Northeastern University
College of Engineering

*STEM Newsletter 24- **Grand Challenges** (11.23.2020)*

Introduction

Engineers constantly strive to improve the world we live in and in 2008, the 14 Grand Challenges were announced as goals for engineers to continue to work towards throughout the century. “The 14 challenges they laid out were culled from hundreds of suggestions from engineers, scientists, policymakers and ordinary people around the world.” While some of them seem rather feasible considering recent advancements, the progress of others has only just begun. "We chose engineering challenges that we feel can, through creativity and commitment, be realistically met, most of them early in this century" - William J. Perry.

Make solar energy affordable.

Solar energy is a renewable source of energy. Our sun will always shine and we can harvest its energy. However, it only provided 1.3% of the global energy as of 2016 when it has a potential of powering much, much more. We just need to learn how to make it affordable.

Provide energy from fusion.

Fusion is the process in which the nuclei of two atoms bond together to form one lighter atom. Fusion frequently occurs in the core of the sun where the pressure and temperatures are high enough to combine four hydrogen nuclei into one helium atom, with a byproduct of energy in the form of light. This release of energy keeps the sun at a very high temperature. Recently, engineers have been trying to find ways to recreate this process on Earth. Fusion is a beneficial energy source for a variety of reasons. Fusing atoms together produces nearly 4 million times more energy than burning coal, oil, or gas. Fusion is environmentally-friendly by being highly sustainable and not producing any toxic byproducts. The major issue at the most is learning how to effectively and safely create this process on Earth.

Develop carbon sequestration methods.

Carbon sequestration is the process of capturing and storing carbon dioxide in order to reduce the amount of carbon dioxide in the atmosphere. Reducing carbon dioxide emissions has become the main focus of reducing climate change. Carbon sequestration methods can generally be put into two categories: advanced options (focused on technology) and natural options (i.e. reforestation). Various governments around the world have begun funding the development of carbon sequestration methods, and agreements have even been formed such as the Paris Agreement (2015) with hopes to reduce carbon dioxide emissions. The efficacy and cost of multiple methods are currently being tested in order to develop the best reduction plan.

Manage the nitrogen cycle.

Nitrogen is a key element in life; it is essential in DNA, the atmosphere, plant growth, etc. However, too much nitrogen can be harmful to the environment. The nitrogen cycle is the process through which nitrogen moves through abiotic (non-living) and biotic (living) factors. This cycle has been disrupted through the excessive addition of nitrogen by humans through the form of fertilizer and various agricultural means. The immoderate amount of nitrogen can lead to eutrophication, a process in which nitrogen-enriched water causes toxic algae blooms, and other processes harmful to the environment. Engineers have been working to develop ways to maintain a stable food supply that are not dependent on large amounts of nitrogen. This research is looking to improve the human efficiency of reducing nitrogen.

Provide access to clean water.

Globally, 2 billion people only have access to a contaminated water source. Contaminated water causes 485,000 diarrhoea deaths annually. Unfortunately, the millions of deaths caused by the lack of clean water could have been prevented if the risk factors had been addressed. Apart from the detrimental health effects of contaminated water, contaminated water also has long-term economic and social consequences. Disease caused by unclean water comes with harsh medical costs as well as time taken away from the productivity of the economy. Global organizations as well as multiple countries have made efforts to implement water quality guidelines with a focus on drinking-water, safe use of wastewater, and safe recreational water environments.

Restore and improve urban infrastructure

Infrastructure is the basic facilities and installations that help a community run, this includes roads, schools, phone lines, sewage treatment plants, and power generation. Infrastructure is necessary to continue to progress societies and improve living standards. Recently, as our societies have been advancing, our infrastructure has been lagging behind with insufficient funds to restore and improve it. The world is rapidly changing from rural to urban, presenting many more challenges. Established cities must find ways to adapt to the stress caused by the massive expansion of populations in concentrated spaces. Transportation has become a key, yet complex, issue. Urban economies and societies could potentially suffer greatly if city transport networks are insufficient to meet demand. Engineers now face the challenge of improving various branches of infrastructure as well as making them more sustainable.

Advance health informatics.

