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The Impact Of Economics and Ethics On The Adoption of Human Biotechnology

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Introduction and Rationale

I teach Precalculus to 11th and 12th grade students at James Hillhouse High School, within the New Haven Public School System. Established in 1859, James Hillhouse High School is the oldest high school in New Haven. It's one of the only two comprehensive high schools in the city. Hillhouse currently serves 949 students in ninth through twelfth grade. The student population comprises of 63% Black/African American, 31% Hispanic/Latino, 5% Caucasian, and less than 1% Asian, Native Americans and other unspecified ethnic minorities. Hillhouse students originate from thirty-two countries across the globe and speak twelve languages. A significant percentage of our student population are from Sub-Saharan Africa and mid-Eastern countries. Thus, Hillhouse student's population mirrors to a large extent a mix of the demographics of low, mid and high-income countries.

This curriculum unit will look at the Impact Of Economics and Ethics On The Adoption of Human Centered Biotechnology. I have developed this Precalculus unit to help my students understand health and economy disparities between developing and developed countries. A significant proportion of my students have experienced these disparities in their lives. Developing lesson objectives that are relatable to student's life experiences are best for student's engagement and generating authentic conversations. Students will analyze data using economic and health indicators from both developing and developed countries. Additionally, students will conduct an opinion survey addressing ethical questions, such as why these disparities have persisted over the years and how best to address them.

Background Information

GDP per capita and Life Expectancy

The World Health Organization defines health to be "a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity[1] . A major health indicator of a population is its life expectancy, while the GDP per capita is a major indicator of its economic status. Life expectancy at birth indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life.[2] While, GDP per capita is gross domestic product divided by midyear population[3] .

Many studies have shown that the health status of a population is frequently correlated with the economic status and income expenditure of the population. In the 1800's income and life expectancy among the nations of the world were similar with low income (earning less than $2000.00 per year), poor health and life expectancy below 40 years. The current world population as of 2016 by the US census bureau was at 7.3 billion, about half of the world population 3.4 billion people still struggles to meet basic needs.

Living on less than $3.20 per day reflects poverty lines in lower-middle-income countries, while $5.50 a day reflects standards in upper-middle-income countries according to the World Bank[4] .While rates of extreme poverty have declined substantially, falling from 36 percent in 1990, over 1.9 billion people, or 26.2 percent of the world's population, were living on less than $3.20 per day in 2015. Close to 46 percent of the world's population was living on less than $5.50 a day[5] . As of 2013 about 766 million people still live in extreme poverty (people living on less than $1.90 per day revised upward in 2015 from $1.25).

A better understanding of socio-economic patterns and health status of the world population can be gained using data from the following 5 representatives' countries, namely Malawi, Bangladesh, India, China and the USA. The potential causative relationship between economics and health outcomes for each of these countries will be analyzed in this curriculum unit. At the extreme lower end of the socio-economic scale is Malawi, with a GDP per capita of about $338.00 and life expectancy of about 63 years. Malawi essentially captures the state of about 10% of the world population living in extreme poverty. An estimate of about 1.9 billion people live in poverty and have socio-economic characteristics similar to those of Bangladesh. Bangladesh has a GDP per capita of about $1500 and life expectancy of about 72 years. An estimated 3.5 billion of the world population are regarded as middle income with socio-economic characteristics similar to that of India. India has a GDP per capita of about $1900 and life expectancy of about 68 years. In contrast, an estimated 2 billion of the world population are regarded as high income and have socio-economic characteristics similar to China and the USA. China has a GDP per capita of $8800 and life expectancy of 76 years while the USA has a GDP per capita of about $59000 and life expectancy of 79 years.

The average per capita GDP in the LDCs is only $235; this figure is $24,522 on average for all developed countries and the average annual healthcare expenditure in LDCs is only $16 per person, whereas the average annual healthcare expenditure in high income countries is $1800 per person[6] . The average life expectancy in the LDCs is only 51 years, compared to 78 years in industrialized nations[7] . In African countries most affected by the global AIDS pandemic, life expectancy continues to decline – by 2010 the life expectancy in Botswana was only 27 years[8] .

The GINI Coefficient Factor

Generally, economic and health indicators suggest that people live longer in countries with a higher GDP per capita compared to countries with lower GDP per capita, however exceptions do occur. For instance, Bangladesh has a higher life expectancy than India, though India has a higher per capita GDP than Bangladesh. This discrepancy reflects that GDP per capita alone is insufficient to predict the health outcomes, including mortality and life expectancy, of any one country.

Other socio – economic factors, such as education and lifestyle choices, do play a major role in determining health outcomes in a population. Also, economic disparities that occur within countries measured by metrics such as the GINI coefficient can impact health outcomes. GINI coefficients can be used to measure the concentration of any distribution, not just the distributions of income. Higher concentrations translate into higher inequality. Lower concentrations mean lower inequality.[9] The most recent GINI coefficient available for Bangladesh was 32.4 from 2016 while that of India was 35.4 from 2011[10] . Comparing the GINI coefficient for Bangladesh and India suggests that Bangladesh has lower income inequality than India. This difference in inequality may be a significant factor in explaining why Bangladesh has a higher life expectancy than India, though India has a higher GDP per capita.

As a result of these economic disparities, there could be a huge difference in life expectancy even between countries on the same income level, depending on how the money is distributed and how it is used[11] . Simply put, for the most part the rich tend to live longer, whether comparing between rich and poor nations or comparing low income individual to high income earners within the same economy. Understandably, analyzing multiple economic and health indicators will provide a more robust understanding of causative relationships between economies and health outcomes. However, giving the scope and pacing of the New Haven Precalculus curriculum, this curriculum unit will be restricted to looking at data on GDP per capita and life expectancy of the 5 representative countries listed above. This curriculum unit, however, should not be limited to a Precalculus class alone, the curriculum unit could be expanded upon. Incorporating this unit in to a Statistics or Economic course would allow for further analysis of additional economic and health indicators.

