Chapter 2
Science Education: A Veritable Tool for Development

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2.1 Introduction

Science education covers the teaching and learning of science by non-scientists (Hurd, 1991a, b; Jegstad & Sinnes, 2015) which could include pupils and students in primary and secondary schools (Plate 2.1) and even members of the general public (Plate 2.2). Kids feel proud to become scientists after science education events like Science Festival, Science in the Pub, Street Science, Soapbox Science, etc. Science education grooms curiosity about the world and enhances scientific thinking (Gilbert, 2015) and could identify the qualitative factors that deter women from pursuing careers in STEMM and promote much sought-after diversity. It could bring and keep more women and girls into science, technology, engineering, mathematics and medicine (STEMM) careers (Plate 2.3).

The field of science education involves science content, science process (the scientific method), some social science and some teaching pedagogy. The standards for science education provide expectations for the development of understanding

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Plate 2.1 Next Einstein Forum Fellow, Eucharia O. Nwaichi, and Next Einstein Forum Ambassador, Stephen Manchishi, running science education activity in Zambia. Selected primary and high school students were exposed to coding, and they could create cartoons and similar programmes

for students through the entire course of their kindergarten education and beyond. The traditional subjects included in the standards are physical, life, earth, space and human sciences.

2.2 Content of Science to Non-traditional Scientists

Fenichel and Schweingruber (2010) argued that ascertaining what learning looks like, getting a recipe to measure it and a blueprint to guarantee that people of all ages, from different cultures and settings, have a helpful learning experience should be an all-important consideration for practitioners in informal science backgrounds such as herbaria, museums, libraries, repositories, post-school programmes, science and technology parks, media outfits, aquariums, sanctuaries, wildlife parks and conservatories.

Delivering content of science to non-traditional scientists is complex and requires science leaders who are both task- and relationship-oriented. Gratton and Erickson (2007) posited that relationship-oriented leadership style would be most appropriate

Plate 2.2 Eucharia Nwaichi and her research team at the Institute of Agrophysics, Lublin, Poland, participated at Science Festival in Lublin and came second. To the general public, this science education activity provided an informal and a less-tensed platform for public learning, inspiration and scientific debate

in complex teams, given that team members are more likely to share knowledge in an environment of trust and goodwill. To effectively deliver on science education, objectives must be clear, assigned tasks must be specific and communicated, and monitoring and feedback must be provided. Communication approach (Fig. 2.1) making great considerations for content, human element (from the crusader), structure and packaging of intended message gives good outcomes. STEMM crusaders should strive for increased trust among non-science audience as Nwaichi and Abbey (2015) reported heightened performance and norming frictions between research networks and community members when trust was established. They suggested development of message content and structure, delivery style and presence (Fig. 2.1) to effectively communicate goal, being mindful of entry and appropriate language register in an informal setting.

Fenichel and Schweingruber (2010) posited that the standards for science education provide expectations for the development of understanding to the learners that may include heterogeneous public, children, college students, etc. The traditional science subjects included in the standards are physical, life, earth, space and human sciences. Life science has taught that a chick pecks its way out of the egg, a fingerling fights to get out of the mother fish's belly but a human baby needs a push to get

Plate 2.3 As a UNESCO-L'Oréal Fellow, Eucharia O. Nwaichi worked with Host, Magdalena Frac, to excite more youth (especially girls) into science. Stakeholders like the principal of selected schools in Poland were engaged for sustainability of project outcomes

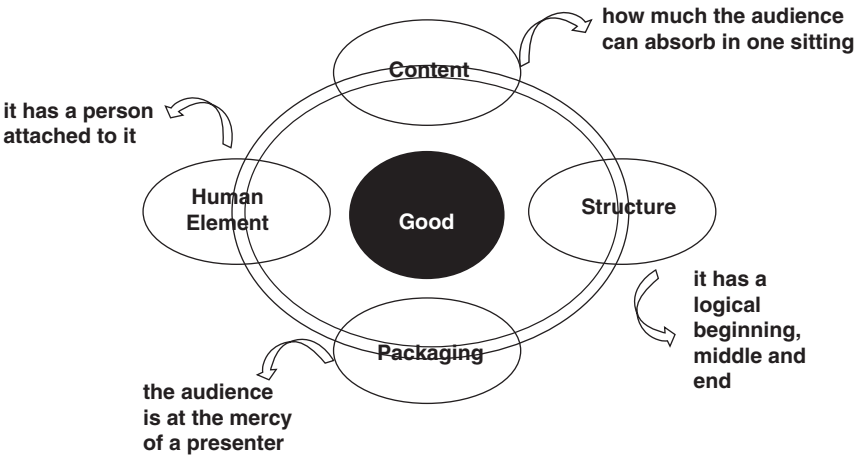

Fig. 2.1 Scientific communication approach. (Nwaichi & Abbey, 2015)

out of the womb. This push in development is the job of science education! A clarion call goes out to learn from these traditional sciences for effective development: break the laws sometimes (physical sciences); innovation comes only by doing 'thinking outside the box' stuff, humans naturally love push (life science); encouragement like the science prize inspires more work, protect nature for it is an amazing thing to do (earth science); sustainability, give people some space to innovate (space sciences); spaces are needed to examine performance, the solution to our challenges lie within (human sciences); untapped potentials can be strategically unleashed.

2.3 The Concept of Development

A multitude of meanings has been attached to the idea of development. The term is complex, contested, ambiguous and elusive. However, in the simplest terms, development can be defined as bringing about change that allows people to achieve their human potential. An important point to emphasize is that development is a political term. It has a range of meanings that depend on the context in which the term is used, and it may also be used to reflect and to justify a variety of different agenda held by different people or organizations. This point has important implications for the task of understanding sustainable development, because much of the confusion about the meaning of the term 'sustainable development' arises because people hold very different ideas about the meaning of development. Another important point is that development is a process rather than an outcome. It is dynamic in that it involves a change from one state or condition to another. Ideally, such a change is a positive one – an improvement of some sort. Furthermore, development is often regarded as something that is done by one group (such as a development agency) to another (such as rural farmers in a developing country). Again, this demonstrates that development is a political process, because it raises questions about who has the power to do what to whom.

