Columbia Undergraduate Scholars Program

2010-11 COLUMBIA JOURNEY SEMINAR

GRAND ENGINEERING CHALLENGES HANDBOOK
Welcome to the Columbia Journey Seminar, and to the year-long project that will be the culmination of your First-Year Scholar experience! We invite you to use this Handbook and the challenges it presents as a springboard to pursuing larger research questions through issues that are close to your heart. Investigate the topics that pique your interest, and check out the sample fields of inquiry to get a sense of how to adapt those broad topics to questions you may have about New York City communities. *Is it safe to swim at Brooklyn’s beaches? Have downtown Manhattan neighborhoods recovered from the impacts of 9/11? Who advocates for new technology in public schools?* You may explore these questions, or questions of your own.

The Columbia Journey Seminar will be a starting point for you to explore research questions that will be meaningful to your future. The Grand Engineering Challenges, created by the National Academy of Engineering, represent opportunities to increase your knowledge of broad subjects like sustainable energy, clean water, or virtual reality, and to hone your skills of critical inquiry as you examine the processes required to, for instance, improve urban infrastructure, design artificial intelligence, or develop new medicines. Most of all, they will help you expand the role of imagination in the process of designing your own research project — your creativity is essential to the success and safety of the future!

While your projects will respond to the areas of concern outlined in the Challenges, you will also begin to gain access to the processes that will become central to your development as a researcher. You will learn how to navigate the libraries and research collections of Columbia University and its partner institutions, become a responsible researcher familiar with many facets of academic publishing, and work closely with students and faculty with expertise in a variety of fields. Imagine co-authoring a scholarly paper with your favorite professor or presenting at an academic conference with your closest friends! You will also begin to amass a collection of individual research — papers, presentations and project reports — that will reflect your interests and become the basis of your identity as a scholar. Furthermore, in increasing your familiarity with a topic of inquiry, you will develop a relationship to a community, a neighborhood or a small group of individuals whose experiences help you model your project and inform your conclusions. And of course, you will have fun! You will be creating a dynamic community with fellow Scholars who will quickly become your friends. The entire CUSP staff is excited to enjoy the ride with you.

This Project Handbook is filled with resources and sample projects that will help you begin the process of exploring these Challenges. The Graduate Student Mentors have compiled this information, and we encourage you to follow your curiosity to whatever Challenges interest you. Now it is your challenge to make these topics personal, and to create research projects that truly unite your scholarly work with advocacy, civic engagement and passionate inquiry. We invite you to dive in.
## 2010-11 JOURNEY SEMINAR GRAND ENGINEERING CHALLENGES

<table>
<thead>
<tr>
<th></th>
<th>Challenge</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Provide Energy From Fusion</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Manage the Nitrogen Cycle</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>Provide Access to Clean Water</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>Restore and Improve Urban Infrastructure</td>
<td>11</td>
</tr>
<tr>
<td>5</td>
<td>Develop Carbon Sequestration Methods</td>
<td>14</td>
</tr>
<tr>
<td>6</td>
<td>Advance Health Informatics</td>
<td>17</td>
</tr>
<tr>
<td>7</td>
<td>Engineer Better Medicines</td>
<td>19</td>
</tr>
<tr>
<td>8</td>
<td>Reverse-Engineer the Brain</td>
<td>22</td>
</tr>
<tr>
<td>9</td>
<td>Prevent Nuclear Terror</td>
<td>25</td>
</tr>
<tr>
<td>10</td>
<td>Secure Cyberspace</td>
<td>28</td>
</tr>
<tr>
<td>11</td>
<td>Enhance Virtual Reality</td>
<td>30</td>
</tr>
<tr>
<td>12</td>
<td>Advance Personalized Learning</td>
<td>34</td>
</tr>
<tr>
<td>13</td>
<td>Make Solar Energy Economical</td>
<td>37</td>
</tr>
<tr>
<td>14</td>
<td>Engineer the Tools of Scientific Discovery</td>
<td>41</td>
</tr>
</tbody>
</table>
PROVIDE ENERGY FROM FUSION

Summary from N.A.E. Grand Challenge for Engineering:

If you have a laptop computer, its battery probably contains the metallic element lithium. In theory, the lithium in that battery could supply your household electricity needs for 15 years.

