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FULL LENGTH ARTICLE

Exploratory Data Analysis of International Student Demographics: Trends, Insights, and Implications

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ABSTRACT

This paper focuses on Exploratory Data Analysis of the data from the "International Student Demographics," which is available on Kaggle and comprises data collected through the academic years, as well as total students, U.S. students, undergraduate, graduate, non-degree students, and OPT columns. In the given work, the author intends to provide a chronological overview of the demographic data of international students. Operations like handling missing values and outliers were done to prepare the data for a more elaborate analysis. All descriptive analyses during the study included time series plots and bar charts where time series was used to evidence key trends and distributions. The analyses of the research questions indicate that there has been growth in international student enrollment over the decades, particularly in undergraduate and OPT student categories, with influences from world events such as COVID-19 and the alteration of immigration policies. Country-wise contribution reveals that the maximum number of articles originated from East Asia and South and Central Asia, with a special focus on engineering, social sciences, and humanities. Solutions: The paper articulates the finality of trends affecting educational institutions and policymakers by focusing on the implications of international students' demographics. Based on the findings above, future research directions are proposed to improve the findings and support evidence-based practice relating to international education.

Keywords: International Students ▪ Demographic Trends ▪ Exploratory Data Analysis ▪ OPT Programs ▪ Higher Education Policy

1. INTRODUCTION

International education is now viewed as a foundational component of academic and cultural exchange in today's interconnected world driven by globalization. Understanding the demographics of international students is essential for colleges and universities as they strive to enroll and retain diverse learners. This understanding not only facilitates the improvement of the educational experience for international students but also aids institutions in decision-making and resource management for this student category. The advent of machine learning (ML) offers increasingly complex data about international student characteristics, which surpasses the capabilities of traditional statistical tools [1, 2, 3].

Machine learning, a branch of artificial intelligence, utilizes algorithms and statistical models to enable computer systems to improve their performance on specific tasks over time with experience. In the context of demographic analyses of international students, ML can identify patterns that might be difficult for the unaided mind to discern. It can process large datasets with numerous variables, allowing for the analysis of factors such as origin, country, age, gender, area of study, and academic performance. Through ML, researchers can

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identify major demographic characteristics, predict future enrollments, and determine factors affecting international students' learning and social integration [4, 5, 6].

This paper aims to examine the use of machine learning in understanding the demographics of international students. The study will employ clustering, classification, and regression techniques using a diverse dataset containing demographic and academic attributes. This investigation seeks to analyze the international student population for the presence of specific demographic groups, forecast enrollment patterns, and determine how demographic factors affect academic performance. For instance, clustering can be used to group students who share similar challenges and requirements, while predictive analytics can assess the probability of success based on demographic indicators [7, 8, 9].

Moreover, the insights gained from this study can benefit educational organizations and policymakers. Understanding the demographic characteristics of learners can guide university officials in tailoring support services to meet the needs of their target students. For example, students needing more assistance with language or those more likely to experience homesickness due to age can be supported more effectively. Additionally, the findings from ML analysis of numerous features can help shape recruitment policies and enhance the success of attracting a more diverse and balanced international audience [10, 11, 12].

In conclusion, applying machine learning to studying international student demographics holds significant potential for improving the understanding of this vital student population. This research aims to provide practical recommendations for enhancing international students' educational processes and outcomes by identifying key trends and determinants. The ultimate goal is to support the development of more diverse and fulfilling learning environments that accommodate an academically and culturally diverse student body.

2. LITERATURE REVIEW

A brief review of the literature reveals that academic scholars have recently been interested in using machine learning to study the demographic patterns of international students. The primary focus is explaining international students' enrollment trends and characteristics. Various approaches have been employed in this domain to expand the understanding of developments in this area.

For instance, many researchers have applied mathematical formulas for clustering to classify the diverse global student populations by demographics. Among such approaches, K-means clustering has notably detected groups of students with similar characteristics [13]. This technique has helped identify patterns related to country of origin, age, and field of study, enabling educational institutions to adjust their services and support in alignment with these observed patterns.