Development is not simply about the interactions between human groups; it also involves the natural environment (i.e. transforms the environment). So, from another point of view, development is about the conversion of natural resources into cultural resources. This conversion has taken place throughout the history of human societies, although the process has generally increased in pace and complexity with time. Also, development brings about economic growth. From this point of view, development means an increase in the size or pace of the economy such that more products and services are produced. Conventionally, a common assumption has been that if an economy generates more products and services, then humans will enjoy a higher standard of living. The aim of many conventional approaches to development has been to increase the size of the economy in order to increase the output of products and services.

According to Shah (2017), development means improvement in country's economic and social conditions. More specifically, it refers to improvements in a way

of managing an area's natural and human resources in order to create wealth and improve people's lives. Dudley Seers while elaborating on the meaning of development suggests that while there can be value judgements on what is development and what is not, it should be a universally acceptable aim of development to make for conditions that lead to a realization of the potentials of human personality (Shah, 2017). Among other conditions, Seers outlined education as what can make for achievement of the aim of development. Empowerment of people takes development much ahead of simply combating or ameliorating poverty. In this sense, development seeks to restore or enhance basic human capabilities and freedoms and enables people to be the agents of their own development. Two major contemporary concerns that require focus in any development initiative are that of human security and sustainability. Fulfilment of basic needs of mankind should be the true objective of development and achievements that either do not contribute to this goal or even disrupt this basic requirement must not be pursued as a development goal.

Additionally, development is the desire and ability to use what is available to continuously advance the quality of life and liberate people from the circle of poverty. It is also tantamount with self-reliance which requires the ability to learn how to advance one's well-being without recourse to others. It involves the ability to act and apply knowledge to improve the knowledge of the process of development and of knowledge itself. Development is linked with scientific and technological progress, modernization, industrialization, electronic and biological revolution, material advancement, the emergence of nuclear energy, new knowledge about man and the universe. It means urbanization, socio-cultural transformation, mass literacy, employment opportunities and the emergence of specialized and independent occupational roles. It includes full growth and expansion of the education, industries, agriculture, social, religious and cultural institutions. The ultimate aim of development must be to bring about sustained improvement in the well-being of the individual and bestow benefits to all self-reliance and mobilization of domestic resources, the transformation of the structure of rural production, the development of small-scale industries and the acquisition of technological and scientific skills. It has been noted that the major factor responsible for the wide gap in the level of development between the so-called developed and developing nations is the level of development of pure and applied science in these nations.

2.4 Sustainable Development

Sustainable development is the organizing principle for meeting human development goals while simultaneously sustaining the ability of natural systems to provide the natural resources and ecosystem services on which the economy and society depend. The desired result is a state of society where living conditions and resources are used to continue to meet human needs without undermining the integrity and stability of the natural system. Sustainable development can be defined as development that meets the needs of the present without compromising the ability of future

generations to meet their own needs. According to Kates et al. (2016), the use of this definition has led many to see sustainable development as having a major focus on intergenerational equity. Although the brief definition does not explicitly mention the environment or development, the subsequent sentences, while rarely quoted, are clear. On development, it is stated that human needs are basic and essential; that economic growth – but also equity to share resources with the poor – is required to sustain them; and that equity is encouraged by effective citizen participation. On the environment, the concept of sustainable development does imply limits – not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities.

Sustainable development is rooted in earlier ideas about sustainable forest management and environmental concerns. As the concept of sustainable development developed, it has shifted its focus more towards the economic development, social development and environmental protection for future generations. It has been suggested that the term sustainability should be viewed as humanity's target goal of human-ecosystem equilibrium, while sustainable development refers to the holistic approach and temporal processes that lead us to the endpoint of sustainability (Shaker, 2015).

In September 2015, the General Assembly adopted the 2030 Agenda for Sustainable Development that includes 17 Sustainable Development Goals (SDGs). Building on the principle of 'leaving no one behind', the new Agenda emphasizes a holistic approach to achieving sustainable development for all. The 17 SDGs to transform our world include Goal 1: No Poverty; Goal 2: Zero Hunger; Goal 3: Good Health and Well-Being; Goal 4: Quality Education; Goal 5: Gender Equality; Goal 6: Clean Water and Sanitation; Goal 7: Affordable and Clean Energy; Goal 8: Decent Work and Economic Growth; Goal 9: Industry, Innovation and Infrastructure; Goal 10: Reduced Inequality; Goal 11: Sustainable Cities and Communities; Goal 12: Responsible Consumption and Production; Goal 13: Climate Action; Goal 14: Life Below Water; Goal 15: Life on Land; Goal 16: Peace and Justice Strong Institutions; and Goal 17: Partnerships to Achieve the Goal. Thus, the concept of sustainability has been adapted to address very different challenges, ranging from the planning of sustainable cities to sustainable livelihoods, sustainable agriculture to sustainable fishing, and the efforts to develop common corporate standards in the UN Global Compact and in the World Business Council for Sustainable Development.

2.5 Development Indices

Gross National Product Index

In the history of development economics, gross national product (GNP) has been thought of as a key indicator in measuring development of a nation. Prior to the 1970s, economic development was evaluated in terms of the GNP and per capita income, which stood alone as the ultimate standard of national progress and prosperity. However, over the years, researchers have found that the GNP is not a single indicator that can be used to measure development. Numerous efforts have been done to create other composite indicators that could serve as complements or alternatives to the traditional measure.

A major breakthrough in the thinking about development came between 1995 and 1999 which led to a re-definition of the development process from one that focuses solely on economic growth to one in which the fruits of economic growth benefit the population in terms of higher literacy rates and education levels, better health and nutrition, higher levels of social cohesion and social skills, and more equality. In a similar line of thinking, the United Nations Development Programme (UNDP) has developed the Human Development Index (HDI), which goes beyond narrow monetary income definitions of development.

Consequently, a new view of development has emerged which is described as a multidimensional process involving major structural changes in social attitudes and national institutions as well as the acceleration of economic growth, the reduction of inequality and the eradication of poverty. Simply stated, development refers to the process of improving the quality of life of all human lives. A major effort in this direction was the development of a composite 'Physical Quality of Life Index' (PQLI). This index was based on a country's life expectancy, infant mortality rate and literacy rate. Overall, good development measurement requires researchers to develop indicators which take into account economic, social, political, environmental and technological concerns.