Economic Development, Biotechnological Advances and Health Impact

The overall health of all nations of the world has improved significantly as a result of medical advances and the successful diffusion and adoption of such technology from more advanced countries to less developed ones. However, the goal of bioengineering to meet global health challenges given resource constraints remains elusive. There remains a large disparity between developing and developed countries of the world in terms of economic power and access to human centered biotechnological advancements.

Additionally, income inequality within a country among its different socio-economic groups strongly influences the populations ability to have access to state-of-the-art health care. Medical research and biotechnology development does not come cheap. Though the goal of medical research is to improve health coupled with it is also the goal of profit maximization of entrepreneurs. Investors in research and development of biotechnology designs not only look forward to recouping their investment, but also to make profit. Unfortunately, not all research results in technologies that are cost effective to be massively produced or will be adopted by society, sometimes due to cultural values and religious beliefs.

All of these complexities raise both economic and ethical challenges in the research, development, dissemination and adoption of human centered biotechnology. On one hand, an argument can be made that biotechnology designs should be cost effective; developed with the purchasing ability, cultural values and beliefs of the consumer of the product in mind. While, on the other hand, a major ethical concern that will be considered in this unit is: what should be the role of government and society in providing access to quality and timely health care for all socio-economic group within her population.

Through to the 1950s conditions such as stroke, heart attack, cancer and diabetes were regarded as degenerative diseases, but statistical analysis of their frequency pattern and distribution provided evidence that many of these conditions had a major environmental component. For example, death certificate rates for cancers of the stomach and lung rose so sharply between 1950 and 1973 that major environmental factors must have been at work generating these diseases in different populations[12] .

China, for instance witnessed rapid economic growth during the 1980s and 1990s that transformed the country and lifted millions of its citizens out of poverty. The economic boom, however, has been accompanied by environmental degradation, including a severe deterioration in the water quality of the country's rivers and lakes. Extensive use of fertilizers by farmers and industrial wastewater dumping by manufacturing firms have rendered the water in many lakes and rivers unfit for human consumption[13] . China's water monitoring system indicates that roughly 70% of the river water is unsafe for human consumption, although many farmers in rural areas still rely on these sources for drinking water [14] . Concurrent with the decline in water quality in China's lakes and rivers, the country experienced an increase in rural cancer rates during the 1990s. Stomach cancer and liver cancer now represent China's fourth and sixth leading causes of death and, in combination with other digestive tract cancers (such as esophageal), account for 11% of all fatalities and nearly 1 million deaths annually in China.[15]

The use of sophisticated statistical methods was first applied to the study of noninfectious disease after world war 2 to analyze the patterns and associations of diseases in large populations. The emergence of clinical epidemiology marked one of the most important successes of the medical sciences in the 20th century[16] . By 1950 there was a global trend towards better health, health started to improve even in the poorest countries partly due to the economic development in many countries and partly due to medical advancements that by this time could be applied everywhere, e.g. antibiotics[17] .

In fact, a better understanding of the physiology and disorders of pregnancy together with improved prenatal care and obstetric skills has led to a steady reduction in maternal mortality. In an industrial country, few children now die of child-hood infection; the major pediatric problems are genetic and congenital disorders, which account for about 40 percent of admissions in pediatric wards, and behavioral problems[18] . Infant death are below ten per thousand births throughout Europe and the USA whereas over a 100 infants die per thousand in countries like Liberia and Ethiopia. Many of these premature babies would have survived with access to incubators, but modern incubators are complex and expensive. A standard incubator in an American hospital might cost more than $40,000. In addition to the expensive cost of the incubators, the knowledge, skill, right environmental conditions and utilities such as electricity needed to maintain the incubators are lacking in most developing countries of the world.

It has been suggested that as much as 95 percent of medical technology donated to developing countries breaks within the first five years of use.[19] This shows that while technology may be successful and effective in one region of the world it may not be effective in other regions of the world. For technology transfer and adoption to be successful between regions of the world, there has to be similarities in terms of infrastructure, available skills, knowledge and economic empowerment. Many developing countries are still living in dire poverty with dysfunctional health care systems and extremely limited access to basic medical care. In contrast, the developed world is constantly clamoring more for the latest advancement in technology that would save more lives, improve health status and improve quality and delivery of health care.

Numerous studies have shown that there is a strong correlation between economic development and technological advancement, as a result, low income country continue to be at a disadvantage. Take for instance the case of Malawi: The Global Funds to Fight AIDS, TB and Malaria saw it fit only to give funding of $1 a day for anti-retroviral treatment for just 25,000 of 900,000 Malawians infected with AIDS over a five-year period. A death warrant from the international community for the people of Malawi. Sadly, one sixth of humanity lives as Malawians the poorest of the poor-too ill, hungry or destitute to step on the first rung of the development ladder. There is a valid ethical question about what could possibly be the rational for this decision by the international community.

Rising Costs and Unintended Consequences of Biotechnological Advances

In developed economies, technological advancements such as organ transplantation, diagnostic imaging systems, genetic manipulation are big ticket items that have significantly contributed to rising medical costs. While it is true that new technologies on the average improve the quality of medical care by improving health outcomes, this is not true of every technology in clinical use. Many new technologies are ineffective or redundant and do not improve health outcome. It is however difficult to discriminate between effective and ineffective technologies when they are being introduced.