Decision trees and random forests are among the most used models, especially for demographic studies, due to their performance in explaining the inter-relationships of complex and non-linear data inputs. Decision trees effectively sort options into tiers, making results easily interpretable and helping to identify primary demographic factors [14]. For instance, factors such as the language of instruction, the student's ability to pay tuition, and the level of education attained before the current program have been found to correlate with international students' success and retention. Random forests, an ensemble method, enhance decision trees by overcoming the problem of overfitting and minimizing the volatile performance associated with individual trees [15]. This approach has proven highly effective in addressing the complex issues related to demographic data analysis.

Other techniques, such as Support Vector Machines (SVM), have also been used to analyze international students' demographics when the correlation between attributes or variables is not necessarily linear [16]. SVMs are particularly powerful in high-dimensional spaces and less prone to overfitting, making them suitable for analyzing demographic datasets with many attributes. For example, an SVM model can be trained to distinguish student enrollment patterns based on a combination of socio-economic parameters, academic results, visa regimes, and other relevant factors, demonstrating the effectiveness and stability of SVM methods.

Over the past decade, deep learning models have shown promising results in scenarios involving demographic analysis due to their ability to implicitly learn features from raw data. Recent trends involve using neural networks, particularly multi-layer (deep) neural networks, to identify the demographic variables of international students with high accuracy [17]. These models can learn complex patterns and dependencies in data that may be challenging for classical approaches to capture. For example, a deep learning model can learn patterns in visa application data and admissions trends to forecast future international student enrollment.

Ensemble learning strategies, which combine several models to generate better predictions, have also been employed. Methods like boosting and bagging have been used to leverage the strengths of individual models while mitigating their weaknesses [18]. Consequently, ensemble methods tend to outperform single models in analyzing demographic data. For instance, an ensemble approach that integrates decision trees, SVMs, and neural networks can effectively analyze the demographics of international students.

Additionally, factor analysis and Principal Component Analysis (PCA) have been applied to explore the factors influencing international students' demographics. These techniques help uncover hidden factors influencing student mobility and are valuable in policy formulation and development [19]. For example, factor analysis might reveal how external factors such as geopolitics, economics, and educational opportunities affect students' mobility.

Educational data mining has seen the integration of multiple algorithms to enhance analysis accuracy. For instance, combining regression models with machine learning algorithms has been shown to offer broader and more accurate results [20]. A composite model might use basic linear regression to identify overarching trends while leveraging machine learning algorithms to unravel more complex demographic data, providing a more precise and detailed picture of international student distribution.

Furthermore, the literature highlights that feature selection is crucial in evaluating demographic information. Consequently, selecting the most relevant features from educational data is

essential to improve model accuracy and ensure the sensible application of analysis models. Techniques such as recursive feature elimination (RFE) and Lasso regression have been employed to predict student mobility and success and identify critical predictors [21]. For instance, RFE can iteratively remove less critical features, improving a model's efficiency and performance.

Finally, the incorporation of political climate, visa regulations, and other global economic factors into demographic analysis models has been discussed. Research has shown that these attributes significantly influence international student enrollment, and their inclusion in models enhances accuracy [22]. For example, a model that incorporates variables related to visa policies and geopolitical factors might provide a broader perspective on the challenges faced by international students, aiding educational institutions in developing more effective solutions.