Many studies have been conducted to identify the indicators that represent the development level of a country. In the meantime, some researchers have come up with a variety of development indices to rank the countries according to their national performance. To construct comprehensive development indices, economic, human, social and environmental concerns and other related representative indicators must be carefully selected. The existing development indices are systematically classified into three main categories of development frameworks, namely human development, social development and sustainable development (Aziz et al., 2015). Indices categorized under human development mainly focus on developing human potentials to the optimum level, and their scopes are mainly for the individual. Indices under the social development category are more all-encompassing – focusing on the good of the greater society, with scopes that go beyond the individual. Meanwhile, indices classified under sustainable development focus on a more

multidimensional way where economic, social and environmental dimensions are being considered and integrated.

Human Development Framework

The definition of human development and its aspects are very important as it will affect the choices of performance indicators. The human development concept is broader than other people-oriented approaches to development. It represents a multidimensional and holistic approach to development because it encompasses all aspects of well-being. Human development has been defined by United Nations Development Programme (UNDP) as the process of enlarging people's choices and improving human capabilities (the range of things that they can do or be in life), freedoms, guaranteed human rights and self-respect so they can live a long and healthy life, access to education and a decent standard of living, participate in their community and the decisions that affect their lives. It is expected that the existing indices and indicators used to measure human development will vary based on how they define human development and its dimensions. Some scholars only focused on the physical aspects of human beings in measuring human development, and some others also included the spiritual concerns of human being in their measurement. Since the 1960s, a broader measure of human well-being combining suitable indicators has been created by many scholars and development agencies. The efforts to construct a comprehensive index as a measurement of human development are still active. The discussions on this issue have led to the development of some significant indices to measure human development. The indices are presented as follows.

A. *Physical Quality of Life Index (PQLI)*

The Physical Quality of Life Index (PQLI) was created as another measurement of human development based on the most basic needs of the people. It is important to note that three main physical indicators, namely life expectancy at the age of 1, infant mortality and adult literacy, were combined to construct the PQLI and used for a cross-country comparison. The index enables researchers to rank countries not by incomes but by the performance of a country in meeting their people's basic needs. Initially, PQLI is developed to study the effect of US aid or assistance given to developing countries. To combine the variables, the scaling procedure which transforms the variables with the lowest value put at 0 and the highest value at 100 was used and a simple average of the three transformed variables was taken to arrive at the required PQLI.

PQLI is a simple and easily computed composite index and can be used to calculate changes in countries over time as well as to measure ethnic, regional, gender and rural-urban differences. PQLI became instantaneously popular because the selected indicators conform with the logical understanding of human development. However, PQLI has not been used for regional comparison and rather focuses on a cross-country comparison. One limitation of the PQLI is that the three indicators

were insufficient to capture the quality of life. It fails to take into account problems associated with basic needs like nutrition, health, sanitation, housing, etc. Therefore, the PQLI is inadequate to comprehensively and accurately portray the real level of development of a society. Another limitation of this index is that it measures comprehensive development by only considering the physical aspects of life. By doing so, this index does not include freedom, justice, security and other intangible elements that are important in the overall concept of human development, and, more importantly, only measures how well societies satisfy certain specific life-serving social characteristics.

B. *Human Development Index (HDI)*

It has been correctly recognized that development is much more than just the expansion of income and wealth. Development should emphasize economic growth as a means and not the end of development and therefore should consider health, education, standard of living, human rights, political freedom and self-respect as more important concerns of human development. In 1990, the Human Development Report (HDR) developed a composite index, the Human Development Index (HDI), on the basis of three basic dimensions of human development – to lead a long and healthy life, to acquire knowledge and to have access to resources needed for a decent standard of living. This index has since been equated to human development as it has become one of the important alternatives to the traditional one-dimensional measure of development, the GDP. The HDI contains four variables to represent the three dimensions – life expectancy at birth, to represent the dimension of a long, healthy life; adult literacy rate and combined enrolment rate at the primary, secondary and tertiary levels, to represent the knowledge dimension; and real GDP per capita, to serve as a proxy for the resources needed for a decent standard of living. HDI is similar to PQLI in terms of the indicators but differs on the inclusion of income level in HDI and exclusion of the same from PQLI. HDI attempts to rank all countries on a scale of 0 (lowest human development) to 1 (highest human development) based on three goals or end products of development which are longevity, knowledge and standard of living. HDI is known as one of the most ambitious attempts to systematically and comprehensively analyse the comparative status of socio-economic development in both developing and developed nations. HDI works better than PQLI as a measure of development because it represents both the physical and financial attributes of development. Moreover, HDI is better than other development indices because it effectively facilitates the evaluation of the progress of countries which allows inter-country comparison and inter-temporal comparisons of living levels. This is because HDI uses data that are available in most countries which allow for the widespread international comparisons. The composition of HDI appears to benefit various social policies because the government can specifically find an associated cost or effort required to directly improve the three indicators of HDI. HDI is not short of criticisms, although it has been reported as one of the significant indices to measure countries' performance on the dimension of human development. The small number of indicators in HDI somehow impedes it to successfully capture various aspects of development, thus making it unable to

respond better to social problems like corruption. HDI is also argued to be a reductionist measure as it incorporates just a subset of possible human choices and leaves out many aspects of life that are of fundamental importance. Along the same line, HDI has ignored the gender inequality aspect in a society to represent the development of a country. The index also overlooked two important dimensions of human development, which are environment and equity. The exclusion of ecological considerations and equity as indicators of development inhibits the accurate representation of the realities of the world. Furthermore, focusing exclusively on national performance and ranking does not accurately portray development from a global perspective. HDI has been criticized to be an incomplete measure of human development and painted a distorted picture of the world. While HDI carries useful information about a country's current development, it ignores the future level of development as the index used an off-count of past efforts rather than the estimation of the present efforts or prediction of the future. Overall, the HDI has been criticized for not successfully capturing the richness and breadth of the concept of human development. Furthermore, the use of the equal weighted sums of each indicator in the HDI is also an issue. On one hand, the equal-weighted sums of each indicator is a limitation to effectively measure the level ofdevelopment, while on the other hand, it improves the index's goodness of fit given the added complexity of usingassumptions based on unequal weights. From the analysis, it can be concluded that HDI is basically devised as a summary, not a comprehensive measure of human development. Therefore, it is recommended that HDI be refined to be more comprehensive and reflect more aspects of human development and inequalities within a country.