Not in the form of a battery, of course. Rather, lithium could someday be the critical element for producing power from nuclear fusion, the energy source for the sun and hydrogen bombs. Power plants based on lithium and using forms of hydrogen as fuel could in principle provide a major sustainable source of clean energy in the future.

What is fusion?

Fusion is the energy source for the sun. To be sure, producing power from fusion here on Earth is much more challenging than in the sun. There, enormous heat and gravitational pressure compress the nuclei of certain atoms into heavier nuclei, releasing energy. The single proton nuclei of two hydrogen isotopes, for example, are fused together to create the heavier nucleus of helium and a neutron. In that conversion, a tiny amount of mass is lost, transformed into energy as quantified by Einstein's famous equation, $E=mc^2$.

Earthbound reactors cannot achieve the high pressures of the sun's interior (such pressures have been achieved on Earth only in thermonuclear weapons, which use the radiation from a fission explosion to compress the fuel). But temperatures much higher than the sun's can be created to compensate for the lesser pressure, especially if heavier forms of hydrogen, known as deuterium (with one proton and one neutron) and tritium (one proton plus two neutrons) are fused.

Deuterium is a relatively uncommon form of hydrogen, but water -- each molecule comprising two atoms of hydrogen and one atom of oxygen -- is abundant enough to make deuterium supplies essentially unlimited. Oceans could meet the world's current energy needs for literally billions of years.

Tritium, on the other hand, is radioactive and is extremely scarce in nature. That's where lithium comes in. Simple nuclear reactions can convert lithium into the tritium needed to fuse with deuterium. Lithium is more abundant than lead or tin in the Earth's crust, and even more lithium is available from seawater. A 1,000 megawatt fusion-powered generating station would require only a few metric tons of lithium per year. As the oceans contain trillions of metric tons of lithium, supply would not be a problem for millions of years. (Click here to read entire N.A.E. Grand Challenge.)
Sample Journey Seminar field of inquiry: How is nuclear fusion research coordinated within the university community, in the New York City, online, and internationally? What technical, social, and political challenges do we face to developing fusion as safe and abundant energy source in the future, and how can we learn from local research?

**Examples of relevant questions:**

- How does fusion produce energy?
- What advantages and disadvantages does fusion hold in comparison with other energy sources?
- What are the technical challenges that must be met in order to make fusion a safe and affordable source of energy?
- What natural resources are required to generate and store energy from fusion, and where are these resources available?
- Fusion promises to provide a virtually unlimited supply of energy. To what uses could or should such energy be put?
- The technical and economic resources required to produce energy from nuclear fusion require a high level of professional and political coordination. How should the costs, risks and benefits associated with this emerging energy source be distributed internationally?

**Possible project topics:**

- Compare fusion energy (the type of energy produced by the sun) to solar energy (energy collected from the sun) and analyze each as a potential energy source.
- DIY (Do It Yourself) Fusion? Visit the laboratory of amateur physicist Mark Suppes and analyze the technical and social implications of his effort to build a fusion reactor in a Brooklyn warehouse.
- How is radioactive waste from Columbia’s fusion research managed? What risks does such research pose to the surrounding community and how can they be minimized?

**Potential target neighborhoods:**

- Columbia University campus and Morningside Heights
- Locate amateur fusion researchers in New York City

**Columbia University resources:**

- [Columbia Plasma Physics Laboratory](http://plasma.phys.columbia.edu/), “The Plasma Physics Laboratory was founded in 1961 and is an integral part of the Department of Applied Physics and Applied Mathematics. It is an experimental research facility devoted to the study of basic and applied plasma physics in a broad range of applications.” Includes links to Columbia and external fusion resources.
• “The HBT-EP Tokamak is the fourth toroidal magnetic experiment constructed within the Columbia University Plasma Laboratory.”