3. PROPOSED METHODOLOGY

3.1 Dataset Description

The dataset employed for this analysis is the International Student Demographics dataset retrieved from Kaggle. This dataset provides general details about the demographics of international students by academic year, making it useful for identifying enrollment patterns. The dataset columns are described below:

- **Year:** This column shows the academic year in the format YYYY/YY, such as 2019/20 or 2020/21. It is an important variable for time series analysis, enabling the observation of the dynamics of student numbers and their specific features over time. By analyzing the data year-wise, one can reveal trends such as the continuous increase in student numbers and the influence of factors like policy changes or critical circumstances (e.g., the pandemic) on student enrollment.
- **Students:** This column contains the students for each academic year. It offers a general overview of the entire student body and assesses overall enrollment trends, including areas of expansion and contraction. Such evaluations can guide decisions on resource allocation and institutional settings.
- **US Students:** This column indicates the enrollment status of domestic students (those who are not international students). Comparing this figure with the total student body allows for estimating trends and rates of international student enrollment. This comparison is crucial for understanding specific trends related to the international student population about the general student population.
- **Undergraduate:** This column indicates the number of undergraduate students. Analyzing this data helps understand the distribution of the target audience across different levels of education, particularly those enrolled in bachelor's programs. This information is vital for universities to assess the market for accredited undergraduate programs and to direct their offerings and services accordingly.
- **Graduate:** This column shows the number of graduate students. This data is essential for understanding the demographics of learners pursuing master's and doctoral studies and their trends over the years. Knowledge of the graduate student population helps evaluate the demand for advanced education, the effectiveness of graduate studies, and the role of international students in academic and research endeavors.
- **Non-Degree:** This column captures non-degree students who are enrolled in courses or programs that do not earn credit toward a degree, such as certificate programs, exchange programs, or professional short-term courses. This information helps identify trends among nontraditional learners and supports institutions in promoting diverse educational options.
- **OPT:** This column shows the number of students engaged in Optional Practical Training (OPT). OPT allows international students to work in the United States for a period after completing their studies. Analyzing this column sheds light on post-graduation work trends among international students, providing insights into their economic participation. OPT data analysis can help predict the employment patterns of international graduates and assess OPT policy outcomes.

By conducting a detailed Exploratory Data Analysis (EDA) on these columns, it is possible to uncover further trends, patterns, and insights regarding the target population, which is the international student population over time. This data may interest educational institutions, governments, and other entities involved in international education. This paper argues that the insights gained from EDA can help identify factors affecting student enrollment, guide policy and program reviews, and support decision-making to enhance the education of international students.

Figure 1 illustrates the population split by academic types: undergraduate, graduate, non-degree, and OPT students. The number of students in each group can also be easily determined from the bar chart, revealing that most students belong to the undergraduate group. Standard deviations are represented by error bars, providing insight into how dispersed the student numbers are in the given dataset.

3.2 Exploratory Data Analysis (EDA)

Exploratory Data Analysis (EDA) is a critical process in data analysis that provides insights into the data, helps discover new patterns or anomalies, tests hypotheses, and checks assumptions using statistical measures and graphical representations. In this case, EDA will be performed on the "International Student Demographics" dataset to analyze trends and characteristics of students across several consecutive years. The following steps will be undertaken to ensure that the data is clean and ready for analysis:

3.2.1 Data Cleaning and Preparation

Data cleaning, also known as data munging, involves preparing the data for proper analysis. These steps include:

- **Handle Missing Values:** Missing values can lead to biased results and incorrect conclusions. The first step in data cleaning is normalizing the data, which involves identifying and handling missing values. This can be done through imputation using the mean, median, or mode or by deleting