Health informatics is the acquisition, management and use of information in health and health care systems. This tool can greatly enhance the quality and efficiency of medical care and the response to widespread public health care emergencies. Health informatics encompasses issues from all scales, ranging from person to global, thorough medical records for individual patients and sharing data among governments and international health organizations when needed. Ideally to advance health informatics a new system of computing tools that would collect authorized medical data about patients to help deliver quick and efficient care would be made. This would be done by updating technologies from paper to computers, sharing of data with built-in guarantees of accurate updating, ways to verify a patient's identity and trusted systems to store sensitive data.

Engineer better medicines.

Engineers are developing new systems and mechanisms to utilize genetic information combined with biological information to sense changes in the body in order to produce new

drugs, vaccines and therapies. People differ in their susceptibility to diseases and the factors that mediate various illnesses so the medications produced need to encompass that variability, this occurs with personalized medicine. The goal of personalized medicine is to optimally tailor drugs and doses to meet the unique needs of an individual patient and act as a comprehensive approach to preventing, diagnosing, treating and monitoring diseases for optimal individual healthcare. Researchers have been able to implement personalized medicines for variants of a gene linked to breast cancer, by doing so they are able to predict a women's likely susceptibility to developing or surviving the disease and use it as a guide for preventative measures. Another method of personalized medicines entails delivering personalized drugs rapidly and efficiently to the specific site in the body where the disease is localized. Currently researchers are exploring ways to engineer Mano particles that have the capability to deliver a specific drug to the target site in the body while evading the body's natural immune response. Conclusively, the personalization of medicine has an assortment of advantages. Personalized medicine can help early diagnosis of diseases, create preventative measures, enhance medications and provide optimal healthcare for patients.

Reverse-engineer the brain.

With around 86 billion neurons, the brain is the most complex organ in the human body. Each neuron communicates with many other neurons to form circuits and share information. This is what allows us to feel emotions, form thoughts, move our bodies, and much more. The cognitive human brain has a complexity that goes much further than a system of neurons. A true reverse engineering of the brain requires an understanding of the brain on its most abstract level. This is a challenge that will one day have remarkable outcomes. Reverse engineering the brain will allow engineers to create machines that could think and feel for themselves. This could develop programs with a complexity that goes beyond calculations and data processing. Engineers will also have greater opportunities to understand the brain, therefore, understand the human body. Neurological disorders could one day be challenges of the past if the brain can be thoroughly understood. The applications of this information are endless.

Engineer the tools for scientific discovery

Scientists and engineers work hand in hand to further scientific discovery - much of their work happening to overlap. With the same goals in mind, scientists tend to do the hypothesizing and

experimenting while engineers offer the means to experimentation. In the case of space exploration, engineers need to devise ways to handle many challenges including sufficient sustenance and radiation exposure. Borrowing knowledge from their scientist partners, engineers are able to prototype devices, spacecrafts, etc that can take care of these obstacles. From putting the first man in space in 1961 to now having had 562 people reach the altitude as of 2020, these spacecrafts have been designed, prototyped, revised by scientists and engineers to get to this point and to continue to make more discoveries. This process has been and will continue to be implemented in every field that strives to answer those unsolved problems so long as there are issues to be solved. Through it all, scientists and engineers will work hand in hand to understand the world around them.

Prevent nuclear terror.

Nuclear weapons are currently the most dangerous weapons on Earth. A singular nuclear weapon has the potential to destroy an entire city and kill millions of people. Not only does a nuclear weapon have an enormous blast, it also generates gamma radiation. The radiation from a nuclear explosion contaminates air, water, food, and the ground which has both acute and latent effects on humans. These weapons are created through nuclear fission, a process in which a heavy nucleus splits spontaneously or on impact with another particle. Although this process is extremely difficult to create and control, terrorists could buy parts of a dismantled bomb, or fuel from a nuclear power plant, and build a homemade bomb. Preventing nuclear terror attacks has a variety of challenges including, securing materials, detecting attacks, developing an emergency response, and finding the attacker. Engineers are currently developing plans to prevent and handle nuclear attacks.

Secure cyberspace.