• SEAS Bulletin update on fusion research that is currently being conducted at The Fu Foundation School of Engineering and Applied Science: Levitating Magnet May Yield New Approach to Clean Energy

• Professor Gerald A. Navratil, Department of Applied Physics and Applied Mathematics, “My research concentrates on applying experimental plasma physics to the problem of developing controlled thermonuclear fusion as a source of energy.” Professor Navratil delivered the 2006 Con Edison Lecture "Bold Step by the World to Fusion Energy: ITER"

• Professor Michael E. Mauel, Department of Applied Physics and Applied Mathematics, “I am involved with two major experiments in Columbia’s Plasma Physics Laboratory and with several experimental efforts at the national Plasma Physics Laboratory at nearby Princeton and at the General Atomics DIII-D tokamak located outside San Diego. At each location, large high-beta tokamak devices are used to study the operational limits for fusion-relevant plasma discharges.”

**Background materials:**

• FIRE. “Comprehensive resource on fusion research.”


• “In Hot Pursuit of Fusion (or Folly)” The New York Times, May 25, 2009

• “Ten Serious Nuclear Fusion Projects Making Progress Around the World”, BNET, January 10, 2010

• The International Thermonuclear Experimental Reactor or ITER. “ITER is a large-scale scientific experiment intended to prove the viability of fusion as an energy source, and to collect the data necessary for the design and subsequent operation of the first electricity-producing fusion power plant. Launched as an idea for international collaboration in 1985, the ITER Agreement includes China, the European Union, India, Japan, Korea, Russia and the United States, representing over half of the world's population.”

• U.S. Department of Energy's Office of Science Fusion Energy Sciences Program, “The FES mission is to expand the fundamental understanding of matter at very high temperatures and densities and to develop the scientific foundations needed to develop a fusion energy source.”

• Institute of Physics, Fusion as an Energy Source: Challenges and Opportunities

• FUSOR: The Open Source Research Consortium, “There is now a small cadre of "fusioneers" building "Fusors" in their basements and garages... Building these devices is teaching a grassroots group of dedicated experimenters how to produce fusion. This website - fusor.net - is where these people gather to share their experiences, to swap tips and techniques, and pass on encouragement.”
• How Stuff Works: Nuclear Fusion

• Science. “Special Section: Scaling Up Alternative Energy.” “Science explores worldwide efforts to develop clean, renewable alternatives to fossil fuels. News stories highlight some of the challenges associated with making this energy transition, Perspectives take an in-depth look at how researchers hope to scale up biofuels development, and a Review discusses a two-stage approach for expanding nuclear power generation.” 13 August 2010: ScienceMag.org.
It doesn’t offer as catchy a label as “global warming,” but human-induced changes in the global nitrogen cycle pose engineering challenges just as critical as coping with the environmental consequences of burning fossil fuels for energy.

Why is the nitrogen cycle important?

The nitrogen cycle reflects a more intimate side of energy needs, via its central role in the production of food. It is one of the places where the chemistry of the Earth and life come together, as plants extract nitrogen from their environment, including the air, to make food. Controlling the impact of agriculture on the global cycle of nitrogen is a growing challenge for sustainable development.

Nitrogen is an essential component of amino acids (the building blocks of proteins) and of nucleotides (the building blocks of DNA), and consequently is needed by all living things. Fortunately, the planet’s supply of nitrogen is inexhaustible — it is the main element in the air, making up nearly four-fifths of the atmosphere in the form of nitrogen molecules, each composed of two nitrogen atoms. Unfortunately, that nitrogen is not readily available for use by living organisms, as the molecules do not easily enter into chemical reactions. In nature, breaking up nitrogen requires energy on the scale of lightning strikes, or the specialized chemical abilities of certain types of microbes.

