

1. Introduction

1.1 Background

Plastic mismanagement has been recognised as a dominant issue that needs to be solved for global protection. Since the rapid increase in plastic production since 1950 and its waste, this planet is highly likely to be polluted with plastic. Annual plastic production was 40 billion in 2020, and the prediction indicates that approximately 120 billion plastic will be produced in 2060. Most disposal plastics, such as plastic bags and packages, have been classified as landfilled, as the data shows; the landfill rate is the highest globally among the plastic waste categories of landfill, recycling, incineration and mismanagement. Besides recycling, plastics likely transform into microplastics or toxic chemicals in various ways and pollute the environment. For example, incineration pollutes the air, mismanagement damages marine life, and landfills intoxicate the soil, which destroys the ecosystem.

Not only plastic bags and bottles of water but also clothes and electronic devices plastic materials are used. As the prevailing lifestyle is an overreliance on plastic, it is pivotal to reduce mismanagement and minimise plastic consumption by proper recycling or refraining from disposing of plastic items.

1.2 Objectives

The research about correlations between education and economic growth revealed significant [1]. The richer the countries become, the more money the government dedicates to education. When people are educated and skilled, the chance of obtaining an occupation with a higher salary is raised. Subsequently, more money was used to promote economic growth. This trend could be observed not only at the societal level but also at the individual level. The higher GDP per capita countries showed this tendency for more citizens to spend on education for postsecondary school in developing countries like Luxemburg [2].

However, economic growth does not always correlate to significant practical plastic waste management changes. Despite the fact that GDP growth is upward in all region and their considerable growth, some regions show distinctive trends, notably the world-leading country, the USA. Its GDP score was 10 to 21 trillion between 2000 and 2020, the highest economic growth. Yet, no significant improvement in plastic waste management was observed, although the quality of education(goal 4 in SDG) was maintained at over 90%. In contrast, China ranked 2nd largest economic growth country, experienced rapid growth from 1.2 to 14 trillion with a constant quality education rate of 97%, dramatically improving plastic waste management in mismanagement. India, the country with the third highest GDP, followed this trend in plastic waste mismanagement on a smaller scale in terms of GDP from

0.4 to 2 trillion and a gradual increase in quality education from 60 to 80%. These two Asian countries showed similar trends in plastic management and population with their different level of GDP scores. Conversely, Europe reflected the constant education rate and stable economic growth upon improvements in landfill management, although the GDP level is much lower than in India.

Therefore, this correlational study aims to reveal how much education and economic growth influence plastic management change by category and which regions are significant. Since each continent and country has different features, it is noteworthy to detect the discrepancy between them from heterogeneous perspectives so that the successful region can be a model of the countries that suffer ongoing stagnations with improvement in SDG goals [3].

1.3 Research Question

The research question is: "How do different parts of society influence plastic waste management, and where can we see correlations in plastic management improvement by comparing the education and economic growth rate?". To explore which countries or continents have unique characteristics contributing to plastic management, this correlational research was done by using the score of Quality education (Goal 4) and Decent work and economic growth (Goal 8) from the dataset of SDGs from the United Nations. Classifying the world by continent and world-leading countries in GDP - USA, China and India. Also, the potential causality such as education curricula, regulation of garbage collection and policy will be discussed accordingly.

2. Theoretical Framework

Previous research on the correlations between economic growth and quality education revealed positive results. Regarding sustainability study, " (...) 1% increase in individual environmental knowledge leads to a 0.4% increase in environmental behaviour among university students through model estimation." [4]. Based on this perspective, the correlation between Goal 4 and Goal 8 in SDGS has a theoretically positive correlation with plastic management improvement. However, as Makarenko.I. et al., 2021 indicated, "(...)there is no "correct" way to assess the level of achievement of sustainable development goals", and integrating higher education is needed for SDG 4 implementation [5]. Nevertheless, they also concluded that education is the basis of economic growth as it provides a "knowledge-based economy" [6]. Based on this research result, the strong correlation between education and economic growth is regarded as a knowledge-based economy that results in sustainable economic and education development.

This research employed Spearman's Correlation Coefficient (ρ) mainly because of the previous research about the SDG score conducted by Pakkan. S. et al. 2022 stated that "Spearman's Correlation Coefficient (ρ) provides a measure to evaluate the strength of an association between two variables" and "can capture the nonlinear correlation between the variables and is less sensitive to outliers. Spearman's analysis is widely used to identify

general relations beyond the linear correlation between two variables in various disciplines (Spearman 1987) "[7].