Empirical evidence suggests that medical technology accounts for about 10 to 40% of the increase in health care expenditures over time, albeit some technologies may actually reduce costs by replacing more expensive alternatives or preventing expensive health consequences, but the overall effect is to increase costs.[20] Industrial countries continues to grapple with the problem of the spiraling costs of health care resulting from technological development, public expectations, and in particular the rapidly increasing size of their elderly populations. As the size of the aging population increases, many societies may have to face the ethical question of rationing medical care. Unfortunately, one approach to resolving the rising cost of health care has been to restrict access to health care for a growing segment of the population, primarily the uninsured, while preserving the best available care to those fortunate enough to have coverage.

Other issues arising from technological advancement are their unintended consequences, some of these unintended consequences have been beneficial while others have been detrimental. For example, one of the most versatile technology that has been developed is the Ultrasound technology developed in 1794. The Ultrasound technology was originally developed as a navigation tool by an Italian biologist. This biologist's curiosity on finding how bats find their way in the dark led to the discovery of Sonar; the ability to use sound waves and the echoes they generate would prove to be of immense benefit during World War I to correctly pinpoint the location of German submarines. Doctors also engaged the use of ultrasound in surgery as they discovered that heat generated from sound waves could destroy tissues. Ultrasound would also become useful as a diagnostic tool when a chemist in 1949 employed the technology to locate gallstones in dogs. With the development of the ultrasound physicians began to navigate the human body bouncing sound waves off the internal organs.

Ultrasound thus became a very promising tool to learn more about pregnancy and monitor high risk pregnancy without the risk of exposing the fetus to dangerous x -ray radiation[21] ."In 1959, the Scottish obstetrician Ian Donald used the new technology on a woman who happened to be pregnant and noticed that the fetus returned echoes as well. If Donald suspected that knowledge would translate into fetal selection and subtraction, he probably envisioned women attempting to avoid debilitating sex- linked diseases like hemophilia. (When the first sex-selective abortions had been performed in Denmark using amniocentesis four years earlier, indeed, they were done for that reason - and discriminated against males as a result.) He could have hardly guessed that ultrasound would one day contribute to a sex ratio imbalance involving over 160 million "missing" females in Asia and elsewhere"[22] . This major unintended consequence of the ultrasound technology has led to abnormal sex ratio in the human population.

Without manipulation both sex ratio at birth and population sex ratio are remarkably constant in human populations. Though small alterations do occur naturally for example, a small excess of male births with 105–107 male births for every 100 female births. This slight excess of male births was first documented in 1710 by John Graunt and colleagues for the population of London[23] , and many studies of human populations have confirmed their finding. A key study of births for the period 1962 to 1980 in 24 countries in Europe showed a sex ratio of 105– 107, with a median of 105.9[24] ."The tradition of son preference, however, has distorted these natural sex ratios in large parts of Asia and North Africa. This son preference is manifest in sex-selective abortion and in discrimination in care practices for girls, both of which lead to higher female mortality. Differential gender mortality has been a documented problem for decades and led to reports in the early 1990s of 100 million ''missing women'' across the developing world. Since that time, improved health care and conditions for women have resulted in reductions in female mortality, but these advances have now been offset by a huge increase in the use of sex-selective abortion, which became available in the mid-1980s. Largely as a result of this practice, there are now an estimated 80 million missing females in India and China alone.

The large cohorts of ''surplus'' males now reaching adulthood are predominantly of low socioeconomic class, and concerns have been expressed that their lack of marriageability, and consequent marginalization in society, may lead to antisocial behavior and violence, threatening societal stability and security."[25] .

Health Indicators

Vital statistics, such as the number of live births, and the number of deaths (including infant deaths) by sex, age, and cause are essential in order to accurately assess the health of populations and make decisions regarding health resources; unfortunately, these data are lacking from many areas. Data from many countries are not complete for instance deaths are recorded only in certain areas, while in others all areas are covered but not all deaths are recorded. Average rates of coverage vary widely, from only 10% in Africa, to over 90% in Europe.[26]

Because mortality does not give a complete picture of the burden of disease borne by individuals in different populations, the Disability adjusted life year (DALY) metric was proposed by the 1990 global burden to measure disease burden. The DALYs is a composite measure that shows the effect of premature mortality and the prevalence and the severity of ill-health in populations. DALYs are calculated by adding the number of years of life lost (YLL) to the number of years lived with disability (YLDs) for a certain disease or disorder[27] . DALY is the summary measure used to give an indication of overall burden of disease. One DALY represents the loss of the equivalent of one year of full health. Using DALYs, the burden of diseases that cause premature death but little disability (such as drowning or measles) can be compared to that of diseases that do not cause death but do cause disability (such as cataract causing blindness).[28]

The burden of disease, expressed in DALYs per 1000 population, has decreased in all regions during the period of 2000-2016, with the WHO African region having attained the largest decline (44%). This region, however, still bore the highest burden in 2016, 587 DALYs per 1000 population. This is over two-fold the burden of disease in the region with the lowest DALY rates (270 per 1000 population) in 2016: the WHO Western Pacific region. All regions have seen modest reductions (5-9%) in the contribution of premature death (measured by years of life lost or YLL), to overall burden of disease (measured by total DALYs) between 2000 and 2016. Globally, 29% of total DALYs were caused by communicable, maternal, neonatal and nutritional causes in 2016, a decline from 43% in 2000. The WHO African region has strikingly high proportion (61%) of DALYs due to communicable, maternal, neonatal and nutritional causes compared to other regions. In the WHO European

Region and WHO Western Pacific Region, at least 80% DALYs were due to noncommunicable diseases. Road injuries caused a loss of nearly 83 million years of full health among the world's population in 2016; making it among the 5 leading causes of DALYs. The proportion of total DALYs borne by children under 15 years old globally declined from 47% in 2000 to 32% in 2016, reflecting the massive reduction in deaths among children under 5 years old during this period. Almost all (87%) of DALYs borne by children under 15 years old, however, were caused by premature death, the remaining 13% were caused by ill health and disability. Adults aged 15-59 years old bore 36% of total DALYs in 2016 (up from 31% in 2000), and people aged 60 years and older bore the remaining 33% (up from 22% in 2000[29] .