Such microbes commonly live in soil, and sometimes live symbiotically in roots of certain plants. The microbes use enzymes to convert nitrogen from the environment into the forms that plants can use as nutrients in a process called fixation. Plants turn this fixed nitrogen into organic nitrogen — the form combined with carbon in a wide variety of molecules essential both to plants and to the animals that will eat them.

The opposite of this process is denitrification, in which organisms use nitrogen nutrients as their energy source and return nitrogen molecules to the atmosphere, completing the cycle. Denitrification also produces some nitrogen byproducts that are atmospheric pollutants. (Click here to read entire N.A.E. Grand Challenge.)
Sample Journey Seminar field of inquiry: Minimize nitrogen pollution from New York City wastewater.

**Examples of relevant questions:**

- What are the primary sources of nitrogen in New York City’s wastewater?
- What effects does nitrogen have on the waterways and wildlife habitats in the New York City area, and on human health?
- How is wastewater treated to remove nitrogen? Are there techniques that could enhance wastewater management?
- How much water does each New Yorker use each day? Could water consumption, and thus the need for treatment, be minimized by changing personal habits, industrial practices, and public infrastructure?

**Possible projects:**

- Assess nitrogen levels in New York City waterways
- Engage school children in learning how to conserve water, and to recognize and minimize their impact on local ecosystems
- Develop strategies for remediating damage to New York City’s ecology
- Analyze policy responses to nitrogen pollution

**Target Neighborhoods:**

- Jamaica Bay, Queens (wastewater treatment facility, community, wildlife refuge)
- Morningside Heights, Washington Heights, Manhattan
- Oakwood Beach, Staten Island

**Columbia University Resources:**

- The Earth Institute, Columbia University, “The overarching goal behind the research of the Earth Institute is to achieve environmental sustainability in the context of a world of environmental challenges—from rapid population growth and climate change to extreme poverty and infectious disease.”
- Wastewater Treatment and Climate Change Program, Kartik Chandran Laboratory, Earth and Environmental Engineering
Columbia scientists, shows that the magnitude of N2O emissions from these wastewater treatment plants may be more variable and complex than previously thought.

- Restoring New York City: Proposals for Improving Ecological and Human Health, Edited by Dr. James A. Danoff-Burg, Department of Ecology, Evolution, and Environmental Biology, Columbia University

**Background Information:**

- US Environmental Protection Agency, Water Quality Criteria for Nitrogen and Phosphorus Pollution, “Nutrient pollution, especially from nitrogen and phosphorus, has consistently ranked as one of the top causes of degradation in some U.S. waters for more than a decade. Excess nitrogen and phosphorus lead to significant water quality problems including harmful algal blooms, hypoxia and declines in wildlife and wildlife habitat. Excesses have also been linked to higher amounts of chemicals that make people sick.”

- The International Nitrogen Initiative, “The International Nitrogen Initiative is dedicated to optimizing the use of nitrogen in food production, while minimizing the negative effects of nitrogen on human health and the environment as a result of food and energy production.”

- New York City, Department of Environmental Protection

- New York City’s Wastewater Treatment System, Overview of New York’s wastewater treatment facilities, including capacities, locations, and ways residents can help.

- “New York City Will Halve Nitrogen Pollution to Jamaica Bay”, Environment News Service, March 2, 2010

- Environmental Health Clinic, “The Environmental Health Clinic at NYU is a clinic and lab, modeled on other health clinics at universities. However the project approaches health from an understanding of its dependence on external local environments; rather than on the internal biology and genetic predispositions of an individual.”