3. Methodology

3.1 Data Collection

The primary dataset of SDGs and plastic management was cited from Kaggle. The SDG database is the same as the prototype on the United Nations' website. The number of datasets used was minimised to avoid measurement error, therefore, this research was conducted to observe three correlations of education, economic growth, and plastic management based on these two datasets. In addition to this, the other csv files stemmed from the same plastic management datasets were used to predict the plastic production and detecting the matching countries to the plastic management dataset by region that was used as main dataset in this research. In addition to that, a dataset of GDP in US dollars were used to visualise the overview of respective trend(matplotlib and seaborn were used for most data visualisation).

Preprocessing was executed from modifying names of columns in one dataset that match to another so that these datasets could be merged(pandas). Then, data Cleaning was processed by detecting the empty values, however, no missing value was detected. Subsequently, sampling size was extracted by extracting matching country by their name and country codes. The sample size of countries extracted was approximately 70 % of those listed in the SDG data (N = 195, n = 140). For this research, Spearman correlation was mainly employed, as mentioned in the theoretical framework section. In the process on data analysis, Fisher's z standardisation were applied to the result of Spearman correlation so that all the data could be appropriate for corelational research. Data was mainly vidualised in linegraphs adn heatmaps. When all the data was combined for holistic correlation approach, standardising all the data above was applied adn they were visualised individually biplot to visualise the tendencies in one place.

3.2 Data Analysis Methods

Firstly, SDG and plastic management datasets were tested to clarify their distribution. The data from goal 4 and goal 8 and plastic waste management skewness and kurtosis analysis and Shapiro-Wilk and KS tests(scipy.stats). Also, the value in the column named year was converted in string type".astype(str)" to display the year in discrete continuous number. Both values for Goal 4 and Goal 8 are skewed, although Goal 4 is significantly negatively skewed, while Goal 8 is almost normally distributed but still skewed. Also, plastic management data in 4 categories are skewed considerably. As all the distribution is skewed, the Spearman correlation is mainly employed in this research. Due to the outliers and smaller size continents such as Oceania(n = 12), Kendall Tau is also applied for the

regional research. Moreover, Fischer's z-transformation was applied to the Spearman correlation of Goal 4 and plastic managers and Goal 8 and plastic management.

Secondly, SDG dataset and plastic waste management dataset were visualised: Calculating the median of correlations between Goal 4, Goal 8 and plastic waste rate by category, the respective distribution by region of correlation scores were clarified. After that, p value of correlation between goal 4 and plastic management, goal 8 and plastic management were calculated at the global level and continent level to determine the statistical significance. Then, Spearman correlations were calculated and they were visualised in heatmaps to determine the regional tendency of plastic waste management by category. Subsequently, Fisher's Z test was employed as well to check if these correlations are **statistically different** across datasets or groups. Lastly unsupervised machine learning of **Principal Component Analysis (PCA)** was employed to uncover hidden patterns visually. The value was standardised to merge all the value in one place (sklearn.decomposition for PCA, sklearn.preprocessing to import StandardScaler).

3.3 Limitations

Limitations are measurement inconsistency and accuracy. As different measurements were used to collect the data on plastic management rates and SDGs, it would be controversial to confirm the statistical accuracy, although the relatively larger sample size extracted via matching countries were proceeded. Also, the SDG data collection may have different measurements before and after 2015, when the SDG goals were settled.

The dataset on quality of education might also include people who have completed post-secondary and higher education, especially in developed countries. Considering this, some countries and continent does not reflect the level of education accurately. For example, citizens in Europe may have completed higher education such as bachelor, on the other hand, other countries are not this case.

Moreover, ceiling limitation is another issue when data analysis is conducted, as all the data are converted into percentages. For future study, the data with absolute numbers - the population, the number of competition of higher education in detail and GSP in US dollars will be needed.