The trend from the result above shows that disease burden are shifting from communicable disease to non-communicable disease, and from premature death to years lived with disability particularly in high income populations. This is in line with expectations, since high income countries are at the forefront of bio-technological advancement. On the other hand, low income countries in sub-Saharan Africa, the dominant causes of disease burden still largely remain communicable, maternal, neonatal, and nutritional disorders. This is rather unfortunate, but does not defy expectations because bio-technological advancements are a rarity in this region of the world.

Lesson Objectives, Activities and Teaching Strategies

The health of a nation and the effectiveness of the technology available in such regions, and what technology needs to be improved upon and developed to meet the needs of their population are measured by economic and health indicators. The importance of economic indicators such as per capita income (GDP) and expenditure and health indicators such as life expectancy, infant mortality, number of death and causes, disease incidence and prevalence, immunization records and DALYs cannot be overemphasized. Also, there are ethical issues industrial and developing countries continue to grapple with, such as providing an adequate level of health care equally to every income and age group within their population.

The New Haven Public School Precalculus Curriculum covers mathematical modeling and applications of polynomial functions, power functions, exponential and logarithmic functions to real life situations. This curriculum unit will be aligned with the eight common core state standards of mathematical practices and the high school Precalculus common core content standards on functions.

The curriculum unit will look at data on economic and health indicators specifically GDP per capita and life expectancy from 5 representatives' countries-USA, China, Malawi, India and Bangladesh. Life expectancy is generally higher in countries with higher income per person, this is hardly surprising and there are many reasons for this pattern. Higher income levels mean that people can afford to eat sufficiently, so problems related to undernutrition decrease or disappear altogether. Higher income levels can fund better hospitals, more medicines, vaccination and campaigns to eradicate diseases. Higher income levels can also fund better sanitation, so that people do not have to drink contaminated water or have to live near piles of garbage. People can afford better heating and cooking equipment so that they do not suffer from indoor air-pollution.[30]

However, as seen earlier, comparing data between Bangladesh and India, higher per capita does not always translate to higher life expectancy. Other factors such as the GINI coefficient may also influence life expectancy. This curriculum unit, however, will be restricted to looking at two indicators given time constraint.

Students will collect and analyze economic data on GDP per capita and health data on life expectancy of the 5 identified representative countries. The lesson unit will include interactive videos /graphs from Gapminder[31] , the world bank data[32] and Google explore data[33] .

Using the statistical tool on the TI graphing calculator, students will work in small groups. Each group will focus on data set from one representative country and create scatter plots from their data set. They will generate appropriate regression models of the scatter plot, analyze their graphs and use the trend line to make predictions, recommendations and to justify their reasonings. Each group will present their findings to the rest of the class using either a PowerPoint presentation or by creating a poster. Students will compare and contrast the results from the 5 representative countries, critique each other's work and provide justifications for their conclusions.

Specific Objectives and Common Core Standards

Students will:

- Analyze algebraic and graphical representation of parent functions of polynomial, exponential and logarithmic functions. (HSF-IF.C.7c ; HSF-IF.C.7e; HSF-LE.A.3)
- Explore the inverse relationship between exponents and logarithms. (HSF-BF.B.5; HSF-LE.A.4)
- Graph, analyze and write equation to model data sets using technology. (HSF-IF.C.7; HSS-ID.B.6a)
- Understand and differentiate between low-income, mid-income and high- income countries. (SMP 2; SMP 6)
- Define and describe economic and health indicators, such as GDP per capita, GINI coefficient and life expectancy within the context of low-income, mid-income and high - income countries. (SMP 2; SMP 6)
- Organize, graph, analyze and write an equation that models a data set on GDP per capita between 1960 to 2017 from Malawi, Bangladesh, India, China and the USA.(HSF-IF.B.4; HSS-ID.B.6; HSS-ID.B.6a)
- Organize, graph, analyze and write an equation that models a data set on life expectancy between 1960 to 2017 from Malawi, Bangladesh, India, China and the USA.(HSF-IF.B.4; HSS-ID.B.6; HSS-ID.B.6a)
- Create a scatter plot showing the relationship between GDP per capita and life expectancy between 1960 to 2017 using raw data sets from Malawi, Bangladesh, India, China and the USA.(HSS-ID.B.6; HSS-ID.B.6a)
- Create a scatter plot showing the relationship between GDP per capita and life expectancy between 1960 to 2017 using log -log transformed data sets from Malawi, Bangladesh, India, China and the USA.(HSS-ID.B.6; HSS-ID.B.6a; HSS-ID.B.6c)
- Interpret the correlation coefficient (r), and other parameters of the linear regression model generated from the transformed data.(HSS-ID.C.8; HSS-ID.C.7)
- Develop, administer and analyze an opinion survey on ethical issues addressing accessibility to Human Centered Biotechnology. (SMP 1)
- Make recommendations for possible solutions based on their findings from the opinion survey and overall understanding of the unit. (SMP 3)

Opinion Survey on Ethical Concerns

Numerous studies have documented a strong correlation between economic development, technological advancement, and health outcomes. However, as the cost of health care delivery continue to grow, it remains out of reach of low income to mid-income earners. Consequently, there are valid ethical questions behind the rational for the continuous advancement of human centered biotechnology if it is not made affordable and adoptable. One of the major steps that has been taken to assess the impact of technology was the establishment of Office Technology Assessment in the 1960s by the USA. Health technology assessment was then developed as an off shoot to the office of Technology Assessment. Unfortunately, this initiative was dissolved in 1995 due to criticism that it was duplicating other agencies work.

