to inform decision-making and policy development related to the safe reopening of limited face-to-face classes in higher education.

2. Assessment of Risk Level of NEMSU-Tagbina Campus using the Fuzzy Logic Mode

Table 1. Risk Level of NEMSU-Tagbina per Input Variable

Input Variables	Numerical Value	Linguistic Value	Risk
Staffing	0.40	Fair	Moderate
Class Size	0.50	Medium	High
Social Distancing	1.20	Good	Low
Hygiene Implementation	0.90	Too Strict	Low
Awareness	0.70	Moderately Aware	Low
Crowdedness	0.40	Desirable	Low
Facilities	0.65	Excellent Ventilation	Low

The values of the input variables used in the developed model were determined based on the current situation of the NEMSU-Tagbina Campus, as shown in Table 1. The researchers collected data from expert opinions, observed behaviors, and surveys to assign values to the input variables. The data were then fed into the developed model to calculate the risk value associated with the resumption of limited face-to-face classes on campus. To ensure comparability across input variables with different units of measurement, the values of input variables were normalized to range from 0 to 1, except for social distancing which used meters as a unit of measurement. Of the seven (7) input variables used in the model, five (5) initially resulted in low risk, while the other two variables resulted in moderate and high risk. These findings provide important insights into the potential risk associated with the resumption of limited face-to-face classes on the NEMSU-Tagbina campus and can be used to inform decision-making related to the reopening of classes in the higher education context.

The researchers utilized the Centroid method of defuzzification to generate a crisp output of COVID-19 risk associated with the resumption of limited face-to-face classes on the NEMSU-Tagbina campus. Using this method, the researchers were able to generate a crisp output value for the COVID-19 risk associated with the resumption of limited face-to-face classes on the NEMSU-Tagbina campus. Figure 3 shows the output value of 0.385 or 38.5% risk, calculated based on the values of the input variables shown in Table 1. These findings provide valuable insights into the level of

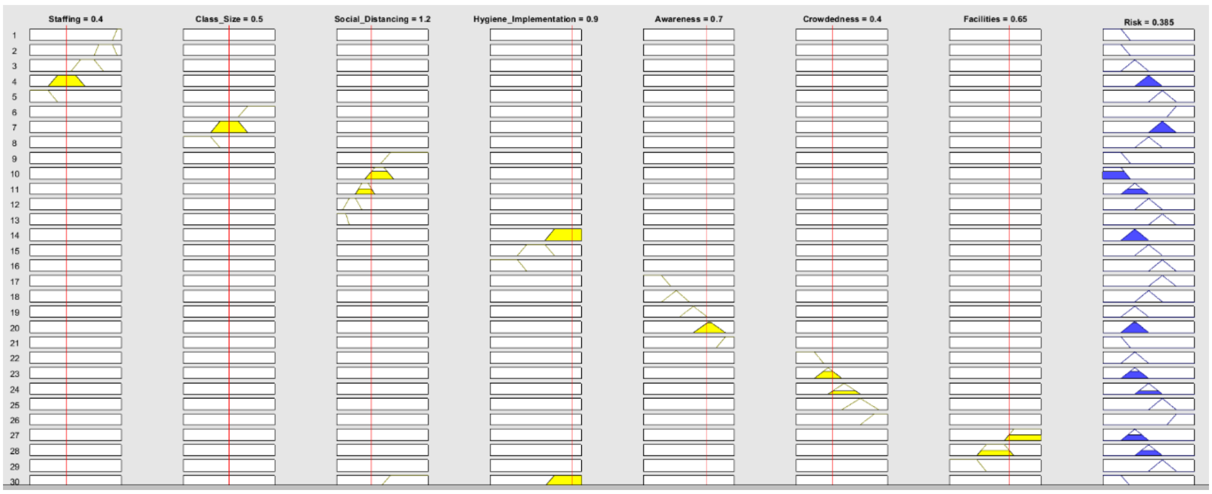

Figure 3. Fuzzy Logic Model showing the Overall Risk of NEMSU-Tagbina

COVID-19 risk associated with the resumption of limited face-to-face classes on the NEMSU-Tagbina campus, which can be used to inform decision-making related to the reopening of classes in the higher education context. The developed model and its findings can also be applied to other similar settings to assess and mitigate the risk of COVID-19 transmission in the classroom setting.