C. *Gender-Related Development Index (GDI) and Gender Empowerment Measure (GEM)*

Besides HDI, other composite measures, a gender related-index, namely Gender-Related Development Index (GDI) and Gender Empowerment Measure (GEM), have been created. Both GDI and GEM were created to include gender inequality issues in human development. GDI takes into account gender inequality in its overall assessment of aggregate human development in a country. GDI measures in the same dimension as HDI, discounting them for gender inequality. This means GDI should be interpreted as HDI discounted for gender disparities in its three components and should not be interpreted independently of HDI. Meanwhile, GEM is meant to be interpreted as an index of gender equity in political and economic participation and decision-making as well as power over economic resources. GEM consists of three indicators which are focusing on empowerment dimension. The selected indicators are male and female shares of parliamentary seats; male and female shares of administrative, professional, technical and managerial positions; and power over economic resources. Since the introduction of GDI and GEM in 1995, several other indicators that directly measure gender inequality have also been constructed such as the Relative Status of Women (RSW) Index, the Standardized Index of Gender Equality (SIGE) and the Gender Equality Index (GEI). These indices were developed due to the shortcomings and misinterpretation of GDI and GEM in many reports and academic writings. Researchers are looking

for indicators which directly measure gender inequality. GDI and GEM are both known as rarely used indices which receive minimal attention and have not been highlighted in the international press. This is because of their limited information and empirical value added. In addition, GDI has always been misunderstood by most studies as a direct measure of gender inequality, therefore leading to the misinterpretation and misuse of the index. This shows that the computation of GDI is confusing and vague for people to understand the idea of this index. Besides that, GDI and GEM were also criticized because they do not adequately reflect gender inequality dimensions neither in developing countries nor in developed countries. However, both of these indices have an advantage compared to other gender equality indicators in terms of the separation of dimensions of basic capabilities (GDI) and empowerment (GEM). It has been suggested that it is preferable to separate these two dimensions because different countries may have gender equality in basic capabilities but look very different in the dimension of empowerment and vice versa.

D. *Meaning in Life Index (MILI)*

Taking spirituality of human beings into account, Meaning in Life Index (MILI) was developed and used to see the relationship of MILI with personality and religious behaviours and beliefs among UK undergraduate students. The MILI is an index that measures the extent to which individuals believe their lives have meaning, not just on life quality or life satisfaction. It aims to establish any association that exists between MILI and Eysenck's personality factors of extraversion, neuroticism, psychoticism and social conformity, as well as some religious variables such as church membership and frequency of church attendance. The MILI aspires to cover personality and religious dimension as an extension to the Purpose in Life (PIL) Index. This instrument has gained adequate face validity, internal consistency and scale reliability which allows it for other future research. However, the MILI scores are greatly dependent on who the person is or in other words the personality type. A person's personality has a big influence on how life is considered as having meaning. In addition, data on religiosity showed no association with extrinsic or quest religiosity and a significant but weak relationship between the MILI scores and intrinsic religiosity.

Social Development Framework

Social development can be defined in two ways. It can refer to improvement in the welfare and quality of life of individuals, or changes in societies which make development more equitable and inclusive for all members of a society. These two definitions are based on the meaning of social which refers to people's welfare and to relationships (between individuals and groups within a society). Since 1954, there have been substantial efforts on the areas of social concern and the representative indicators to describe development. The efforts to promote social development in the Western industrial countries can be traced back in the 1970s when social

workers experienced in development work first sought to popularize social development ideas in the United States and elsewhere. Ever since, social development has become more widely known in these countries. But it is largely as a result of the World Summit on Social Development that social development has become more widely known in the Global North. Organized by the United Nations in Copenhagen in 1995, the Summit called the Copenhagen Declaration on Social Development addressed a number of pressing global concerns ranging from poverty and unemployment to ethnic conflict and gender oppression. It was agreed, among other things (Danjuma and Ikpe, 2019), to create a framework for development dedicated to the eradication of poverty and to increase the resources spent on education and health. In addition, they pledged to support development that is people-centred and participatory; that takes account of non-discriminatory and gender sensitivity; that promotes accountability and transparency in government; and that builds the capacity of all development actors, including the state, the private sector and civil society. It was also affirmed that economic and social goals are inextricably linked and that both economic and social factors contribute to sustainable development.

A. *Social Development Index (SDI)*

Social Development Index (SDI) was initiated in 1989 to measure countries' social development. Multiple indicators have been used to construct this index. Initially, SDI was created with as many as 13 physical variables to represent social development across 40 countries. These selected indicators represent urbanization and industrialization, health conditions, nutritional level, level of education and social communication dimensions. However, in 2008, SDI was reintroduced with only 10 physical variables representing various areas of social concern across 102 countries including 21 Organisation for Economic Co-operation and Development (OECD) countries and socialist countries like China. This index captures a large number of social indicators to represent more areas of social concern and is associated with an objective method of deriving weights for combining multiple physical indicators. However, although SDI includes a large number of social indicators to represent the level of development, the economic condition is being ignored as no financial variable is included. This is one of the limitations of SDI in presenting a more holistic view of the development.