- *Science*. “Special Section: Scaling Up Alternative Energy.” “Science explores worldwide efforts to develop clean, renewable alternatives to fossil fuels. News stories highlight some of the challenges associated with making this energy transition, Perspectives take an in-depth look at how researchers hope to scale up biofuels development, and a Review discusses a two-stage approach for expanding nuclear power generation.” 13 August 2010: ScienceMag.org.
PROVIDE ACCESS TO CLEAN WATER

Summary from N.A.E. Grand Challenge for Engineering:

When Samuel Taylor Coleridge wrote “water, water, everywhere, nor any drop to drink,” he did not have the 21st century’s global water situation in mind. But allowing for poetic license, he wasn’t far from correct. Today, the availability of water for drinking and other uses is a critical problem in many areas of the world.

How serious is our water challenge?

Lack of clean water is responsible for more deaths in the world than war. About 1 out of every 6 people living today do not have adequate access to water, and more than double that number lack basic sanitation, for which water is needed. In some countries, half the population does not have access to safe drinking water, and hence is afflicted with poor health. By some estimates, each day nearly 5,000 children worldwide die from diarrhea-related diseases, a toll that would drop dramatically if sufficient water for sanitation was available.

It’s not that the world does not possess enough water. Globally, water is available in abundance. It is just not always located where it is needed. For example, Canada has plenty of water, far more than its people need, while the Middle East and northern Africa — to name just two of many — suffer from perpetual shortages. Even within specific countries, such as Brazil, some regions are awash in fresh water while other regions, afflicted by drought, go wanting. In many instances, political and economic barriers prevent access to water even in areas where it is otherwise available. And in some developing countries, water supplies are contaminated not only by the people discharging toxic contaminants, but also by arsenic and other naturally occurring poisonous pollutants found in groundwater aquifers.

Water for drinking and personal use is only a small part of society’s total water needs — household water usually accounts for less than 5 percent of total water use. In addition to sanitation, most of the water we use is for agriculture and industry. Of course, water is also needed for ecological processes not directly related to human use. For a healthy, sustainable future for the planet, developing methods of ensuring adequate water supplies pose engineering challenges of the first magnitude.

Of course, by far most of the world’s water is in the oceans, and therefore salty and not usable for most purposes without desalination. About 3 percent of the planet’s water is fresh, but most of that is in the form of snow or ice. Water contained in many groundwater aquifers was mostly deposited in earlier, wetter times, and the rate of use from some aquifers today exceeds the rate of their replenishment.

“Overcoming the crisis in water and sanitation is one of the greatest human development challenges of the early 21st century,” a recent U.N. report warns. (Click here to read entire N.A.E. Grand Challenge.)
Sample Journey Seminar field of inquiry: measuring the extent of environmental contamination of New York City waterways.

Examples of relevant questions:

- What are the major sources of environmental contamination of waterways in NYC?
- Have any areas in NYC been designated as Superfund sites?
- Which contaminants are most prevalent?
- What communities have been affected?
- Has there been a community response to the contamination?

Potential project topics:

- Taking inventory of the progress made with regard to cleanup of contaminated NYC waterways.
- Identifying potentially neglected areas of heavy contamination.
- Prioritizing cleanup efforts based both on toxicity of contaminants and on available water remediation technologies.

Potential target neighborhoods:

- Around the Newtown Creek: Long Island City, Woodside, Sunnyside and Maspeth neighborhoods of Queens and Greenpoint, Brooklyn.
- Around the Gowanus Canal: Gowanus, Red Hook and Carroll Gardens neighborhoods of Brooklyn.
- Hudson River waterfront.

Columbia University resources:

- Department of Earth and Environmental Engineering. “Strives to develop effective solutions to complex and multidisciplinary environmental problems, reconciling a deep concern for the environment with the needs of our global industrialized society. Our central theme is the conscientious stewardship of our finite natural resources, namely minerals, fuels, energy, water, and land.” [EEE website]