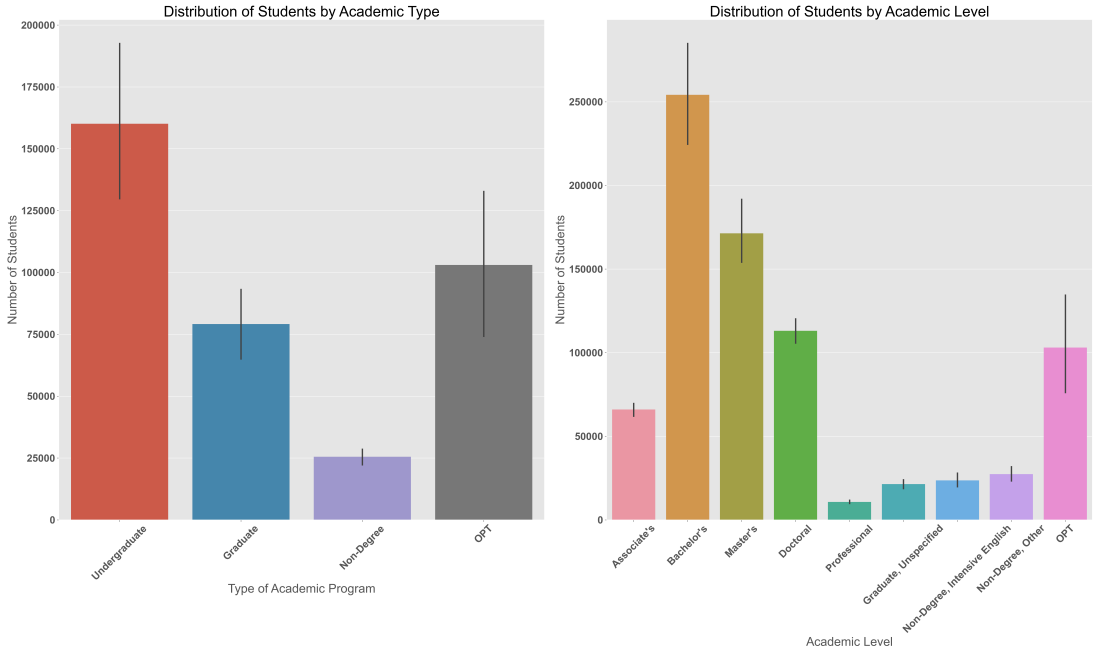


Figure 1. Distribution of Students by Academic Type.

rows or columns with a large percentage of missing values, depending on the situation and the extent of missing data.

- **Handle Outliers:** Outliers are data points that differ significantly from other observations. They can skew results and lead to incorrect inferences. Outliers should be identified and managed using statistical tests or visualization techniques (e.g., box plots) and by understanding the context of the data. Depending on the analysis requirements, outliers may need to be excluded, transformed, or thoroughly investigated.
- **Convert Data Types:** Ensuring the correct data type is essential for accurate analysis. For example, the `Year` variable should be in a format suitable for time series analysis, such as date-time. Similarly, numerical columns should be in the correct statistical format for proper statistical analysis and data visualization.
- **Create New Features:** Sometimes, creating new features can provide additional insights and improve the analysis. For instance, calculating the proportion of international students by dividing the total number of students by the number of domestic students can be helpful. New features can help reveal relative patterns in the data and provide a deeper understanding of the interactions within the dataset.

The cleaning and preparation process lays a strong foundation for exploratory analysis. It ensures that the dataset is ready for EDA, enabling the extraction of insights and conclusions about the demographic profile of international students.

3.2.2 Descriptive Statistics

The Descriptive Statistics section consists of a brief elaboration of the main characteristics of the data that were used in this research. The first step for any data analysis is the identification of the patterns and distributions of data provided in this analysis. Thus, this section aims to provide general information regarding the demographic characteristics of international students using a variety of statistical measures and graphical illustrations that compare the data of different years, programs, and regions.

In this section, the primary measures of central tendencies, dispersions, and distributions of the primary variables such as the academic type of the students such as undergraduate, graduate, non-degree, and OPT, geographical background, and the area of concentration of the students enrolled in the university will be presented.

Having discussed the methods of analyzing the data, the general trends of the given parameters will be shown in the form of pie charts, bar charts, or time series plots to indicate the presence of some minor peculiarities, if possible. The findings from this descriptive evaluation shall be used as a starting point for the subsequent vigorous statistical methodologies and predictive models, as seen in this paper's subsequent sections.

Figure 2 presents the distribution of student numbers by academic type and academic year. It allows for identifying trends, such as increasing or decreasing patterns among various student groups, and shows how the student demographics have evolved.