Cyberspace is virtually everything within the Internet as well as the electronic medium that is used to facilitate online communication. This includes radio and TV signals, cell phones, e-mails, and generally every form of communication and transportation. Serious breaches in cybersecurity would allow people to have access to the personal information of millions of people. Attackers exploit vulnerabilities in cyberspace to steal information and money. Statistics show that a hacker attacks a computer every 39 seconds, this demonstrates how much of an issue online security has become. Cybersecurity is the practice of protecting systems, networks, and programs from digital attacks. People working in cybersecurity have an enormous role in an organization. They must protect internet connections, websites, email access, customer portals, and much more. Implementing effective cybersecurity measures has become very challenging because today, there are more devices than people and attackers are

becoming more innovative. Computer engineers now face the challenge of developing better cyber defenses and more secure software.

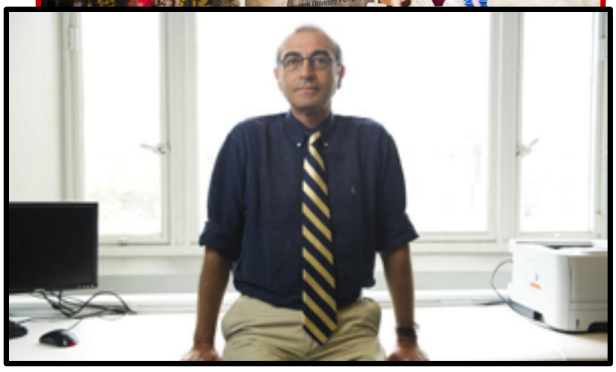
Enhance virtual reality.

Through the advancement of technology, you can now be somewhere you're not. Virtual reality is the use of technology to create an illusionary environment, which places the user inside an experience. And studies have shown that these experiences are so seemingly realistic, that those who use virtual reality react just as they would if they were actually in those situations.

Over the years, the use for virtual reality has broadened from enhancing video games to training practitioners and treating patients. The uses for virtual reality not only provides for a short-term escape into another reality, but can be also used by doctors to practice surgeons before actually performing them, soldiers to learn combat tactics, and those with phobias to combat them. However, despite its success, virtual reality still struggles in certain aspects such as virtual human interaction. From speech recognition to creating accurate facial expressions and movements, it is extremely difficult to produce natural and realistic human interaction through technology. Incorporating the other senses, such as touch, is also difficult to reproduce for the users. By incorporating other senses, this can benefit the medical field, as surgeons who use virtual reality to practice can experience the resistance cutting through tissues. Through further improvements and enhancing, the possibilities that can be created with virtual reality is limitless.

Advance personalized learning.

Everyone learns at different rates and in different ways. Some are visual learners and are able to better grasp an idea if they can actually see it while others may be tactile learners and need hands on experience to understand the information. However, education has always been one size fits all with similar curriculums. But with advances in the understanding of how the brain functions, it's time to invest in personalized learning to better suit the preferences of different peoples' minds. Not only will this be more efficient for people who prefer the less "traditional" educational methods but it allows for more and quicker progress to be made on future innovation.



Northeastern Connections

Faculty Connection

Engineers are continuously searching for ways to make their research projects energy and economically efficient. For instance an electrical engineer may use a light-emitting diode (LED) light bulb or a compact fluorescent light (CFL) bulb that requires less energy than an incandescent light bulb that would produce the same amount of light. It's about finding ways to complete the same task but in a more energy efficient way while also lowering cost. Northeastern has a plethora of faculty members that integrate world energy resources in their research and engineering careers.

Ali Abur, a professor of electrical and computer engineering at Northeastern University's College of Engineering is currently engaging in research aimed at developing and implementing real time measurements and predictive data for solar grid operators to optimize system performance using sensors, communication and data analytic technologies. Professor Abud was one of 13 projects selected by the Department of Energy's Office of Energy Efficiency and Renewable Energy SunShot initiative and was recently awarded a $792K grant from the Enabling Extreme Real-time Grid Integration of Solar Energy (ENERGISE) funding program. With this research, Professor Abur and his time will be able to develop tools to accurately monitor a substantial number of solar power sources, solar grids, in providing technical guidance for

wiring systems to enable their efficient integration and dispatch under varying operating conditions. To learn more about Professor Ali Abur's research visit the following link: Research to Help Add Solar to the Grid.

Another professor of Electrical and Computer Engineering Northeastern University's College of Engineering who works heavily with making solar energy economical is Professor Brad Lehman. Professor Lehman is conducting research on fault detection and protection for Solar (photovoltaic) PV Systems. Solar PV systems convert the sun's radiation, in the form of light into usable electricity. He plans to discover unique fault scenarios, the comparison between the measured and model prediction results of the power production, in solar PV arrays and develop new fault detection and preservation mechanisms.