- Lamont-Doherty Earth Observatory: Hudson River Research & Center for Rivers and Estuaries, The Earth Institute. “An association of scientists from Columbia University that study various aspects of rivers and estuaries world wide including the distribution of sediments, the transport and flux of sediments, contaminants, carbon, nutrients, organic material, and aerosols, the evolution and linkage of marshes and wetlands. Much of the research of this center is done in the Hudson River in the vicinity of Columbia University.” [CRE website]
Earth Engineering Center for Sustainable Waste Management. “The mission of EEC is to identify and help develop the most suitable means for managing various solid wastes research, and disseminate this information by means of publications, the web, and technical meetings. The guiding principle is that responsible management of wastes must be based on science and best available technology and not on ideology and economics that exclude environmental costs.” [EEC website]

Department of Environmental Health Sciences, Mailman School of Public Health. The Dept. of EHS houses a number of initiatives based in Northern Manhattan and in conjunction with community-based organizations such as the West Harlem Environmental Justice Alliance to examine the detrimental health effects of contaminants.

Background materials:


- U.S Environmental Protection Agency. Superfund Home page. “This Web site provides topical information for the general public and for those involved in the Superfund program. On this site, you’ll find information about Superfund sites in your area, the health effects of common contaminants, cleanup efforts, and how you can become involved in cleanup activities in your community.” [SF website]

- Riverkeeper website on Contaminated Sites in NYC. Provides background information on the presence of PBCs in the Hudson River, the Greenpoint Oil Spill and the Gowanus Canal.

- Gowanus Canal Community Development Corporation. “GCCDC is a neighborhood preservation non-profit organization dedicated to the revitalization of the Gowanus Canal area in Brooklyn for the past twenty-nine years. Our community-based group has an extensive record of initiatives and involvement in the physical improvement of the Gowanus Canal and the surrounding communities. GCCDC’s efforts are focused on the environmental remediation of the Gowanus Canal, housing, economic development, and commercial revitalization.” [GCCDC website]

- Newtown Creek Alliance. “Formed in 2002, the Newtown Creek Alliance works to educate leaders and decision makers about Newtown Creek, advocate for an end to persistent sources of Creek pollution, host community events on and around Newtown Creek, and much more. NCA members include elected officials, environmental advocates, community residents, business leaders, Newtown Creek users and more.” [NCA website]

- New York City Department of Environmental Protection (DEP) webpage on Harbor Water. Provides information on numerous programs run by the NYC DEP designed to improve and monitor sewage handling and treatment. The DEP operates 14 sewage treatment plants that together treat around 1.3 billion gallons of sewage each day, and the agency also employs a fleet of boats that are used to monitor the waters and the shoreline for water quality and sources of pollution. [NYC DEP website]

In 2005, the American Society of Civil Engineers issued a report card, grading various categories of U.S. infrastructure. The average grade was D.

What is infrastructure?

Infrastructure is the combination of fundamental systems that support a community, region, or country. It includes everything from water and sewer systems to road and rail networks to the national power and natural gas grids. Perhaps there will be a hydrogen grid in the future as well.

What is the current state of our infrastructure?

It is no secret that America's infrastructure, along with those of many other countries, is aging and failing, and that funding has been insufficient to repair and replace it. Engineers of the 21st century face the formidable challenge of modernizing the fundamental structures that support civilization.

The problem is particularly acute in urban areas, where growing populations stress society's support systems, and natural disasters, accidents, and terrorist attacks threaten infrastructure safety and security. And urban infrastructure is not just a U.S. issue; special challenges are posed by the problems of megacities, with populations exceeding 10 million, which are found mostly in Asia. In many parts of the world, basic infrastructure needs are still problematic, and engineers will be challenged to economically provide such services more broadly.

Furthermore, solutions to these problems must be designed for sustainability, giving proper attention to environmental and energy-use considerations (though cities take up just a small percentage of the Earth’s surface, they disproportionately exhaust resources and generate pollution), along with concern for the aesthetic elements that contribute to the quality of life. (Click here to read entire N.A.E. Grand Challenge.)
Sample Journey Seminar field of inquiry: improve the supply of affordable housing in New York City.