Technology Assessment particularly in the USA, focused on such issues as the implications of supersonic transport, pollution of the environment, and ethics of genetic screening[34] . In its early years, a health-related technology assessment was called a "medical technology assessment" (MTA). In the 1980s, the term "healthcare technology assessment" became the dominant term. In the 1990s, "health technology assessment" (HTA) came into wide usage. The change to healthcare technology assessment seems more appropriate given that "medical technology" usually refers to just physicians, though technology related to health is much broader. Multiple U.S. public agencies were attracted to the ideas of technology assessment and attempted to apply them to health technologies. In 1973, the U.S. Academy of Sciences published a report that examined the broad implications of four health technologies: in vitro fertilization, choosing the sex of children, retardation of aging, and modifying human behavior[35] .

Although early work in HTA was inspired by general perspectives of health technology, such work in the field tended only to focus on efficacy, safety, and cost-effectiveness.[36] In particular, healthcare ethics were usually given little or no attention in HTA reports, despite growing interest in ethics in health and among some experts in HTA[37] . If the goal of Healthcare decision makers worldwide is to improve health outcomes across their populations, best practices in HTA has to be adopted. Hence, a well-developed HTA program should not only assess the medical and economic benefits of healthcare technology. The social and ethical implications of the development, affordability and adoptability of a healthcare technology should be an integral part of an effective HTA program.

Students will conduct and analyze an opinion survey on the rising cost of health care, its affordability and accessibility to all income groups. The survey will solicit responses on questions such as: "who should bear the cost of development of human centered biotechnology -the government versus private developers"; "should human centered design be driven by the goal of profit maximization or by a moral obligation for a healthier population"; "is there a moral obligation on the part of the developed world to design bio-technology that will be affordable and adoptable by the developing world?"

Lesson Guide with Classroom Activities

Lesson Title	Content	Strategies and Activities
Global Development Since 1800	Introduce lesson with video on global development on 200 years that changed the world by Hans Rosling from www.gapminder.org/videos/200-years-that-changed-the-world/.	Note taking while viewing video. Respond to questions based on video. Incorporate strategies from Gapminder teacher's guide for class discussion.
Introduction to Economic and Health Indicators/Terminologies	Define and describe measures of infant mortality, life expectancy, birth rate, death rate, DALYs, poverty rate, per capita income, gross domestic product, GINI Coefficient, low, middle- and high-income countries.	Graphic organizers for comparing and contrasting; calculating key indicators and terminologies.

Consequences of Industrialization And Biotechnology Advances	Readings from articles: How Ultrasound Changed the Human Sex Ratio; Abnormal Sex Ratios in Human Populations: Causes and Consequences; The Consequences of Industrialization: Evidence from Water Pollution and Digestive Cancers in China	Annotation and summary of major points in small groups; Group Discussion Classroom discourse: critique each other's arguments and justify their position.
Economic and Health Disparities among Nations	Handout and web resources - Health and Economic Data: A Global Comparison; World Bank Data and Google Explore data on life expectancy and GDP within the context of the following five representative countries: Malawi, Bangladesh, India, China and USA	Work in small groups of 4 using data from a representative country. Create scatter plots, generate appropriate regression models : linear, quadratic, exponential and logarithms using the statistical tool on the TI graphing calculator. Interpret results and parameters from data analysis, Slope, intercept, Correlation coefficient.Representatives from small groups discusses and share country's result with whole class
Ethical Issues And Biotechnological Advances	Focused primary research on the role of ethics in development, affordability and adoptability of advances in healthcare technology.	Whole class: review and discuss health care costs and coverage; Generate questionnaire for opinion survey from discourse. Small groups: administer and analyze opinion survey, present results to the class both digitally and orally. Whole class: summarize major findings; recommend possible solutions to address issues raised.

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Appendix

Standards Addressed in this unit:

Both content and mathematical practices standards are addressed in this unit. The content standards related to each specific objective are listed in parenthesis next to the objective in the Specific Objectives And Common Core Standards subsection. In addition to the content's standards, students will have opportunity to demonstrate all eight standards of mathematical practices during the course of this unit. Students will strategically make use of the results from their data analysis, mathematical models, opinion surveys and precise terminologies to construct viable arguments and critique each other's reasoning. Students will make sense of economic and health disparities among nations quantitatively and in abstract terms. Finally, students will make justifiable recommendations to address the observed patterns of economic and health disparities among nations.

Content Standards:

- HSF-IF.C.7e Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude.
- HSF-LE.A.4 For exponential models, express as a logarithm the solution to $ab^{ct} = d$ where a, c, and d are numbers and the base b is 2, 10, or e; evaluate the logarithm using technology.
- HSF-IF.B.4 For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. Key features include: intercepts; intervals where the function is increasing, decreasing, positive, or negative; relative maximums and minimums; symmetries; end behavior; and periodicity.
- HSF-BF.B.5 Understand the inverse relationship between exponents and logarithms and use this relationship to solve problems involving logarithms and exponents.
- HSF-IF.C.7 Graph functions expressed symbolically and show key features of the graph, by hand in

simple cases and using technology for more complicated cases.