B. *Human Poverty Index (HPI)*

Between 1997 and 2009, another composite measure, namely the Human Poverty Index (HPI), which is an index of human deprivation and a non-income-based measure of human poverty was created. The index values and the rank of countries show how the intensity of poverty varies across countries. The index recognizes that poverty is multidimensional and that poverty measures based on the income criterion do not capture deprivation of many kinds. Human poverty is more than income poverty as it denies people's choices and opportunities for living a tolerable life. The HPI for developing countries incorporates three types of deprivation as important dimensions of poverty – in survival, in education and knowledge and in economic provisioning. Survival deprivation is measured by the percentage of people (in a given

country) not expected to survive to the age of 40 years; meanwhile, deprivation in education and knowledge is measured by the adult literacy rate. Deprivation in economic provisioning is computed as the mean of three variables: percentage of population without access to safe water, population without access to health services and malnutrition among children less than 5 years of age. The HPI is then obtained as the cube root of the average of cubes of the three above components of deprivation. The HPI can be used in at least three ways – as a tool of advocacy, as a planning tool for identifying areas of concentrated poverty within a country and as a research tool. This composite index has several advantages in determining the social state of development in terms of poverty level for each country. HPI gives a real picture of poverty level in a country since it moves away from income poverty measures to relative deprivation measures and successfully reflects more basic opportunities and choices in terms of survival, education and health. Furthermore, although there is no universal agreement that HPI can identify the causes of poverty, it can illuminate the different dimensions of poverty which policymakers have to address. In addition, like all such indices, the HPI summarizes information especially the extent of poverty along several dimensions. However, it has no obvious merit as a summary measure, particularly in relation to simpler, more easily understood, indices such as the simple mean. Another limitation of the HPI is about the particular choice of variables for describing and quantifying deprivation and about the reliability of the data actually used. There are so many related variables being excluded from the index which are the deprivation in terms of food, clothing and shelter as applicable to the whole population, deprivation of gainful employment, deprivation of basic human rights including equality before law and justice, etc. It has been emphasized that the concept of human poverty is actually larger than the HPI. This is because some important dimensions are difficult to quantify, or data do not exist. Examples of such dimensions include political freedom, personal security and exclusion.

C. *Multidimensional Poverty Index (MPI)*

In 2010, HPI was supplanted by Multidimensional Poverty Index (MPI). The index was developed by Oxford Poverty & Human Development Initiative (OPHI) and the United Nations Development Programme (UNDP). The MPI constitutes a set of poverty measures which can be used to create a comprehensive picture of people living in poverty. The index offers a valuable complement to traditional income-based poverty measures by considering multiple deprivations at the household level. The index identifies deprivations across the same three dimensions as the HDI with ten indicators; two represent health (malnutrition and child mortality), two are educational achievements (years of schooling and school enrolment), and six aim to capture standard of living (access to electricity, drinking water, sanitation, flooring, cooking fuel and basic assets like a radio or bicycle). The three broad categories (health, education and living standards) are weighted equally (one-third each) to form the composite index which shows the number of people who are multidimensionally poor (suffering deprivations in 33% of weighted indicators) and the number of deprivations with which poor households typically contend. The MPI relies on three main databases that are publicly available and comparable for most

developing countries: the Demographic and Health Survey (DHS), the Multiple Indicator Cluster Survey (MICS) and the World Health Survey (WHS). There are some advantages of the MPI compared to the HPI. The index is able to capture the severe deprivations that each person faces at the same time and can reflect both the incidence of multidimensional deprivation and its intensity – how many deprivations people experience at the same time. Thus, this addresses the shortcoming of the HPI which could not identify specific individuals, households or larger groups of people as jointly deprived as it used country averages to reflect aggregate deprivations in health, education and standard of living. In addition, the MPI can be broken down by indicator to show how the composition of multidimensional poverty changes for different regions, ethnic groups, urban and rural location as well as other key household and community characteristics. This is why MPI is described as a high-resolution lens on poverty as it can be used as an analytical tool to identify the most prevailing deprivations. Besides, the methodology of MPI shows aspects in which the poor are deprived and help to reveal the interconnections among those deprivations. This enables policymakers to target resources and design policies more effectively. This is especially useful where the MPI reveals areas or groups characterized by severe deprivation. However, the MPI also has several drawbacks. First, the indicators included in this index are from different elements because the data are not available for all dimensions. Some indicators are based on outputs (such as years of schooling) and others based on inputs (such as cooking fuel). Second, in order to be considered the multidimensional poor, the MPI stated that households must be deprived in at least six standard of living indicators or in three standard of living indicators and one health or education indicator. However, data availability for all indicators is questionable. Therefore, careful judgements were needed to address missing data in some cases. Third, while the MPI goes well beyond a headcount to include the intensity of poverty experienced, it does not measure inequality among the poor, although decompositions by group can be used to reveal group-based inequalities. Finally, the estimates are based on publicly available data which limits direct cross-country comparability. These drawbacks are mainly due to data constraints. With these drawbacks, it is expected that this index will evolve over time just like the other development indices.

D. *Corruption Perception Index (CPI)*

The Corruption Perceptions Index (CPI), created by a non-governmental organization, the Berlin-based Transparency International (TI), and first released in 1995, has been designed to provide a more systematic and extensive snapshot of corruption within countries. These perceptions enhance our understanding of real levels of corruption from one country to another. The CPI combines a number of different indicators into one composite index to measure corruption. This means that the CPI is a homogeneous index in the sense that all the components upon which it is based seek to measure the same thing. The CPI is based on data collected over a number of years prior to release of the index. As the calculation of CPI is the combination of data sources, the index that results from it is highly reliable because the probability of misrepresenting a country is lowered. Other than that, by using CPI, human

behaviour and attitude towards investment decision, political participation and any other activities can be predicted. From this prediction, government and other related institutions may plan for further action to counter all the consequences and possibilities. However, CPI does not reflect the actual corruption incidence experienced by a country, and it does not explain the characteristic of a country that may affect the calculation of the index. Moreover, corruption is an issue which has a broad concept of discussion, and it can occur in many ways. Thus, CPI does not define specifically what perception on corruption is being measured. Other than that, CPI also may be biased as the index may be on the perception of the people of government or the people on the opposition side.