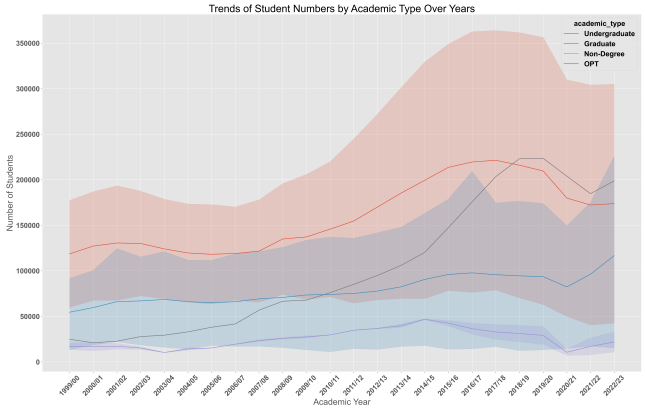


Figure 2. Trends of Average Student Numbers by Academic Type Over the Years.

Figure 3 provides an aggregate view of international student enrollments by year. It offers a straightforward graphical representation of the changes in total international student numbers over the decades, making it easy to identify major trends and shifts in enrollment quickly.

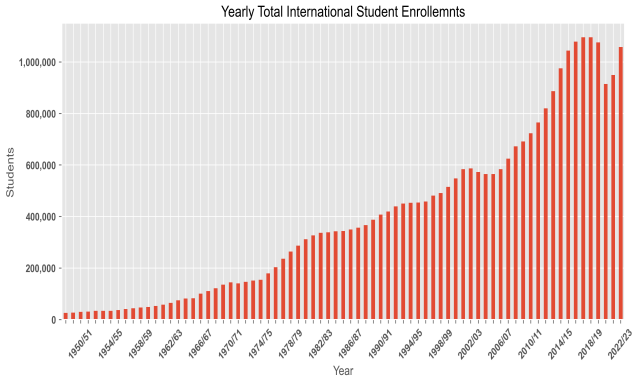


Figure 3. Yearly Total International Student Enrollments.

Figure 4 shows the regional distribution of different academic types: undergraduate, graduate, non-degree, and OPT students. It analyzes the variation of international students by region and field of study, demonstrating which regions contribute to which types of academic programs.

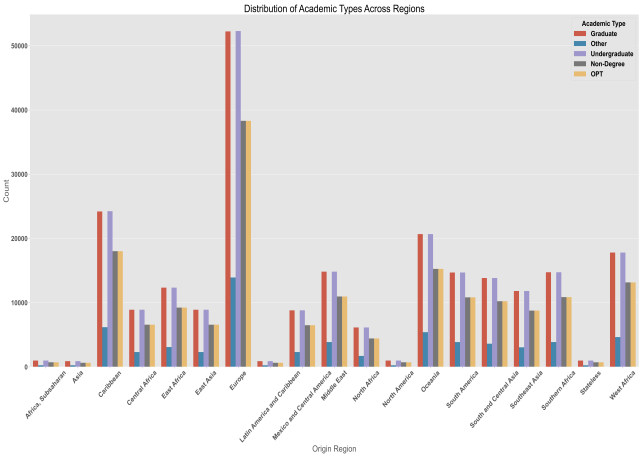


Figure 4. Distribution of Academic Types Across Regions.

Figure 5 shows the percentage of students based on their area of specialization to give the international community a chance to know the most popular field of study. This figure shows major areas of interest, including engineering, social and natural sciences, humanities, and arts, to understand the preferences of students from different backgrounds. That way, we can map the distribution that depicts students' choices within the era in academic fields, which depict fields that continuously attract or repel international students and have some oscillation. This information is also essential for educational institutions to understand better and adjust to international students' needs and wants to maintain prospective international students' desire to attend these institutions.

Figure 6 illustrates the overall trends in student enrollment over time. The shaded area indicates the degree of volatility in student numbers while emphasizing the general trend of growth or decline.

