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SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS (STEM) LEARNING: INFORMATICS AND THE UNITED NATIONS SUSTAINABLE DEVELOPMENT GOALS

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Abstract: The premise of this paper is based on the application of general systems theory, particularly complex adaptive systems, to some thorny and interrelated problems, i.e. achieving sustainable economic development as defined by the United Nations Sustainable Development Goals (UN17) by 2030. We ask, "STEM (Science, Technology, Engineering, and Math) for whom?" of the Academy. The modern university functions as a knowledge watershed for civilization and STEM subjects are universally needed. More importantly, quantifiable research in sustainability science is needed for application to a new management paradigm that factors in the costs of a comfortable and secure society, a verdant and sustainable economy, and a resilient environment for communities and businesses to thrive. Teachers and researchers in informatics train students to create, distribute, mediate, interpret and utilize the products of technology, but there is a need to take it a step further to accomplish the UN17. The mantra "Think globally; act locally" guides the synergy of educating students to take their place both as citizens and stakeholders at every level in emerging fields and disciplines.

Keywords: STEM education, UN 17 by 2030 Sustainability Goals, sustainable development, resilience

Introduction

Beginning in the 1980's, the impact of global warming was predicted, and largely ignored until the 1990's [1]. Today, as we observe and directly experience these impacts, including wildfires, floods, droughts, hurricanes and tornadoes on an annual basis, societies are increasingly at a loss as how to deal with these incrementally severe and frequent events. The good news is guidance is available. During the Bush and Obama administrations, spurred by the events of 9-11, Hurricane Katrina and Superstorm Sandy, community-based emergency response was initiated [2]. These federal efforts have been augmented by programs at the state level [3]. Infrastructure improvement initiatives, particularly aimed at the electric grid and mass communications, have been largely uncoordinated and sporadic, but research and development of new systems and technologies for smart and connected communities is an important part of this effort [4]. As we look for an overarching framework to guide the implementation of continuous infrastructure improvement, the United Nations 17 by 2030 sustainability goals (UN17) offer a valuable starting point (Figure 1).

We have selected the UN17 as the focus of our analysis. The United Nations Sustainable Development Goals (SDGs) are a "call for action by all countries – poor, rich and middle-income – to promote prosperity while protecting the planet." Built into the goals is the recognition that the end of poverty goes hand-in-hand with strategies that build economic growth and address a range of social needs, or it will not be sustainable. Our concerns include education, health, social protection, and job opportunities, while tackling climate change and environmental protection [5].

Resilience and sustainability are not the

Figure 1. The United Nations Sustainable Development Goals (UN17)

same thing, but without resilience, sustainability is not achievable; reaching these goals depends upon improving not only infrastructure resilience, but social, environmental and economic resilience as well. Furthermore, these goals cannot be achieved by our own efforts alone, only to be forgotten by future generations, as the effects of climate change cannot be quickly reversed. As educators, we seek pathways to initiate forward-looking, adaptive, persistent education programs that will prepare present and future students to deal with the challenges of extreme events and natural disasters, while moving global society toward sustainability. The United Nations (UN), as the largest intergovernmental organization in the world, offers vision and international co-operation. The UN General Assembly instituted the UN17 program at the United Nations Conference on Sustainable Development (UNCSD) in Rio de Janeiro, Brazil in 2012 [6]. This paper examines what ordering and governance the UN17 offers and what contribution educators can make to further these goals.

Consider the technological changes in the world over the last twelve years; the growth of the world-wide web, Internet, social media, wireless communications, and the rise of Google, Facebook and Amazon, mega-corporations with minimal physical assets but tremendous virtual presence. As forces for change, these technologies have been a mixed blessing. Citizens now have unprecedented abilities to observe, analyze and communicate, but as a planet, we have taken several hits with the economic roller-coaster, the environmental shake-down and international game-playing. Stable, disciplined governance with long term institutions in place is needed to attain the UN17, but the globe is currently facing unprecedented levels of destabilizing actions from bad actors driven by increasing levels of greed and corruption, enabled by new technologies, resulting in unforeseen levels of exploitation. We look at international governance, regulatory agencies, the private sector, and industry actions while also paying close attention to our local neighborhoods, the friends

and students we meet each day, the plans we have for the coming weekends. The evolving forms of regulatory institutions will determine whether humanity cultivates a happier, more resilient future on our planet or succumbs to the forces of populism, nationalism, corporate greed, and environmental destruction.