Sustainable Development Framework

There has been a significant research effort to define and operationalize measures of development. In practice, measures of development tend to concentrate explicitly only on economic and social dimensions and neglect the aspect of the environment. However, since the Earth Summit in Rio de Janeiro in 1992, the role of social and environmental indicators has become the focus of much attention. Rio's Agenda 21 commits all 178 signatory countries to expand their national accounts by including environmental costs, benefits and values. This worldwide interdisciplinary effort to integrate economic, social and environmental dimensions in development measurement is aiming to put all countries on its path towards sustainable development. Sustainable development has been defined in many ways, but the most frequently quoted definition is from the Brundtland Report in 1987 where development is said to be sustainable if it 'meets the needs of the present without compromising the ability of future generations to meet their own needs'. This explains sustainable development as a multidimensional concept of development where economic, social and environmental dimensions are being considered and integrated. In addition, sustainable development considers the long-term perspectives of the socio-economic system, to ensure that improvements occurring in the short term will not be detrimental to the future status or development potential of the system. Sustainable development has also been defined as minimizing the use of exhaustible resources such as energy, water, land and air, or at least ensuring that revenues obtained from them are used to create a constant flow of income across generations, and making an appropriate use of renewable resources. Also, three main components of sustainability have been noted which are environmental, social and economic sustainability. Environmental sustainability is described as natural capital remaining intact which means the functions of the environment should not be degraded. Meanwhile, social sustainability requires the cohesion of society and its ability to work towards common goals be maintained and at the same time all basic human needs be met. Economic sustainability means the country is financially feasible when development moves towards social and environmental sustainability. Therefore, in 2005, the German Council for Sustainable Development agreed that the concept of sustainability has to be extended

beyond environmental concerns, to include social and economic sustainability. The well-being of these three areas is so intertwined that it is difficult to neatly separate them. This means that people today have to leave the future generations an intact ecological, social and economic system. These definitions show that meeting the needs of the future depends on how well we balance social, economic and environmental objectives or needs when making decisions today. Nationally, there are some well-developed SDI programmes such as Sustainable Seattle 1993, and some have been given the lead by existing State of the Environment (SOE) reporting programmes such as SOE Canada 1991. However, it has been noted that despite the considerable attention devoted to SDIs in several years since 1992, no set has emerged with universal appeal, and new SDI sets experience difficulty in gaining wide acceptance. In addition, there are many arguments provoked on the usefulness of the indicators selected to promote sustainable development. Initially, there were three most common sustainable development indicators, namely economic, social and environmental, used in the literature. It has to be realized that most of the existing indicators are the aggregated single index where only one variable is reported. These essentially identical indicators involve the estimation of a range of economic, social and environmental benefits in monetary terms but with a different name. In 1989, the Index of Sustainable Economic Welfare (ISEW) was introduced. This index takes into account commuting costs and the costs of accidents, water, air and noise pollution, loss of farmlands and wetlands and others. Then, in less than 10 years, in 1995, the Genuine Progress Indicator (GPI) was introduced. Following that, in 1999, the Sustainable Net Benefit Index (SNBI) was introduced. However, it was observed that these three measures are far from ideal and might cause confusion since they have identical indices but go by different names. This aggregated single index, such as the ISEW, is not widely used, although the index is receiving quite considerable academic attention for several years and has been applied to the United States, the United Kingdom and Scotland. The most widely accepted move towards sustainable development measurement is the development of methods for 'green accounting' which includes ecological and resource stock valuation in the system of national accounts. In Green Reporting, all indicators involved measure real-world results. However, it is argued that 'green' GNP, like all economic-based measures, can never be an adequate measure of sustainable development due to the problems with evaluating common goods that exist outside the market place and due to problems in elucidating social equity. Generally, all these existing single aggregated indices of sustainable development are not likely to be adequate if used alone because they are difficult to be applied at regional and local scales due to patchy data availability. Also, these indicators are not user friendly as they are not readily understood by the laymen. These single aggregated indices may well communicate changes in sustainable development but are unlikely to be effective in identifying the changes that are required to promote sustainable development at the local level. So, a set of simpler indicators is required to better promote sustainability. This set of SDIs is expected to complement the use of the single aggregated index and is essential to promote sustainable development at all levels. However, it has been established that indicators produced by one group of specific local authorities are

often found to be unsatisfactory to another. In order to produce a common set of SDIs and implement it on a larger scale, a preliminary analysis of composite indicators of sustainable development using Spearman's rank correlation was proposed. There are numerous single and composite indicators of sustainability used which include environmental, social, economic and sustainable development dimensions. They were the Direct Material Consumption Index (DMC), well-being (WB), Ecological Well-Being Index (EWB), Environmental Sustainability Index (ESI), ecological footprint (EF), CO_2 ecological footprint (EFCO2), Human Development Index (HDI), Dashboard of Sustainability (DS-SDI), Dashboard of Sustainability Environmental Sector (DSEnv), Geobiosphere Load (GBL), Gross Domestic Product (GDP), Happiness Indicator and Quality of Life (QoL). In summary, it is indeed very difficult and challenging to identify a core set of SDIs common to all localities and to produce a genuine composite index of sustainable development which addresses global sustainability concerns.

2.6 Nexus Between Education and Development

Science Education and National Development

It is a global knowledge that there is a positive relationship between education and economic, political and cultural development. According to Chabbott and Ramirez (2000), two rationales played a major role in buttressing confidence in the relationship between education and development. The first constructs education as an investment in human capital, which will increase the productivity of labour and contribute to economic growth and development at the societal level. This rationale is closely tied to global norms about science, progress, material well-being and economic development. The second general rationale constructs education as a human right, imagining education as the prime mechanism for human beings to better themselves and to participate fully in the economy, politics and culture of their societies. This rationale is tied to notions of justice, equality and individual human rights (Igbaji et al., 2017).

Education, like other forms of investment in human capital, can contribute to economic development and raise the incomes of the poor just as much as investment in physical capital, such as transport, communications, power or irrigation. Education supports the growth of civil society, democracy, political stability and citizens' rights. Education can contribute to the development of human rights, human development, human capital and social cohesion. In today's knowledge-driven economies, access to quality education and the chances for development are two sides of the same coin. That is why targets must be set for secondary education while improving quality and learning outcomes at all levels. That is what the sustainable development goal on education aims to do; hence, governments should work with parent and teacher associations, as well as the private sector and civil

society organizations, to find the best and most constructive ways to improve the quality of education.