- HSF-LE.A.3 Observe using graphs and tables that a quantity increasing exponentially eventually exceeds a quantity increasing linearly, quadratically, or (more generally) as a polynomial function.
- HSS-ID.B.6 Represent data on two quantitative variables on a scatter plot, and describe how the variables are related.
- HSS-ID.B.6a Fit a function to the data; use functions fitted to data to solve problems in the context of the data. Use given functions or choose a function suggested by the context. Emphasize linear, quadratic, and exponential models.
- HSS-ID.B.6c Fit a linear function for a scatter plot that suggests a linear association.
- HSS-ID.C.7 Interpret the slope (rate of change) and the intercept (constant term) of a linear model in the context of the data.
- HSS-ID.C.8 Compute (using technology) and interpret the correlation coefficient of a linear fit.

Standards For Mathematical Practices Addressed in this unit:

- MATH.PRACTICE.MP1Make sense of problems and persevere in solving them.
- MATH.PRACTICE.MP2Reason abstractly and quantitatively.
- MATH.PRACTICE.MP3Construct viable arguments and critique the reasoning of others.
- MATH.PRACTICE.MP4 Model with mathematics.
- MATH.PRACTICE.MP5Use appropriate tools strategically.
- MATH.PRACTICE.MP6 Attend to precision.
- MATH.PRACTICE.MP7Look for and make use of structure.
- MATH.PRACTICE.MP8Look for and express regularity in repeated reasoning.

Data Tables And Graphs:

Table 1 - Life Expectancy data For Malawi, Bangladesh, India, China and United States: 1960 - 2017

	Life Expectancy				
Year	**Bangladesh**	**China**	**Malawi**	**United States**	**India**
1960	45.8	43.7	37.8	69.8	41.2
1965	48.7	49.5	38.9	70.2	44.4
1970	47.5	59.1	40.6	70.8	47.7
1975	48.9	63.9	42.8	72.6	51
1980	53.5	66.8	44.8	73.6	53.8
1985	55.6	68.5	46.1	74.6	55.8
1990	58.4	69.3	46.6	75.2	57.9
1995	61.9	70.2	46.6	75.6	60.4
2000	65.3	72	46.5	76.6	62.6
2005	67.9	74	49.8	77.5	64.6
2009	69.8	75	55.7	78.4	66.2
2010	70.2	75.2	57.3	78.5	66.6
2011	70.6	75.4	58.7	78.6	67

2012	71	75.6	59.9	78.7	67.4
2013	71.4	75.8	61	78.7	67.7
2014	71.8	75.9	61.9	78.8	68
2015	72.2	76.1	62.7	78.7	68.3
2016	72.5	76.3	63.2	78.5	68.6
2017	72.8	76.4	63.7	78.5	68.8

Generated from World Development Indicators; https://databank.worldbank.org/indicator/SP.DYN.LE00.IN/1ff4a498/Popular-Indicators

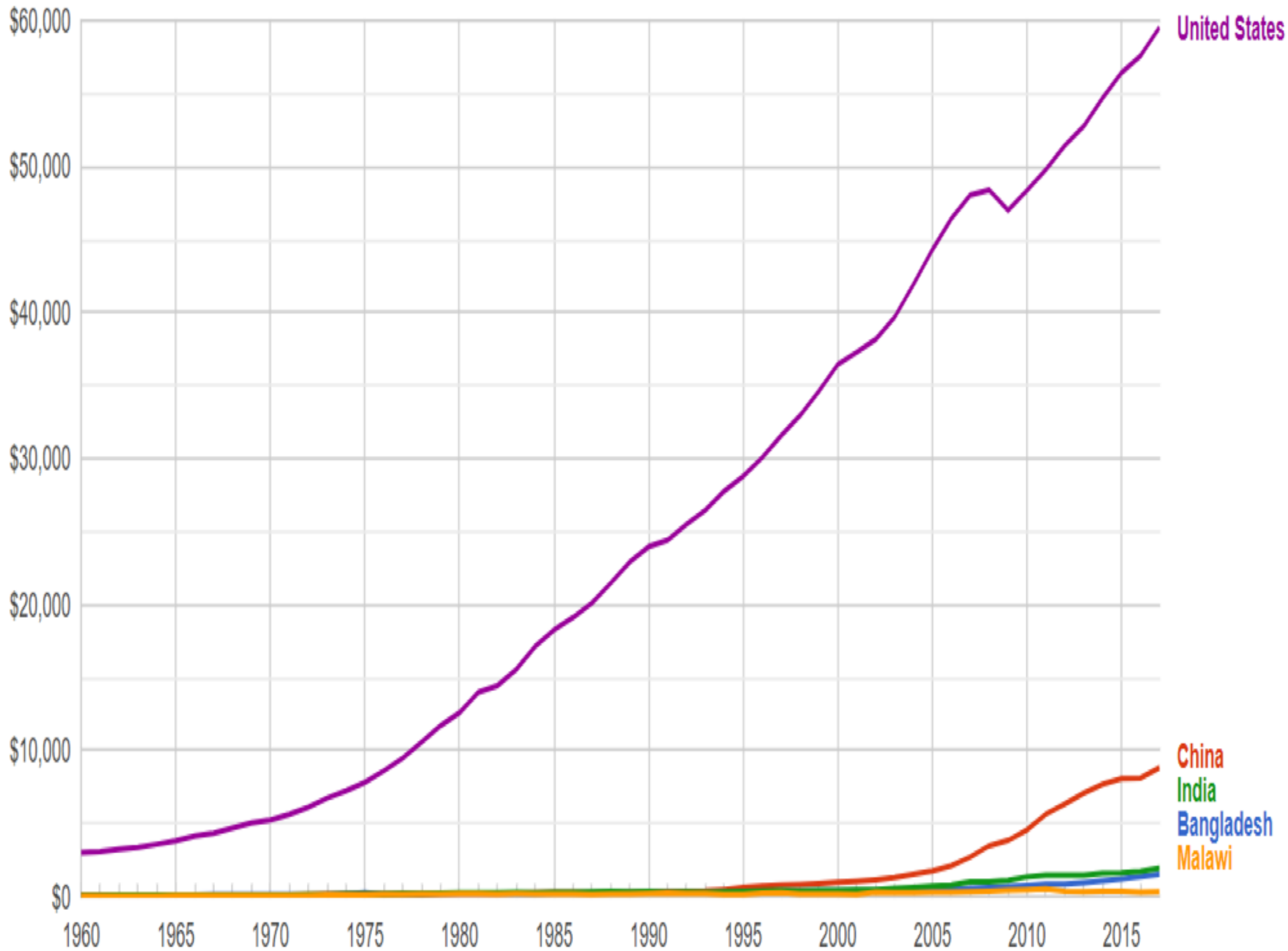
Table 2 - GDP per capita data For Malawi, Bangladesh, India, China and United States: 1960 - 2018