2 Ranking the UN17

This paper asks, 'What kind of layered, levelled, regulated living organizations are required to accomplish a project as forward looking and as optimistic as the UN17 goals'? What education, research and information access will be effective in achieving such lofty goals? University educators should be challenging university educated citizens to consider these 17 goals both as a mandate for life choices and a guide for employment/future career paths. With the training to evaluate these goals communally, how shall we as educators prioritize these goals?

The first thing on the list is 'No Poverty'. The world is very far from the elimination of poverty, but there have been encouraging improvements over the last twenty years [7]. However, more research is needed to determine what actions are most effective and what policies work best in alleviating poverty. Of primary importance is to define poverty, and thereby determine what factors constitute adequate resources for its relief. Goals 2) 'Zero Hunger.' 3) 'Good health and Well-being,' 6) 'Clean Water and Sanitation' and 7) 'Affordable and Clean Energy' are obvious prerequisites to reaching Goal 1, with 6) being foremost. Poignant examples include the water crisis in the city of Flint, Michigan (USA), beginning on April 22, 2014 and the water problems in hurricane-devastated Puerto Rico, South Africa and many other places around the globe. Clearly, the need to provide clean, safe water is paramount.

Water is necessary for survival, regardless of poverty level and is the foundation for food production as well. The elimination of poverty could be accomplished by simply giving deprived people money, but money is worthless if there is no available food, water, shelter or health care to be purchased. The New York Times reported the situation in San Cristobal De Las Casas, Mexico, where Coca Cola has become as cheap and more readily available than water, resulting in rates of diabetes increasing by 30% between the years 2013-2016 [8].

It thus follows that Goal 1 may not be meaningfully achieved solely by monetary payment; truly eliminating poverty depends at a minimum upon the implementation of local policies and investments to ensure clean water, clean air, and enough to eat for all. Similarly, Goal 1 also depends upon conserving and supporting life in the water (Goal 14) and life on land (Goal 15), because without these elements we cannot sustain what we eat, drink or breathe. Therefore, the authors believe that water conservation should top the list because clean, safe drinking water is basic to reaching so many other goals. Can it not be argued persuasively for clean, safe water as a human right, and to stop corporate environmental destruction and the co-option of water for profit?

Cannot educated people who have lived long enough and seen enough to believe in the need for such conservation now see the need to question the wisdom of the United Nations. We can see the notion of "No Poverty" as "going for the branches of evil and failing to go for the root" [9]. This notion needs to be broken down and the goals looked at from a more universal perspective. The authors advocate for the introduction of a dimension of enlightened self-interest driven by scientific fact to accomplish an institutional evolution toward a happier, more sustainable and resilient future. The
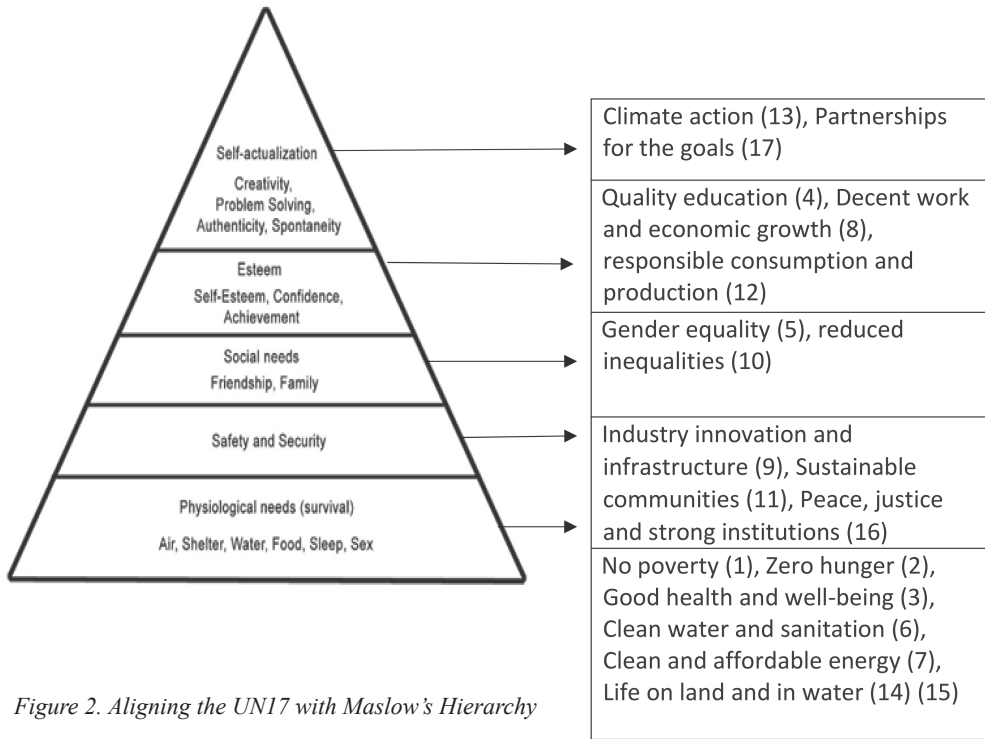
Figure 2. Aligning the UN17 with Maslow's Hierarchy