A sound educational system is known to be the pivotal for sustainable development of every nation. Generally, science is considered as the process through which knowledge is arranged in an organized pattern. That is, science could be described as the structure and behaviour of the physical and natural world and society, especially through observation and experience. Science education emerged as an applied field of education saddled with the responsibility of disseminating scientific skills and knowledge. In other words, science education is concerned with the sharing of scientific knowledge with people not traditionally considered part of the scientific community. It must be emphasized that science education transforms the typical teacher-centred classroom lecture into a discovery and problem-solving arena.

The practical impact of scientific research enables the emergence of science policies and influences the scientific enterprise by prioritizing the development of commercial products, healthcare, public infrastructure and environmental fortification. There is currently a dearth of human resource for science education (Eilks, 2015; Jonna, 2020). The world must put in place concerted efforts to increase the number of young boys and girls studying science. Science education is a veritable tool for pushing out these concerns and in turn bringing development. The process of science education encourages creativity and originality, which demands the active engagement of students in identifying problems and looking for solutions. Hence, teaching and learning of science education address issues that are typical to local environment and expose students to national issues in other environments around the world, thereby producing students that are globally inclined to thinking. Accordingly, the goals of science education are to (a) cultivate inquiring, knowing and rational mind for the conduct of a good life, (b) produce scientists for national development, (c) service studies in engineering/technology and the cause of technological development and (d) provide knowledge and understanding of the complexity of the physical world, the forms and the conduct of life.

Science education is desired to meet the needs of industries and citizens as well as satisfy the practical needs of the society (Miswaru and Sadiyya, 2017). It is directed towards acquiring critical thinking and exploration. It is a process of teaching or training especially in school to improve one's knowledge about the environment and to develop one's skill of systematic inquiry as well as natural attitudinal characteristics.

Science education is germane to the scientific and technological advancement of any nation.

This is because science education comprises the comprehensive study of proven scientific concepts and principles. McCarthy (2017) describes progress made with science education in China and the resulting bumper harvest of STEMM graduates. He reported 40% completion of a degree in STEM subject in China, more than twice the share in American third level institutions. He also documented increasing importance of workers with STEM qualifications to global prosperity, and unsurprisingly, China is leading the way (Fig. 2.2).According to McCarthy (2017), China had 4.7 million new STEM graduates in 2016, India had 2.6 million, while the

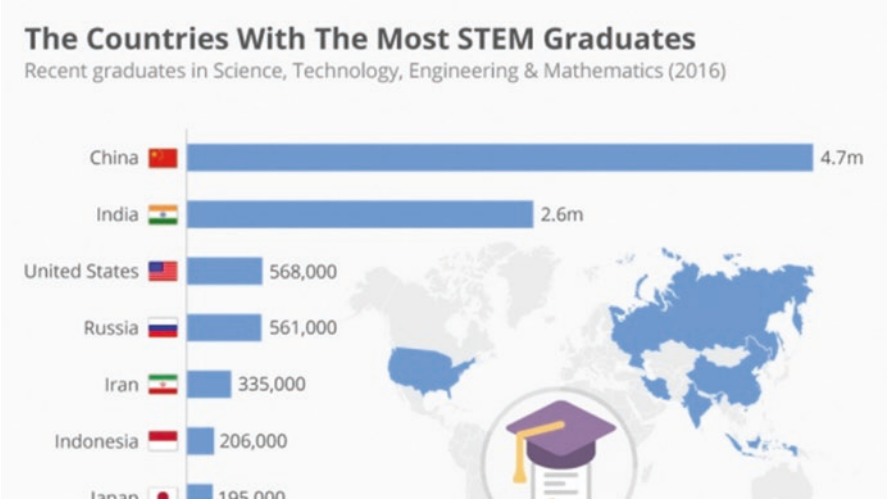

Fig. 2.2 Countries with the most STEMM graduates. (McCarthy, 2017)

United States had 568,000. Recent STEM graduates in 2016 as presented at a World Economic Forum and reported in the work of McCarthy (2017).

Science education identifies natural phenomena appropriate to a child's interest and skills. This implies that science education equips teachers, learners and society with knowledge, skills, equipment and freedom to perform noble tasks useful for improving socio-economic standards. Thus, the goal of science education is to produce a sufficient number and diversity of skilled and motivated future scientists, engineers and other science-based professionals.

However, it has been reported that if the aim of science education has to be accomplished in any country, then there is the need to promote effective teaching of science subjects in the schools right from primary through secondary to tertiary levels (Onwukwe & Agommuoh, 2016). Also, it has been opined that part of the reason why many developing countries may not attain their Development Goals is curriculum-based. In addition, it has been explained that the problem with science education in most developing countries is a lack of a good curriculum and must be fixed for the aim of science education to be realized (Onwukwe & Agommuoh, 2016).

Application of Science Education (Engineering) and Development

Engineering plays a crucial role in supporting the growth and development of the economy of a nation as well as in improving the quality of life for mankind. Thus, there is a vital link between a country's engineering capacity and its economic development. Engineering covers numerous types of activity. Engineers make

things, make things work and make things work better as well as design solutions to the world's problems and help build the future. Engineering has been defined by the Royal Academy of Engineering as the 'creative application of scientific principles', principles that are put into practice to invent, design, build, maintain and improve structures, machines, devices, systems, materials and processes. This definition is broad and intended to account for the fact that the scope of engineering is continually evolving.

Engineers are responsible for some of the most important advances in biomedicine, and they have played a key role in building the infrastructures around mankind, ranging from roads to utility networks. Engineers also play a role in the processing of foods and the development of new materials to be used in manufacturing. With millions of people living in poverty and without sufficient food or sanitation, engineering continues to have a key role to play in helping countries to progress across the world.

Economic theory suggests that growth in the economy, which is the only means of increasing the prosperity of a country, depends on the quantities of the factors of production employed (labour and capital) and the efficiency with which those quantities are utilized. Growth is sustained by increasing the amounts of labour and/or capital that are used and by increasing the efficiency with which they are used individually and in combination to produce output. Countries in the economic development phase must focus on improving the efficiency of utilization of labour and capital. Economic development is vital in creating the conditions necessary to achieve long-run national growth.