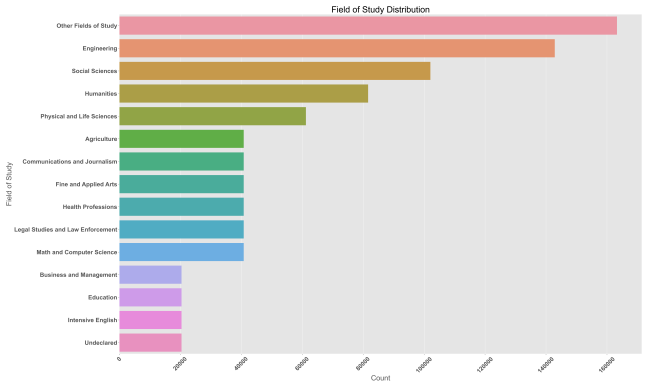


Figure 5. Distribution of Students by Field of Study.

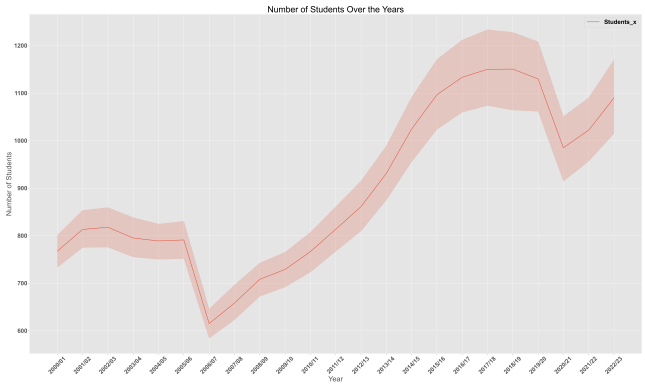


Figure 6. Number of Student Enrollments Over the Years.

Figure 7 compares the distribution of students by academic type (undergraduate, graduate, OPT, non-degree) and level (bachelor's, master's, doctoral, etc.), providing a quantitative comparison of different categories within the international student population.

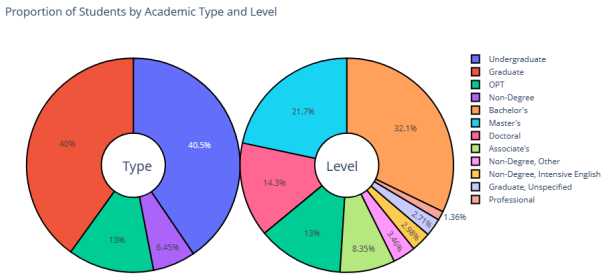


Figure 7. Distribution of Students by Academic Type and Level.

Figure 8 contains information regarding changes in enrollment in the subsequent years within the academic level achieved, comprising associate's, bachelor's, master's, and doctorate degrees. In terms of value, it illustrates how the students' preferences by academic level have evolved, and this can be paralleled to the changes in the expectations and career objectives of international students. Thus, it became possible to study the above trends and understand how different factors that characterize the tendencies of the global economy, policy alteration, and shifting job market demands impacted the call for pedagogical levels of education. Such findings also explain students' interest in postgraduate programs such as master's and doctoral programs, which offer a vantage

training ground for highly specialized research. Universities must comprehend these trends as they consider strategies in their program provisions and funding for their programs to fit the new demands of international students.

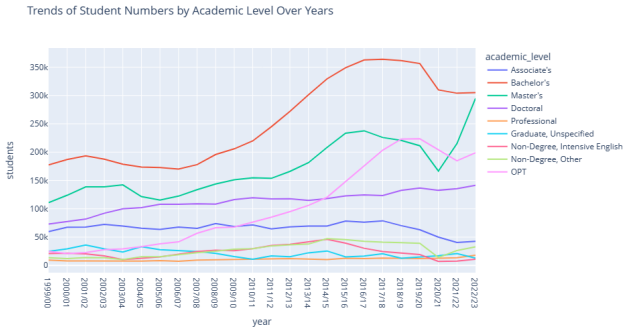


Figure 8. Trends of Student Numbers by Academic Level Over the Years.