Student Connection

Engineers play an important role in furthering scientific discovery. While scientists plan out the experiments to test their hypothesis, engineers can lend a hand in providing the means to this experimentation. Often, the two will work together towards these large goals. Northeastern's Innovators for Global Health does exactly that. More specifically, their Design Group focuses on designing and producing medical devices for places in need. They target the needs seen from their yearly trips to partnered hospitals around the world and work together to engineer solutions to these issues.

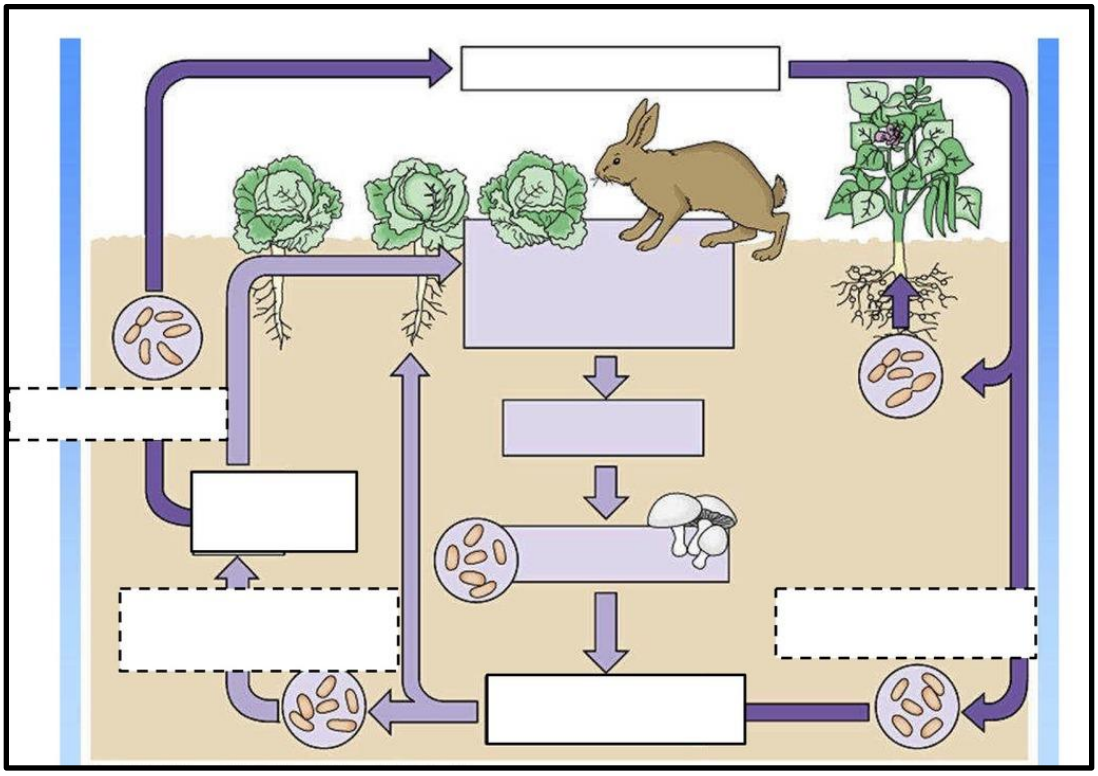
Their most recent venture in Ethiopia focused on creating an LED surgical lamp prototype as power outages were common at that hospital. Working together with the Biomedical Engineering Department, they were able to create a functional model costing only about $150. Their partnership allowed for multiple revisions in their design for the best possible result. This upcoming year, the group is working on ECG electrodes for St. Paul's in Ethiopia and Walkers for hospitals in Rwanda.

Do Now

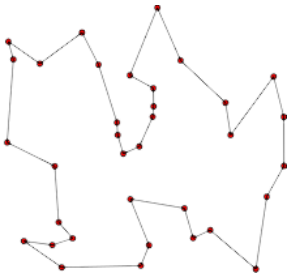
According to NASA, 78% of the Earth's atmosphere is composed of nitrogen. That is a whole lot! However, despite the large abundance, the nitrogen in the air can't be used by plants and animals. Bacteria must first process the nitrogen by changing its bonds so it can be used by plants and animals. Eventually, when these plants and animals die, the nitrogen leaves their bodies and returns to the atmosphere.