structure of this approach can be exemplified by the familiar trope of Maslow's hierarchy of needs which outlines a blueprint for understanding how people are functionally motivated [10]. The pyramid shape of the hierarchy implies that higher level human social evolution depends upon fulfilment of the lower levels. In other words, physical needs come first, e.g. a child who has not eaten for two days is too hungry to focus on learning to read. Fundamental needs like food, air, water and shelter must first be prioritized for society as a whole to reach the higher levels. The ultimate goal is global civil society that functions at the highest level of the pyramid.

When we align the UN17 goals with Maslow's needs (Figure 2), it becomes clear that the key to progress is to first meet basic survival needs. When supporting infrastructures for water, food, shelter, warmth, etc. are in place, they form the necessary foundation for reaching higher levels. At any level within the hierarchy, lack of the basic

requirements means only limited progress can be made. This is the strongest reason for defining and prioritizing basic minimums – if only a small percentage of the population receives the essentials, society as a whole is held back and all suffer accordingly. This is not to say that only the basics matter and the higher levels are unimportant, but that continuing progress and stability are dependent upon maintaining basic needs. The alternative is worsening deprivation and ultimately social destabilization. The challenge is to maintain basic survival needs as the human population grows exponentially and outstrips the available resources. Technology has enhanced our ability to utilize the planet's resources more efficiently and provide at least the basics to most, but the demands only increase faster for the minority. We are currently in the middle of an accelerating mass extinction event; the first caused by human activity [11]. How ironic would it be if the current generation caused our own species to be extinguished? Competition for limited

resources is causing increasing unrest and escalating conflict in many areas and in some cases, war, which is the most environmentally damaging and wasteful way to proceed. Indeed, bitter experience teaches that war creates damage, destruction and deprivation at all levels, and as such is the antithesis of sustainability.[1]

Linking to ecosystem health and well being

Now, by examining some of the UN17 and aligning them with the hierarchy of needs, the next question is, "How can we implement the UN17 when some of the goals are contradictory?" For example, if we eliminate poverty, increased global consumption could increase environmental degradation, thus exhausting the planet's resources even faster. Or if more housing was built, more habitat could be lost, gravely impacting endangered species. The answer is to design and implement systems that can replicate or even accelerate the ecosystem services of healthy natural systems, such as removal of pollutants. To accomplish this, we can ask what individuals and small teams can do to functionally integrate systems, so that waste is not just waste to be disposed, but a food or energy input or other resource for other systems. For example, instead of disposing of consumer electronics, appliances and used building materials in landfills, government and corporate entities could utilize their internationally acquired know-how to follow Japan's example and require manufacturers to design "cradle-to-cradle" supply chains to produce goods that can be repaired and upgraded throughout their useable lives and recycled at the end of it. Production processes that fully utilize

recycled materials instead of raw materials will alleviate shortages by reducing the need to further exploit natural resources to their limits and reduce environmental destruction.

The concept is readily extended to systems beyond manufacturing. The efficient utilization of resources is only one benefit of this approach. Others are the elimination of landfills, pollution prevention and the removal of toxins and pollutants from air, water and the food chain. Trained agents in governmental agencies could prioritize organic agriculture methods such as using food and agricultural waste to fertilize crops, reducing contamination of valuable soil with harmful pesticides. Growing food organically prevents contamination from pesticide applications and reduces health impacts shown to cause cancer and not found in breast milk before the practice began in the 20th century. Raising livestock organically by using organic food waste as feed stock promotes nutrient rich soils and prevents contamination of soil and water with prophylactic medical treatments such as antibiotics and hormones shown to cause harm in the environment. Effective, comprehensive waste management and full reuse of metals, minerals, chemicals and other potentially harmful substances could vastly simplify the management of clean drinking water and storm water systems. Replacing fossil fuel combustion with renewable resources for electricity and energy needs will not only combat the effects of climate change, it will reduce airborne pollution and thereby improve water and soil quality while reducing respiratory deaths and diseases. The oceans will no longer be choked with enormous volumes of the plastic byproducts of fossil fuel refining and human disposal.