Figure 9 visualizes the annual growth rate of international students. Each pair of dots represents the growth rate between two consecutive years, with the connecting line indicating the trend. This plot helps identify years with significant increases or decreases in international student enrollment.

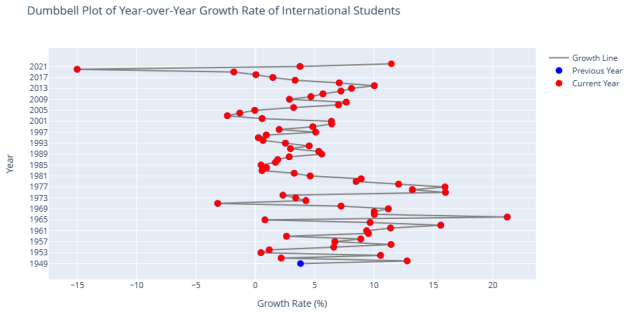


Figure 9. Dumbbell Plot of Year-over-Year Growth Rate of International Students.

Figure 10 displays the trends of student enrollment from the most represented regions year by year. It provides insights into the countries where international students originate and how this distribution has shifted over time, helping to establish the geographical distribution and direction of student enrollment.

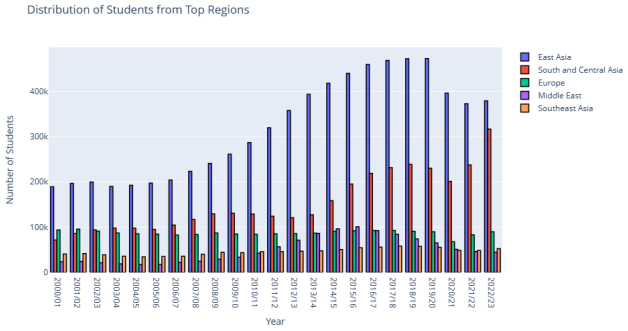


Figure 10. Student Distribution Among the Top Regions.

The descriptive statistics section from the given dataset gives an idea of the demographic profile of international students. By calculating means, medians, modes, ranges, standard deviations and other central tendency and variability measures, we have also located important patterns in enrollment trends, regions, and subjects. Significantly, international students' enrollment has grown over the years and is more concentrated on undergraduate and OPT programs, with the regional distribution of coming from significantly represented by the East Asia and South and Central Asia regions.

In the current paper, the choice of international students by field has been illustrated through the visualizations and statistical summaries that revealed engineering, social sciences, and humanities as the most preferred disciplines. These findings act as an essential framework for the rest of the analysis – the more complex logging, statistical techniques and predictive models, which will be used in the later sections of this paper.

In conclusion, the preliminary exploration of the years of overall and by country international students has not only given an overview of current international student demography but also hinted at underlying directions that need further analysis. It is crucial to formulate and implement common policies and strategies for institutions to improve their ability to provide and market themselves to international students.

3.2.3 Trend Analysis

In this part of the paper, we establish and discuss the discernible patterns in the characteristics of international students over the years. The analysis is based on the information depicted in the figures concerning the dataset.

Identifying Trends. Observing the total international student enrollments by year (Figure 3), a cross-regional pattern shows a significant increase in the presence of international students over the decades. This growth is particularly marked from the early 2000s until the mid-2010s when total enrollments steadily increased yearly. Although there are cyclic trends, identified by slight declines at specific points – such as during the 2020/21 academic year – these are likely due to external factors like the COVID-19 pandemic. Specific tendencies are also revealed by the time series analysis of student numbers by academic type (see Figure 2). Undergraduate enrollments have historically been high and have generally increased over the years, although there has been a slight decline in recent years. Graduate student numbers have also risen, albeit not at the same steep rate as undergraduates. The data on OPT students shows phenomenal enrollment growth starting from the early 2010s, indicating that more students are seeking work permits in the U.S. after completing their studies.