It must be noted that as each additional unit of the factors of production (labour and capital) is added, the resulting amount of additional output tends to diminish. Only increases in the level of technological progress can offset this decline in growth that occurs as diminishing returns to labour and capital set in. Growth over the long run is sustained by increasing the efficiency with which these factors are combined to produce output, a process known as total factor productivity (TFP). Improvements in TFP are driven by a number of variables including the depth and breadth of technical knowledge – as reflected in things like standards, patents and licences (permissions to use, produce or resell). Other drivers include the quality of education, the average number of years of education among the wider population or investment in research and development.

Therefore, economic development, while difficult to precisely define, results from investment in the generation of new ideas through innovation and the creation of new goods and services, the transfer of knowledge and the development of viable infrastructure. Examples of economic development include the creation of infrastructure, not just roads and bridges, but also digital and communications infrastructure, and the creation of knowledge through education and training, which can be utilized by businesses to create new goods and services.

By investing in infrastructures, such as transport, bridges, dams, communication, waste management, water supply and sanitation as well as energy and digital infrastructure, countries can raise their productivity and enhance other economic variables. By having a well-developed transport and communications infrastructure, for

example, countries are better able to get goods and services to market and move workers to jobs. A strong communications network allows a rapid and free flow of information, helping to ensure businesses can communicate and make timely decisions. All of these infrastructure projects require engineers, products of science education.

Ways in Which Application of Science Education (Engineering) Contributes to Economic Development

Engineering is an extensive field that can contribute to economic development through several channels. By investing in infrastructures, such as transport, bridges, communication, waste management, dams, water supply and sanitation, energy and digital infrastructure, nations can increase their productivity and improve other economic variables. By having a well-developed transport and communications infrastructure, for example, nations are better able to move goods and services to market and workers to workplaces. A strong communications network allows a swift and unrestricted flow of information, helping to ensure businesses can communicate and make timely decisions. In other words, no nation can have an economy without engineering (application of scientific knowledge). This is because engineering plays a vital role in the production of goods and services, through creating new knowledge and ensuring there is the capacity in place to produce and move goods and services (such as infrastructure, transportation networks and logistical arrangements). Engineering can also help address challenges that will help countries to meet the United Nations Sustainable Development Goals aimed at ending poverty, fighting inequality and injustice and tackling climate change by 2030.

Engineers help countries by developing infrastructure that provides basic services such as energy; water and food security; transport and infrastructure; communication; and access to education and healthcare. Linked to these goals, engineering should also have a positive impact on factors such as life expectancy that over time can be expected to aid economic development through improvements to productivity, which in turn results in increased GDP. Figure 2.3 illustrates the strong relationship between the quality of infrastructure in a country and the level of economic development achieved across the world. This supports the assertion that engineering contributes to economic development as it has a key role to play in ensuring countries have a strong infrastructure.

2.7 Current and Future Role of the Application of Science (Engineering)

According to the United Nations Educational, Scientific and Cultural Organization (UNESCO), engineering has been, and will continue to be, confronted with designing systems that facilitate education and healthcare, improve quality of life and

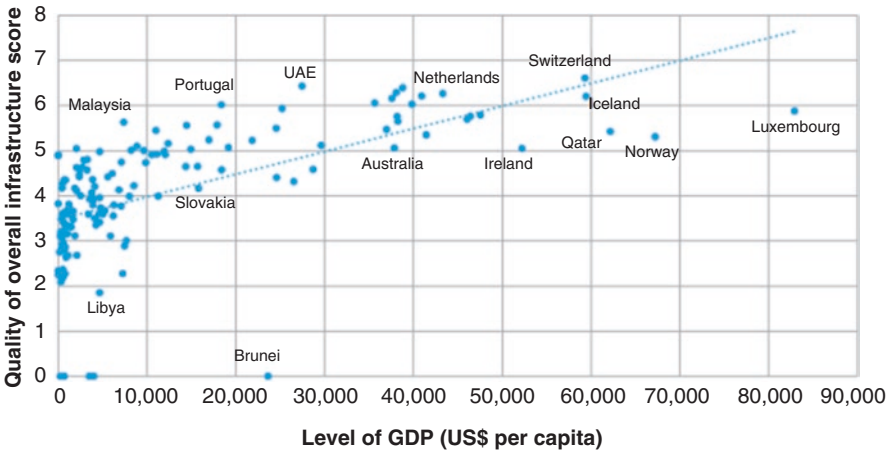

Fig. 2.3 Relationship between the quality of infrastructure in a country and the level of economic development. (Royal Academy of Engineering, 2016)
(Quality of overall infrastructure score: 1 = extremely underdeveloped, 7 = well developed)

assist to eliminate global poverty. It considers that the development of technological approaches that can help prevent or mitigate hostile acts, reduce the impact of natural disasters and motivate humans to reduce their use of the earth's valuable resources will be key challenges for engineering in the coming years. Alongside these, it is expected that engineering will continue to play a key role in helping to avert environmental crises as well as helping to reduce poverty via the provision of community infrastructure. Engineering already plays an important role in managing and conserving resources, from water to food, energy and materials. For example, engineering skills have been essential in ensuring the development of systems relating to water and wastewater treatment. Given that some parts of the world still lack access to water, engineering skills will remain essential to ensure universal access to clean water and sanitation. Engineering has also been extensively involved in finding solutions to reducing carbon emissions alongside ensuring increased portions of the world's population have access to sustainable power. Engineering's role in this area is likely to continue to be important in the coming years, especially as in 2015 it was estimated that 2.8 billion people still did not have access to modern energy services and that over 1.1 billion people were without electricity (Royal Academy of Engineering, 2016). In addition, with the global population expected to grow to 9.7 billion by 2050, engineering will become increasingly important in ensuring future food security (Royal Academy of Engineering, 2016), for example, by ensuring that there are sustainable food production systems in place that maintain ecosystems and by helping to improve land and soil quality. Over and above these growth areas, UNESCO envisages new challenges for engineering across four key areas: materials, energy, information and systems and bioengineering. Each of these fields will require engineers across a range of disciplines to ensure future innovations and success. Therefore, having sufficient numbers of engineering

graduates and professionals focusing on engineering for development in these areas will be essential both now and in the future and should sit unmistakably at the centre of science education.

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