4. Findings

The Spearman correlation coefficient of education and economic growth revealed that the hypothesised correlation between education and economic growth is recognised as true, as most regions showed a positive correlation ($p\text{-value} < 0.05$). However, the United States and China showed statistic insignificance (Spearman r / Spearman ρ respectively 0.210593/ 3.728144e-01, 0.354379/1.252668e-01). (Figure 2)

Regarding the correlation between Goal 4, Goal 8 and plastic management at the global level, it is remarkable that Goal 4 and Goal 8 each contribute to improving plastic management (figure 3), especially in terms of mismanagement/litter (cf. Spearman correlation between Goal 4 and Goal 8 in the SDGs and plastic management (global). These

two showed a similar trend. However, quality of education showed a slightly stronger correlation than GDP in all categories with statistical significance (all p-values except USA < 0.05). However, this trend is mainly a reflection of China and India, and MENA and Sub-Saharan Africa follow the trend; littering rate decreased significantly while the scores in the other categories rose considerably. Countries like Europe, Oceania, Asia excluding India and China showed more decrease in landfilled and littered score while the other score rose moderately.

The USA, however, shows the opposite tendency that the negative correlation in recycling and incineration is significant for Goal 8 and plastics management, but not for Goal 4 ($p < 0.05$). Besides, the USA showed a stronger correlation between Goal 8 and plastics management than the one between Goal 4 and plastics management. Consequently, the regional trend can be categorised into three distinct groups: the USA as a distinct entity, China, India, MENA, and the African region and others.

The PCA biplot visualised the correlation between 3 factors, and different correlations and regional features were detected. Firstly, recycling & incineration are positioned close together, that could be interpreted that they positively correlate with better education & economic growth, such as Europe. Littering & Landfilling are positioned in the opposite direction, indicating that they are more common in regions where education & employment might be lower such as Sub-Saharan Africa and India. Middle East, North Africa, and Americas shows a mix between different waste management practices, however, it showed moderate association with both recycling and landfilling. China is somewhere between this trend, therefore, the country is thought to be in transition of improvement. However, the USA described strong association with landfilling. This could derive from a weak link between education and plastic waste management but stronger connection with economic growth.

Considering the findings above, regions with higher SDG Goal 4 and 8 scores (education & employment) tend to have better plastic waste management (more recycling/incineration). In contrast, countries with lower SDG scores show higher reliance on landfilling & littering, however, education & economic development at lower level still encourage recycling & incineration instead of landfilling & littering. The USA is an exception as only economic growth relate with plastic management that does not influence plastic waste management efficiency and relying on landfill, despite of constant high education rate and economic strength. In other word, recycling & incineration seem to be driven by higher SDG scores (Goal 4 and 8) and countries with strong education & economy manage plastic waste more effectively.

Therefore, Europe is recognised as a model to achieve goal 4 and goal 8 effectively, as they are world leading continent in sustainable waste management, assumably they have better education, economic growth, and advanced plastic waste management strategies.

5. Discussion

Comparing to the prior research concluded the general trend of GDP and education. Therefore, the USA's trend that stronger correlation between economic growth and landfill

was an unexpected finding. Considering this point, it is noteworthy to discuss about potential casualties of this trend in order not to follow this trend for further development. This could derive from their business model or culture of prioritising pursuing profit than sustainability or lack of a strong recycling culture in the US may be a contributing factor. Besides, high plastic waste generation without efficient recycling solutions could be the factor. Or it might be because the USA does not have great infrastructure for plastic waste management unlike Europe. The other aspect would be that majority of citizens has only completed up to secondary school, not for university or college due to the financial difficulties, or low employment rate. As tuition fees for public universities are reasonable, while the USA may represent the value of up to secondary school completion due to the higher tuition fee (the annual tuition fee of public in the USA costs \$9,740 in 4 year In-State and \$3598 2 year In-District at least [8]).

6. Conclusions

The correlation between education and economic growth is positive. The majority of regions followed this trend with a strong correlation between education and plastic waste management: positive in incineration and recycling, negative in littered and landfilled. Conversely, the USA showed an unsustainable rate of plastic management despite its high SDG score and GDP with the considerable correlation between goal 8 and plastic management is stronger than the one with goal 4 described: negative in incineration and recycling, and positive in littered and landfilled. This could be interpreted as the cultural background, availability of landfilling sites in the nation or lack of habitants of recycling and regulation.

A further factor might be high scores in SDG and completion in higher education, such as a bachelor's degree to apply the knowledge gained from sustainability education. Whilst European countries enrich the educational services for citizens, students in the USA likely struggle with cost of living during their study due to the high amount of tuition fee for post secondary education.

As some countries experienced stagnation in the improvement of the score and high rate of littering, European model may offer a viable solution. Not only the education funded by governments but also the eco system and selling plastic free productions encourage the consumer eco-friendly, such as German vending machines recycling cans and plastic bottles with refund of credit for materials.

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