Factors Influencing Trends. Several factors could be influencing these trends:

- **Immigration Policies:** Fluctuations in visa policies and laws of the host country significantly affect international student enrollments. For instance, regulations that limit student entry due to visa reforms or restrictions on international arrivals can reduce the number of students enrolling in institutions.
- **Economic Factors:** Economic conditions in both the students' home and host countries can impact international

education. Economic hardships, such as recessions, may limit students' opportunities to access education abroad, leading to enrollment declines.

- **Global Events:** Global events, such as the COVID-19 pandemic, profoundly impact international student mobility. The contraction in enrollment during the 2020/21 academic year is an example of distance learning, travel restrictions, health emergencies, and interruptions to academic schedules hindering student mobility.
- **Educational Quality and Reputation:** The quality and ranking of educational institutions, both within the host country and globally, influence students' choices. Positive shifts in these aspects can enhance enrollments, as students are attracted to institutions with solid reputations for academic excellence.

3.2.4 Detailed Segment Analysis

Undergraduate vs. Graduate. The trends in undergraduate and graduate international students are analyzed separately to understand their distinct patterns:

- **Undergraduate Students:** As shown in Figure 1, undergraduate students comprise the largest international student population segment. Their numbers have grown, reflecting a strong preference for U.S. undergraduate programs. The slight decline in recent years may be attributed to factors such as the COVID-19 outbreak or changes in immigration laws.
- **Graduate Students:** Although their numbers are lower than undergraduates, graduate students have also shown an upward trend. This growth underscores the U.S. as a preferred destination for advanced education and research opportunities.

Non-Degree and OPT. The demographics and trends of non-degree students and those in OPT provide insights into non-traditional education paths and post-graduation employment trends:

- **Non-Degree Students:** As reflected in Figure 1, non-degree students fall under the grouped category. They have maintained consistent percentages over time, indicating a sustained interest in short-term and exchange programs.
- **OPT Students:** The increase in OPT student numbers (Figure 2) suggests a growing trend where international students seek practical experience in the U.S. after completing their education. This trend highlights the need to retain talent through OPT programs while offering career opportunities for these students.

4. INSIGHTS AND DISCUSSION

4.1 Summarizing the Key Findings from the EDA

- **Overall Growth:** The trend analysis indicates a significant increase in international student enrollment, particularly among undergraduate and OPT students.
- **Impact of Global Events:** The reduction in enrollment during the COVID-19 outbreak suggests that international education is particularly vulnerable to global disruptions.
- **Regional Contributions:** The geographic distribution of students, as shown in Figure 10, highlights that East Asia and South and Central Asia are among the most significant sources of international students. Changes in these regions' economic conditions and policies are likely to impact U.S. enrollments substantially.
- **Field of Study Preferences:** The analysis of the field of study distribution (Figure 5) reveals that engineering, social sciences, and humanities are the most preferred fields among international students. This information could assist institutions in aligning their programs to attract more international students.

4.2 Implications

- **Educational Institutions:** Universities and colleges can utilize these insights to enhance their recruitment strategies, support services for international learners, and overall program offerings to better cater to the diverse nature of the student population.
- **Policymakers:** Understanding these factors can aid in formulating improved immigration and education policies that enhance the attraction and retention of international talent.
- **Stakeholders:** Employers and other community organizations may find the demographic and academic profiles of potential international employees and residents valuable for planning and operations.

5. CONCLUSION

Based on the demographic analysis of international students, dynamic growth trends are evident, particularly in the expansion of the undergraduate student population and the OPT student category. These dynamics are closely related to global phenomena, such as the COVID-19 pandemic and shifts in immigration legislation. The detailed segment analysis provides additional insights into the trends characterizing undergraduate, graduate, non-degree, and OPT students.

As the enrollment status of international students is continually evolving, recommendations and decisions made by various stakeholders, including institutions and policymakers, should be grounded in up-to-date surveys and demographic data. Future analyses could explore student satisfaction with their courses and institutions, the future trajectories of graduates, and emerging trends in the global higher education market. Continuous analysis will ensure that policies and strategies remain well-suited to addressing the dynamic nature of international student populations.

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