	GDP per capita (current US$)				
Year	Bangladesh	China	United States	India	Malawi
1960	89	89.5	3,007.10	82.2	44.5
1965	106.6	98.5	3,827.50	119.3	55.5
1970	140	113.2	5,234.30	112.4	61.8
1975	277.6	178.3	7,801.50	158	113.9
1980	227.8	194.8	12,574.80	266.6	198
1985	245.5	294.5	18,236.80	296.4	155.7
1990	306.3	317.9	23,888.60	376.6	200
1995	329.4	609.7	28,690.90	373.8	142
2000	418.1	959.4	36,334.90	443.3	156.4
2005	499.5	1,753.40	44,114.70	714.9	289.6
2009	702.3	3,832.20	47,100.00	1,102.00	438.2
2010	781.2	4,550.50	48,466.80	1,357.60	478.7
2011	861.8	5,618.10	49,883.10	1,458.10	535
2012	883.1	6,316.90	51,603.50	1,443.90	391.6
2013	981.8	7,050.60	53,106.90	1,449.60	348.4
2014	1,118.90	7,651.40	55,033.00	1,573.90	371.3
2015	1,248.50	8,033.40	56,803.50	1,605.60	380.6
2016	1,401.60	8,078.80	57,904.20	1,729.30	315.8
2017	1,564.00	8,759.00	59,927.90	1,981.50	356.7
2018	1,698.30	9,770.80	62,641.00	2,015	389.4

Generated From World Development Indicators; https://databank.worldbank.org/indicator/NY.GDP.PCAP.CD/1ff4a498/Popular-Indicators

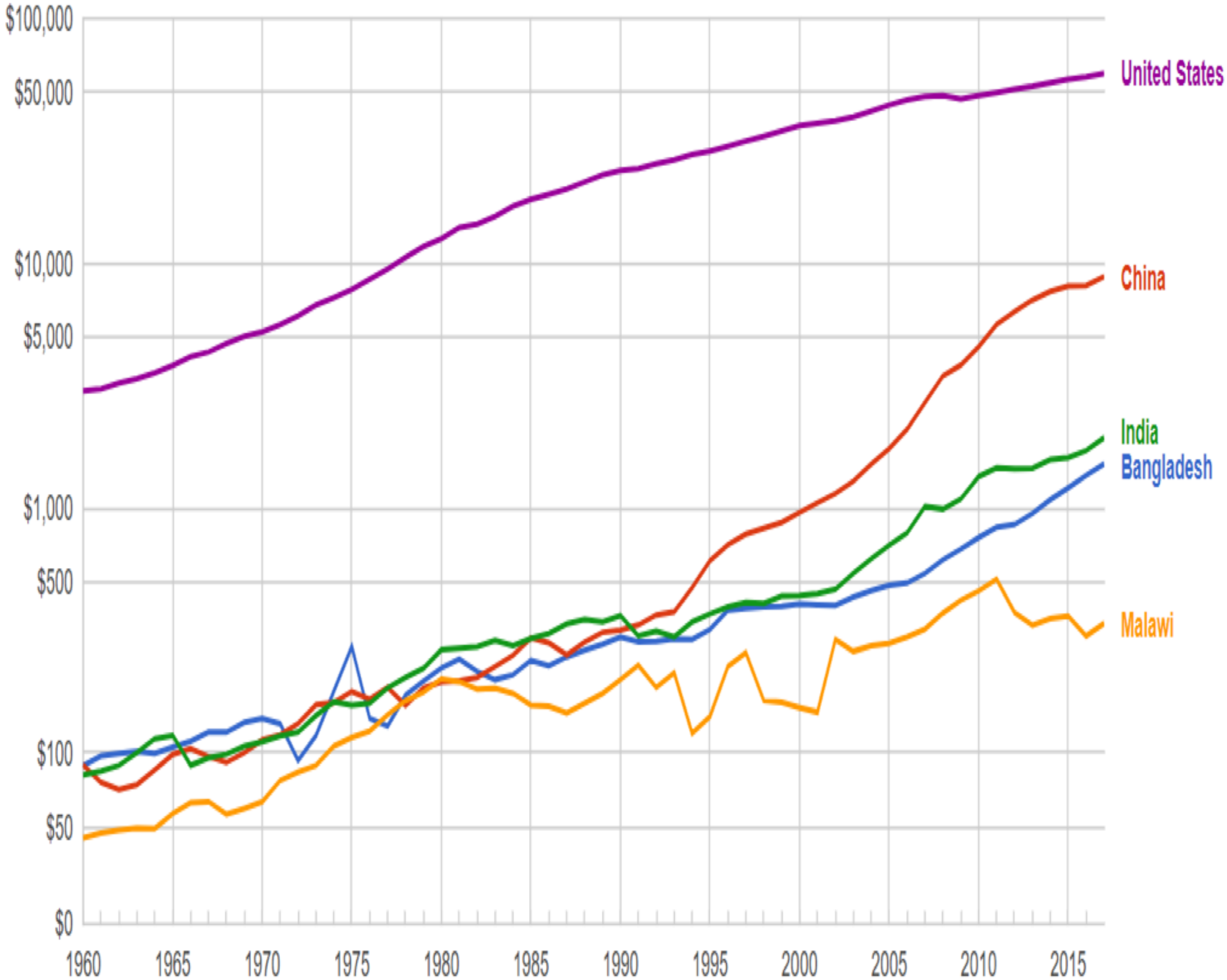
Graphical Representations:

Figure 1- GDP Per Capita (Current US$) For Malawi, Bangladesh, India, China and United States: 1960 - 2015: Y-axis Linear



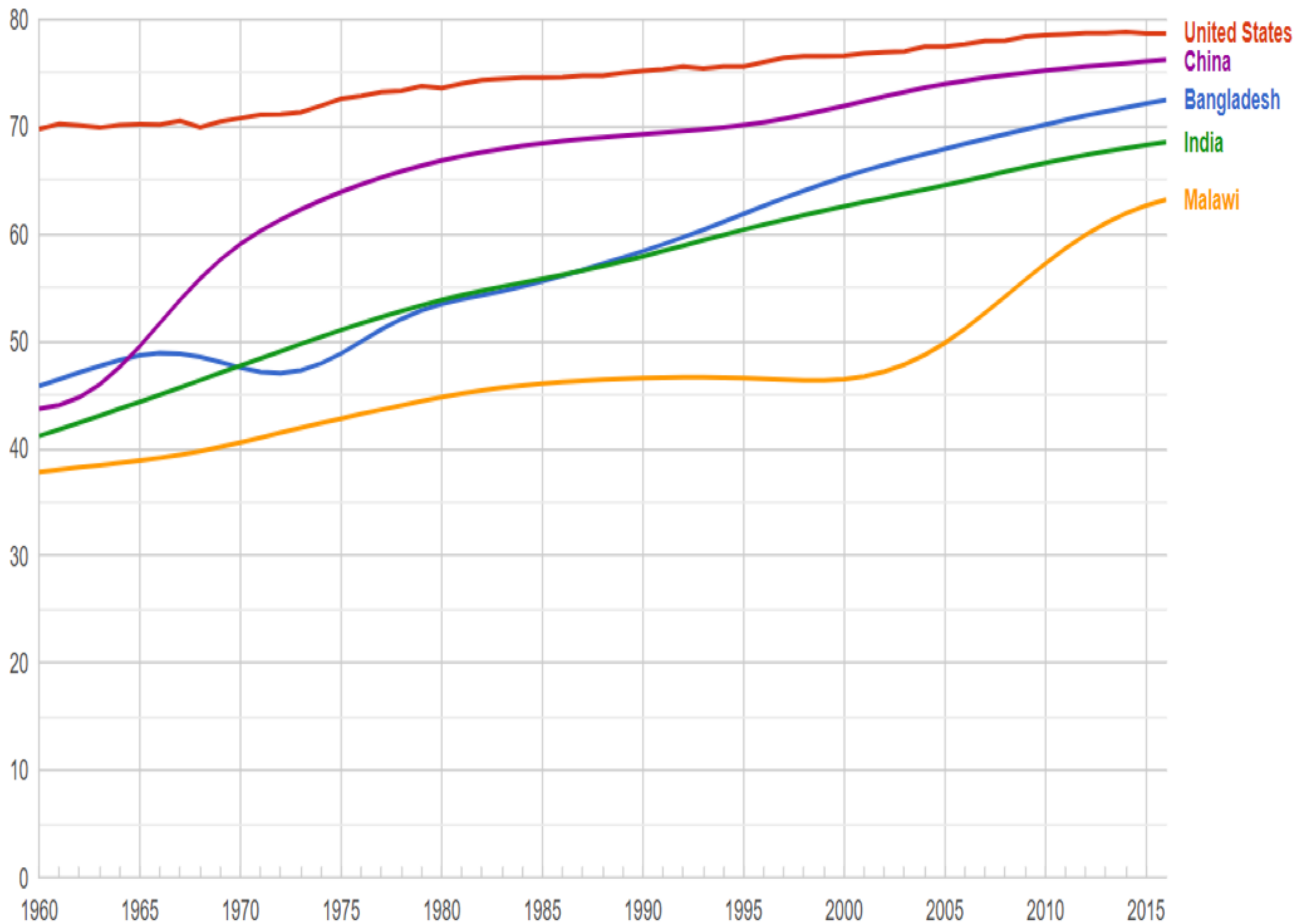
Generated From https: www.google.com/publicdata/explore

Figure 2 - GDP Per Capita (Current US$) For Malawi, Bangladesh, India, China and United States: 1960 - 2017: Y-axis Log



Generated From https: www.google.com/publicdata/explore

Figure 3 - Life Expectancy For Malawi, Bangladesh, India, China and United States: 1960 - 2015



Generated From https: www.google.com/publicdata/explore

Notes:

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1 Constitution of the World Health Organization. International Health Conference 1946 July 22; New York: World Health Organization; 1946.

2 https://data.worldbank.org/indicator/SP.DYN.LE00.IN?end=2017&locations=MW&start=1960&view=chart

3 https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?end=2017&locations=MW&start=1960&view=chart

4 https://www.worldbank.org/en/news/press-release/2018/10/17/nearly-half-the-world-lives-on-less-than-550-a-day

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