findings of Dalton et al. (2020), to reduce the likelihood of transmission in the event of contact. The study's challenges in selecting generated rules and assigning weight values are also observed in other studies. For instance, Suhartono et al. (2018) notes that selecting appropriate input variables and assigning weight values is crucial in developing a reliable fuzzy logic model. The developed model's flexibility and effectiveness in

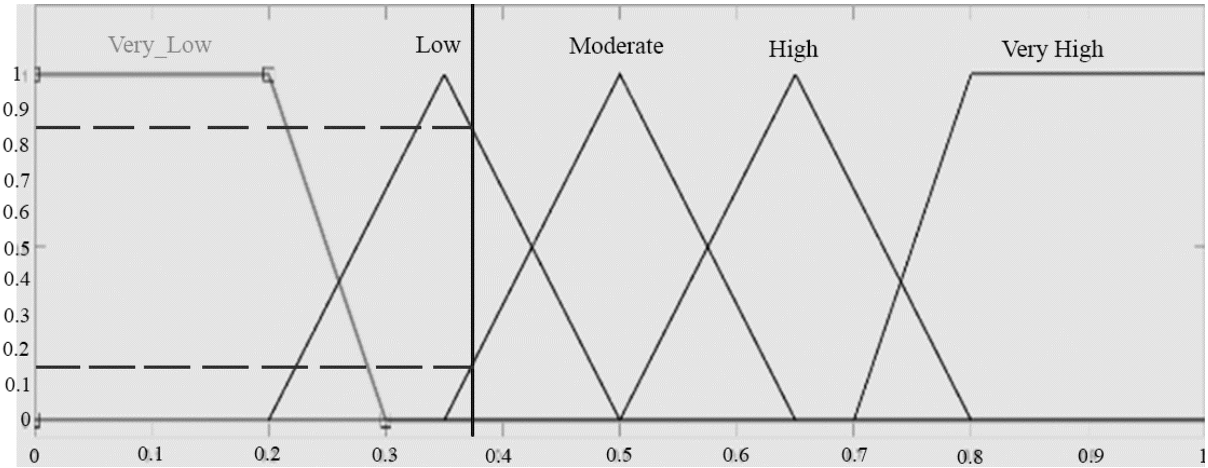

Figure 4. Degree of Membership of Risk Value

Figure 4 presents the degree of membership of the COVID-19 risk value of 38.5% generated using the developed fuzzy logic-based model. As per the concept of fuzzy logic, each value belongs to a certain set with some degree of membership. In this case, the COVID-19 risk value of 38.5% belongs to the set of low risk with a degree of membership of 0.85, and moderate risk with a degree of membership of 0.15. These findings suggest that the risk of COVID-19 transmission associated with the resumption of limited face-to-face classes on the NEMSU-Tagbina campus is mostly low, with a small degree of membership in the moderate risk category.

Discussion

The study's findings contribute to the existing literature on COVID-19 risk assessment in higher education institutions. The findings suggest that maintaining excellent social distancing and small class sizes are essential in reducing the risk of COVID-19 transmission, consistent with the findings of Nurrunabi et al. (2021). Additionally, the study highlights the importance of hygiene precautions, consistent with the calculating COVID-19 risk can aid decision-making related to the reopening of classes in higher education institutions, consistent with the findings of Le et al. (2020). The study's findings also suggest that implementing specific policies such as improving hygiene and social distancing measures can help reduce the frequency and severity of illnesses, consistent with the findings of Yanti et al. (2020). Overall, the study's findings provide valuable insights into the potential risk associated with the resumption of limited face-to-face classes in higher education institutions. The developed model can be used to assess and mitigate the risk of COVID-19 transmission in the classroom setting and can be a useful tool for campus administrators in decision-making related to the reopening of classes.

Suggestion

In conclusion, the study presents a fuzzy logic-based model that aids in decision-making for the safe reopening of limited face-to-face classes in higher education. The findings provide valuable insights into the potential risk associated with the resumption of limited face-to-face classes, highlighting the importance of maintaining excellent social distancing and small class sizes to reduce the risk of COVID-19 transmission. The study also suggests that strict hygiene implementation alone may not be sufficient to mitigate the risk of COVID-19 transmission, particularly in the context of larger class sizes. These findings have significant implications for the reopening of limited face-to-face classes in higher education and can be used to inform decision-making related to the reopening of classes in the higher education context.