By designing and implementing infrastructure systems that perform like natural systems, multiple problems could be solved simultaneously. Table 1 shows the linkages between

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[1] "Every gun that is made, every warship launched, every rocket fired signifies in the final sense, a theft from those who hunger and are not fed, those who are cold and are not clothed. This world in arms is not spending money alone. It is spending the sweat of its laborers, the genius of its scientists, the hopes of its children. [...] This is not a way of life at all in any true sense. Under the clouds of war, it is humanity hanging on a cross of iron."
-- Dwight D. Eisenhower, April 16, 1953

Janet Marsden

Maslow's Hierarchy (reversed)	UN17	Ecosystem services
Survival	1,2,3,6,7,14,15	Food and agricultural goods, breathable air, drinking water and sanitation, energy, basic health care, transportation, shelter and housing, fisheries and wildlife
Safety and security	9,11,16	Industry, markets, governing bodies, democratic institutions, voting rights, laws and courts
Social needs	5,10	Equal opportunity, equal treatment under the law, human rights, animal protections, schools and libraries
Personal satisfaction	4,8,12	Fair business practices, respect for labor at every level, minimum standard of living
Self-actualization	13,17	Coordinated climate actions through partnerships, research and development activities, advanced technology

Table 1. Linkages between Maslow's hierarchy, the UN17 and ecosystem services

basic human needs and wants, the ecosystems that provide those needs globally in the delicate balance that we are trying to preserve into perpetuity, and how the UN17 fits into the overall strategy of prioritizing our efforts to provide basic global health, safety and sustenance.

With advice and support, local communities could manage integrating sustainable design into systems and infrastructure at all levels. An understanding of the inter-connectedness of food production and agriculture will direct the elimination of waste which logically become resource generators of compost or animal feed instead of landfilling food waste. With some adjustments in policy, the animal feed industry will cycle source food waste inputs to its production from restaurant and grocery store chains. Homes, schools, hospitals and health care facilities are also part of the equation, which form a comprehensive, integrated set of evolutionary solutions, as epitomized by the Japanese practice of 'kaizen,' or continuous improvement.

Finally, this paper will address the inevitable question of the economics of these recommendations. Indeed, organic agriculture costs more than mechanized agriculture using artificial fertilizers and pesticides. Recycling isn't cost effective - it doesn't pay for itself. How can the

world afford these changes? The answer is simple. The world can't afford not to do it. Eventually, educated citizens will recognize that the profit motive is false economics and ultimately embrace sustainable practices despite the added costs.

A short story demonstrates this: In the 1980's, Ronald Reagan removed catch limits from the fish stocks of the George's Bank, at the time one of the richest fisheries in the world, and well managed since the 1930's using applied science and research data collected in the field to manage the fish stocks. His reasoning was that free market forces would magically regulate the catch and therefore limits were not needed. If stocks fell, it would cause prices to rise, and people would consume less until supply increased causing prices to fall. Unfortunately, that wasn't what happened. Rather, demand increased, catches increased, and prices increased, until the fishery collapsed from overfishing and has not recovered to this day. The truth is, the profit motive automatically ensures the depletion and destruction of limited resources. The last bluefin tuna in the ocean will be priceless, and once it is gone it is the end.

For most of the 20th century, the world has squandered the resources of the planet while causing untold environmental damage in the

pursuit of unfettered profit. The industrial age has certainly brought great advances in civilization and technology, but has now reached the point where the world is on the verge of irrevocably damaging the global ecosystems upon which our very lives depend. Even worse, there are some commercial interests that cynically exploit people's fears to justify massive arms development and continuous warfare in the name of "defense" and "security," profiting from war while ignoring the depletion of resources, disease, famine, death and destruction caused by continual conflict around the globe. However, it is not guaranteed that the unrestrained pursuit of profit must eventually give way to a new cost-benefit paradigm that emphasizes sustainable use of resources, i.e. only taking what can be replaced, and investing in the innovations needed to achieve that. To embark on a new era of information-guided sustainability, the world must turn to a reasoned cognitive structure of needs that prioritizes some economic sectors, like the basic essentials: air, water, food, energy, health care, education, shelter and governance. These are simply too important for our continued well-being to be subject to the profit motive. Civilization progresses by working toward the stated goals of the US Constitution: "to form a more perfect Union, establish justice, insure domestic tranquility, provide for the common defense, promote the general welfare, and secure the blessings of liberty to ourselves and our posterity." These are aims which should be common to all people. These are also the stated aims of the United Nations.