**Examples of relevant questions:**

- What is the proper definition for affordable housing?
- What are the respective roles of the private sector and government in providing affordable housing?
- Who benefits, and who is hurt, from a lack of affordable housing?
- How have other countries handled this issue.
- Impact of “green” issues on affordable housing.

**Possible project topics:**

- Highlight an innovative housing solution that serves people in their teens and 20s.
- Analyze the most, or least, effective government affordable housing program.
- Assess the impact on children of public housing programs.
- Are New York City’s policies on pets in public housing beneficial or detrimental.

**Potential target neighborhoods:**

- Manhattanville: area where Columbia plans to build its new campus.
- Morningside Heights: impact of Columbia’s main campus.
- Washington Heights: impact of Columbia’s Medical School campus.
- West Harlem: affordable housing east of Morningside Park.
- Other boroughs: for example, initiatives in Queens (“Hunter’s Point South,” “Willet’s Point”) or the Bronx (“Boricua Village”).

**Columbia University resources:**


- Architecture School: Masters of Science in Real Estate Development program. “Columbia’s rigorous Masters of Science in Real Estate Development program — structured in the context of the world’s most innovative laboratory for architecture, planning and
Columbia Undergraduate Scholars Program • 2010-11 Journey Seminar Challenges Handbook • 13

preservation — provides an unrivaled platform to tackle these pressing issues. Building off the extraordinary resources of Columbia University and the City of New York, students learn from both industry leaders who provide current real world knowledge and outstanding faculty who provide a lifelong theoretical underpinning.” See: Vishaan Chakrabarti Director / Marc Holliday Professor of Real Estate Development.

• University: Columbia University Residential Operations and Apartment Housing.

“University Apartment Housing (UAH) is a division of Columbia University Facilities that manages residential units primarily in the immediate vicinity of the Morningside Heights campus, as well as in Washington Heights, Manhattan Valley, and Riverdale. This housing is primarily used to house faculty, students, and certain eligible officers of research, libraries, and administration. The UAH inventory includes apartments of sizes appropriate to the family needs of faculty and staff. The student housing inventory consists of apartment shares, dormitory-style rooms, and a very limited number of studio, one bedroom and family units.”

Background materials:

• EnvisioningDevelopment.net. “‘Affordable Housing.’ The phrase seems plain enough, but it doesn’t always mean what people think it does! It actually has a technical government definition that can determine what gets built and who lives there. Use these tools to answer the all-important question: ‘Affordable to whom?’” (See A. G. Sulzberger. “Unraveling the Mystery of ‘Affordable‘ Housing.” 8 January 2010: NYTimes.com.)

• New York City Affordable Housing Resource Center. “Here you will find information on all aspects of City housing, including renting an apartment, buying a home, and apartment maintenance issues. Through this site, you will also find all of the City’s affordable housing lottery listings.”

• New York City Department of Housing, Preservation and Development.

• National Low Income Housing Coalition. “Dedicated solely to achieving socially just public policy that assures people with the lowest incomes in the United States have affordable and decent homes.”

• U.S. Census Bureau. “Housing Topics.”

• New York University Furman Center for Real Estate and Urban Policy. “A leading academic research center devoted to the public policy aspects of land use, real estate development and housing.”

• Wikipedia. “Affordable Housing.” (Useful information about affordable housing policies in other countries).
DEVELOP CARBON SEQUESTRATION METHODS

Summary from N.A.E. Grand Challenge for Engineering:

The growth in emissions of carbon dioxide, implicated as a prime contributor to global warming, is a problem that can no longer be swept under the rug. But perhaps it can be buried deep underground or beneath the ocean.

Why is carbon dioxide (CO2) a problem?

In pre-industrial times, every million molecules of air contained about 280 molecules of carbon dioxide. Today that proportion exceeds 380 molecules per million, and it continues to climb. Evidence is mounting that carbon dioxide's heat-trapping power has already started to boost average global temperatures. If carbon dioxide levels continue upward, further warming could have dire consequences, resulting from rising sea levels, agriculture disruptions, and stronger storms (e.g. hurricanes) striking more often.