The study's findings suggest that the developed model can be a useful tool for the campus administration to implement certain modalities and policies without posing high COVID-19 risks to the academic community. The model's flexibility allows it to calculate COVID-19 risk despite changing conditions of the campus. Moreover, the study suggests that improving hygiene and social distancing measures and implementing a specific class size policy can all help reduce the frequency and severity of illnesses. Thus, it is recommended that higher education institutions consider these factors when planning to resume limited face-to-face classes. Furthermore, the study highlights the challenges faced during selecting the generated rules and assigning weight values. Thus, future studies should aim to develop more efficient methods to overcome such challenges. Additionally, future research could explore the effectiveness of the developed model in predicting COVID-19 risk in different settings to ensure the generalizability of the findings.

Overall, the study provides a valuable contribution to the literature on the safe reopening of limited face-to-face classes in higher education. The developed model has the potential to aid decision-making related to the reopening of classes in the higher education context, ensuring the safety of students, faculty, and staff amidst the ongoing COVID-19 pandemic.

References

Agaton, C. B., & Cueto, L. J. (2021). Learning at Home: Parents' Lived Experiences on Distance Learning during COVID-19 Pandemic in the Philippines. International Journal of Evaluation and Research in Education, 10(3), 901-911.

Dalton, C. B., Corbett, S. J., Katelaris, A. L., & Kesson, A. M. (2020). Managing COVID-19 in Schools: Mitigation Measures to Prevent Outbreaks and Limit SARS-CoV-2 Transmission. *The Medical Journal of Australia, 213*(5), 228-232. https://doi.org/10.5694/mja2.50702

Lukasiewicz, J. (1930). *Philosophical remarks on many-valued systems of propositional logic*. Reprinted in Selected Works, L. Borkowski, ed., Studies in Logic and the Foundations of Mathematics, North-Holland, Amsterdam, 1970, pp. 153–179.

Le, T., Wang, Y., Liu, L., Yang, J., Yung, Y. L., Li, G., & Seinfeld, J. H. (2020). Unexpected air pollution with marked emission reductions during the COVID-19 outbreak in China. Science, 369(6504), 702-706.

Mamdani, E. H. (1975). Advances in the linguistic synthesis of fuzzy controllers. *International Journal of Man-Machine Studies, 7*(1), 1-13. https://doi.org/10.1016/s0020-7373(75)80002-2

Naciri, M. (2020). *COVID-19: The impact on education.* EDA Today. Retrieved from https://www.eda.europa.eu/eda-today/newsroom/news/2020/06/12/covid-19-the-impact-on-education

National Academies of Sciences, Engineering, and Medicine (NAS). (2020). *Reopening K-12 schools during the COVID-19 pandemic: Prioritizing health, equity, and communities.* New York City: The National Academies Press.

Nurrunabi, M., Rahman, M. M., Hossain, M. A., & Siddika, M. A. (2021). Health and Safety Measures for Reopening Schools amid COVID-19 Pandemic: A Systematic Review. *Journal of Education and Practice, 12*(3), 130-143. Retrieved from https://www.iiste.org/Journals/index.php/JEP/article/view/56108/57780

Romero, C., Master, B., & Shatzel, J. J. (2021). The impact of COVID-19 on education. *MedEdPublish, 10*(1), 290-296.

Sarmiento, P. J. D., Sarmiento, C. L. T., & Tolentino, R. L. B. (2021). Face-to-face classes during COVID-19: a call for deliberate and well-planned school health protocols in the Philippine context. Journal of Public Health, 43(2), 305-306.

Singh-Vergiere. (2020). Safety Prevention Protocols Against Covid-19, Press Release, Department of Health, July 10, 2020.

Suhartono, S., Prastyo, D. D., Kuswanto, H., & Lee, M. H. (2018). Comparison between VAR, GSTAR, FFNN-VAR and FFNN-GSTAR models for forecasting oil production. MATEMATIKA: Malaysian Journal of Industrial and Applied Mathematics, 103-111.

UNESCO. (2020). *Education: From disruption to recovery. COVID-19*. Retrieved from https://en.unesco.org/covid19/educationresponse.

Yanti, B., Mulyadi, E., Wahiduddin, Hatta Novika, R. G., Da'At Arina, Y. M., Martani, N. S., & Nawan. (2020). Community knowledge, attitudes, and behavior towards social distancing policy as a means of preventing transmission of COVID-19 in Indonesia. Indonesian Journal of Health Administration, 8(Special Issue), 4–14. https://doi.org/10.20473/jaki.v8i2.2020.4-14

Zadeh, L. (1965). Fuzzy sets. *Information and Control, 8*(3), 338–353.