Watch the following video to learn more about the Nitrogen Cycle and fill out the blank Nitrogen Cycle sheet below!

Video Link: Carbon and Nitrogen Cycle (You only need to watch the second half!)



Activity



The grand challenge we will be looking at for this activity is **Providing Access to Clean Water.** According to Global WASH (Water, Sanitation, and Hygiene, around 780 million people do not have access to improved water sources (these are water sources that are protected from outside contamination such

as fecal matter). As you may know, having access to clean water is an absolute necessity for us, as we use it for cleaning, cooking, washing, and most importantly, for drinking. In this week's activity, we will be attempting to build a filter for dirty water, so that we can come up with solutions to be able to provide clean water for all.

Source: Who Polluted the Charles River & Water Filtration – Center for STEM Education

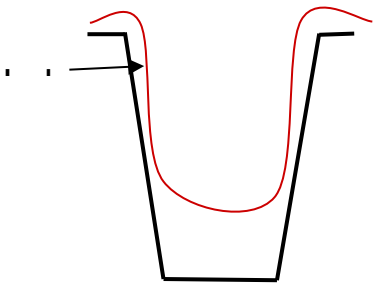
Materials Needed:

You can use any materials you want but here are some suggestions:

- Gravel
- Sand
- Cotton Balls
- Coffee Filter
- Cheese Cloth
- Screen
- Tape
- Pencil and paper
- Clear Plastic cup
- Timer (optional)
- Dirty water (Mix dirt, rocks, and twigs in some water)

Steps:

- You will be building a water filter in a plastic cup. After building the filter, the dirty water will be passed through it. You should observe the clarity of the water to observe how clean the water became (At no point during this activity should you drink the water, even if the filtered water looks clean).
- Using your pencil and paper, plan out the design of your water filter. Draw a cup (as seen below) and label the different materials on your diagram and draw where you would put them.



- After designing the filter, go ahead and start building it with your materials!
- To test out your filter, you will need "polluted" water. You can mix things like dirt, tree leaves, rocks, and sand in some water to make it polluted.
- Once your filter is ready, pour your polluted water into it and wait until a good amount drips through the filter.
- You can time how long it takes all the water to be filtered using a timer if you want.
- Since your cup is clear, you should be able to observe how well your filter did. Feel free to compare this water to the water in your home (DO NOT DRINK THE WATER THAT YOU FILTERED).
- If you are unhappy with your result, make a new filter! Figure out if you need to improve your current design or make a completely new one.

Discussion Questions:

- How clean did your filtered water look?
- How would you improve your design?
- How long did it take to filter the water? What could you do to speed it up without losing the water quality?

Share Your Results

We'd love to know how the activity and/or the "do now" turned out! What worked and what didn't work? Please share with us something you learned and/or send us pictures! Email us at stem@northeastern.edu.

Related links/Extensions

- What are the Grand Challenges of Engineering?
- 22 Inventions that are Saving the Earth -- TechInsider
- Descriptions of the Grand Challenges
- Make Solar Energy Economical:
    - Solar Energy -- Britannica Kids
    - Energysage -- Solar Power, What you need to know

- Reverse-Engineer the Brain:
  - Center for Cognitive and Brain Health
- Enhance Virtual Reality
  - Virtual Reality Rehabilitation Games
- Advance Personalized Learning
  - Center for Advanced Teaching and Learning Through Research
- Engineer Better Medicines
  - Center for Drug Discovery
- Advance Health Informatics
- Restore and Improve Urban Infrastructure
  - Critical Infrastructure Sustainability/Security
- Secure Cyberspace
  - Institution of Information Assurance
- Provide Access to Clean Water
  - PROTECT Program
  - WASH Initiative
- Provide Energy from Fusion
  - Plasma Lab at Northeastern
- Prevent Nuclear Terror
  - Nuclear Threat Detection Research at Northeastern
- Manage the Nitrogen Cycle
  - Nitrogen Cycle at Salt Marshes
- Develop Carbon Sequestration Methods
  - National Soil Project
- Engineer the Tools of Scientific Discovery
  - DIY Microscopes from a Northeastern Student Group