Fair and just treatment builds trust in institutions. The character, integrity, and experience of the governors will guide governments to become sustainable and resilient. To this end, education is fundamental.

Quis Custodiet Ipsos Custodies

How should educators teach Informatics, and to whom? We come to this point in our inquiry as two educators based in two different cultures of information. Shizuoka University's Faculty of Informatics, one of the earliest in Japan, at its inception in 1995 began with two departments, computer science for hardware and software, and information arts for social informatics, communication, and media. In Shizuoka, students are educated to develop and deploy our IT/ICT products. In contrast, the School of Information Studies (iSchool) at Syracuse University from the beginning structured its faculty development plan around information and information technology. What evolved from a program in library science started in 1896 became the first information school in the US in 1974 and today combines expertise in information systems, linguistics, computer science, library science, education, business management, school media, digital literacy, management information systems, telecommunications, wireless and emerging technologies, and communication.

Both authors got their start as academic women in the United States, one in the sciences, one in the humanities. Undergraduate, graduate, and doctoral level work was completed in United States national and private universities. For us, we understood information as classified in libraries with the Dewey Decimal System. Syracuse University lays claim to a deep history of informatics which stands in striking contrast to the history of informatics at Shizuoka University. At Shizuoka, information grew out of calculation machines and image transmission with light in the Faculty of Engineering, which sets its beginning in 1922 in Hamamatsu, Japan. This is not the place to trace either history in depth; suffice it to say, the authors aim to deliver practical and theoretical education measured by an international standard.

The meteoric advances in technology, in hardware and software have only been matched by the hugely complex divisions, developments and doctrines at both governmental and industrial levels. In short, we know who we are, but just like our students, we have to be life-long learners. There is no point when we can say, "We have arrived."

This section started with a quote from the Latin satirist Juvenal, which translates as, "Who shall guard the guardians?" [11] Indeed, who shall call foul to the leaders and demand that they respect and care for all the people in their care? The authors have witnessed in their own lifetime enormous malfeasance and corruption in the highest offices in the lands in which they live. We grew up during the Cold War, a time when World War II and the Great Depression were not just distant memories. Our parents and the parents of our students, both in the United States and Japan, have faced chthonic changes in both economics and educational policy, which now impacts the youngest members of society and all the nations of the world. Third world countries send their best students to our countries to learn about technology for their own countries, to develop their industries, and for their families. The international standard is preserved by policy, protocol, and agreements among universities and colleges, and by the institutions of higher education which we term "The Academy." However, private industry and governments have their own ways of and purposes for funding research, opening seats, delivering grants and scholarships to students selected for their excellence, and conferring degrees and licenses. American President Franklin D. Roosevelt warned against those who would rob citizens of the benefits of "The New Deal" and, in addition, President Eisenhower warned against the "military-industrial complex" in his farewell address to the United States. Unfortunately, those warnings have not been heeded.

The Academy in each country confers credentials and learning to the politicians, lawyers, doctors, and professionals of society. It therefore has responsibility to "guard its own borders," letting in to the higher echelons those who rise through academic achievement, national scores, and letters of reference. Then there are also internal elections, appointments, and promotions that ensure that the goals of the Academy will be protected and fostered with good management. Nevertheless, the pressures from government and industry about financing the Academy are a constant irritant. Standards for training from country to country are not the same, so the international standard must be interpreted in transferring credentials and credits. We can see that these things are not always done with a good conscience unless "top dollar" equals "good conscience."

The authors are also concerned about the "silo" effect of education in technology, forcing narrow specialization and isolation on graduating students looking for a living after graduation. To "preach" that students should aim to work for the common good sounds laudable but can they still raise their family and have a good life without regrets? Decent work for decent pay should also come with a good conscience, one hopes. It isn't fair to demand allegiance to high principles unless one is also practicing them and accepting the same consequences.

There is also another caveat. The biblical dictum, "To whom much has been given, much will be required," asks that those who have received much from family and the community in their upbringing owe a moral debt to the same. It is hoped that young adults will have been instilled with such an understanding and that when they graduate, the society that has waited for them to join the workforce can expect them to undertake gainful employment. Harking back to the earlier warning

that "the guardians" might be "foxes guarding the chicken coop," and the call for higher service to the elite, the authors advocate for a transparent code of honor, accountability, and moral ethics required for those elected to lead. Years of education prepare students to hope for employment that is comfortable, challenging enough, and with compensation that will ensure that they can care for a family. After all of this, can educators ask the young people entrusted to their care to uphold a higher standard than the governing agencies in the world? These are all thorny matters in any country in the world.

Our goal in these higher education programs is to prepare students to take part in society as educated, knowledgeable citizens, teaching them to use information and knowledge not only to earn a living and raise their children but also to prevent pollution and preserve natural resources. Living sustainably on a broad scale means creating economies where people can earn a living wage working a single job, and where jobs that are physically demanding offer a comfortable retirement. Informatics, by promoting the STEM subjects in isolation, seemingly neglects philosophy, law, literature, and art. The best of civilization and culture can only be preserved if we take a global view, an organic, holistic, living systems view, that embraces the integrity of diverse sovereign nations and their peoples, their societies and life-styles, and the need for a just and peaceful world.

Finally, our attention is turned to how implementing sustainable goals may impact the education system for students in informatics. One possibility is to offer courses which teach implementation through projects, train implementation through curriculum design, and invite persons at every level of the educational process to take the time to learn, understand, and commit to understanding and implementing the process. This is the "bottom-up" approach.

Students have input with teachers and parents can oversee their education and participate in it. Parents can contribute by building families that practice sustainability through the community, thereby preserving the environment. Elementary classes in Civics and Society could also be used to promote the UN17 goals. At university, interdisciplinary UN17 courses for all informatics majors could provide a number of expert lectures about the complexity of attaining even the first of the UN17 goals – no poverty, where the basic definition of no poverty is understood as having enough to eat, clean air and water, a safe and secure place to live, access to basic health care and education, a job where effort is valued, fair treatment, and where the challenges of accomplishing 'no poverty' are universally recognized.

Extracurricular activities are also a good avenue for imparting such values and citizenship ideals. Clubs and extracurricular events sponsored by academic institutions can provide students with a social nexus for developing both leadership and social skills while giving them a line or two on their future resume. Students who have chaired, governed or managed events in clubs or institutional events should have the right to present them as worthy accomplishments.

There are also internships. Much can be said about the value and potential of internships, from undergraduate internships, internal internships, external internships, paid and unpaid. The history of required training in medicine, hospitality, teaching and the law suggests that high-ticket internships through recommendation should not be the only kind of internships, and the goals of internship should include developing good work habits and character as well as professional skills. Still, students should receive some form of remuneration for their work as they can be easily exploited without some kind of real compensation, either in school credit, references

or payment for their efforts.

In short, a society which hopes to achieve the UN17 must build the initiative into the education system from the ground up.

Conclusion.

In this paper, the authors have considered the role of academic Faculties of Informatics in the context of the looming environmental crises fueled by modern society's reliance on fossil fuel combustion and exponential human population growth. The rapid growth of technology, although obviously part of the solution, has created additional complications through the destabilizing actions of governmental and nongovernmental bad actors. We take the UN17 Sustainable Development Goals as a pathway to implementing efforts in good faith while looking for further ways we can promote such goals as educators. Sustainable goals need sustainable science. After a close look at these recommended goals we conclude that society cannot accomplish the first goal, the elimination of poverty, without wide-ranging systemic changes. We have offered a reframing and revision of the list utilizing Maslow's Hierarchy of Needs and concluded by recommending system-wide adjustments in the education of students of Informatics by including a grounding in sustainability science to provide both context and direction. We have extended our, We have extended our analysis to include the importance of coordinated action on the part of governments and private corporations, and we reiterate that to be effective, these goals and actions must be adopted broadly.

Fortunately, the UN and other governing and research bodies have provided definions of poverty, pollution levels, clean water and air standards, living wage levels, etc., and benchmarks have been establishedthat can be utilized in ranking systems for countries. Innovative approaches are needed to implement new goals and objectives, but instead of merely imposing more rules on people, it would be better in our view to teach people about why change is needed and ask them to think and use their brains and energy to make the world better, "Think globally, act locally." If every neighborhood engaged in this approach, many problems could be solved.

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