But choking off the stream of carbon dioxide entering the atmosphere does not have a simple solution. Fossil fuels, which provide about 85 percent of the world's energy, are made of hydrocarbons, and burning them releases huge quantities of carbon dioxide. Even as renewable energy sources emerge, fossil-fuel burning will remain substantial. And the fossil fuel in greatest supply — coal — is the worst carbon dioxide emitter per unit of energy produced. A grand challenge for the 21st century's engineers will be developing systems for capturing the carbon dioxide produced by burning fossil fuels and sequestering it safely away from the atmosphere.

What is carbon sequestration?

Carbon sequestration is capturing the carbon dioxide produced by burning fossil fuels and storing it safely away from the atmosphere. (Click here to read entire N.A.E. Grand Challenge.)
Examples of relevant questions:

- How are appropriate facility sites chosen?
- What are the ecological and environmental risks of this technology?
- What are the barriers to proposed methods of carbon capture and sequestration?

Possible Project Topics:

- The use of urban agriculture, including tree planting as a strategy to reduce and sequester carbon emissions throughout New York City.
- Potential site assessments in the New York City metropolitan area. Example: the City Sink project led by Denise Hoffman-Brandt, a City College Landscape Architecture Professor.

Background Materials:

- Carbon Capture - “Carbon Capture Journal is specifically about developments with industrial scale carbon capture and geological storage technology, with news about the major projects and development with government policy.”
- Carbon Capture and Storage Interagency Task Force - “On February 3, 2010, President Obama sent a memorandum to the heads of fourteen Executive Departments and Federal Agencies establishing an Interagency Task Force on Carbon Capture and Storage. The goal was to develop a comprehensive and coordinated Federal strategy to speed the commercial development and deployment of clean coal technologies. The Task Force, co-chaired by the Department of Energy and the Environmental Protection Agency, was charged with proposing a plan to overcome the barriers to the widespread, cost-effective deployment of CCS within 10 years, with a goal of bringing 5 to 10 commercial demonstration projects online by 2016. On August 12, 2010, the Task Force delivered a series of recommendations to the President on overcoming the barriers to the widespread, cost-effective deployment of CCS within ten years. The report concludes that CCS can play an important role in domestic GHG emissions reductions while preserving the option of using abundant domestic fossil energy resources. However, widespread cost-effective deployment of CCS will occur only if the technology is commercially available at economically competitive prices and supportive national policy frameworks are in place. The Task Force’s recommendations include specific actions to help overcome remaining barriers and achieve the President’s goals.”
- National Resources Defense Council - “These materials were presented on March 5, 2009 (New York City), and March 6, 2009 (Washington D.C.), at workshops organized by NRDC and Environmental Defense Fund and co-sponsored by the Global Climate and Energy Project at Stanford University, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, Bureau of Economic Geology at the University of Texas, Bloomberg, Massachusetts Institute of Technology Energy Initiative, Pew Center on Global Climate Change and in association with the Joint Global Change Research Institute.”
- Pew Center on Global Climate Change - “The Pew Center on Global Climate Change brings together business leaders, policy makers, scientists, and other experts to bring a new
approach to a complex and often controversial issue. Our approach is based on sound science, straight talk, and a belief that we can work together to protect the climate while sustaining economic growth.”

- Lawrence Livermore National Laboratory - “As a premier national security laboratory, our mission is to advance and apply science and technology to: Ensure the safety, security, and reliability of the U.S. nuclear deterrent; Reduce or counter threats to national and global security; Enhance the energy and environmental security of the nation; Strengthen the nation’s economic competitiveness; At LLNL, teams of physicists, chemists, biologists, engineers and other researchers work together to achieve technical innovations and scientific breakthroughs and transform these advances into solutions to nationally important problems.”


- Underground: Myths and Realities of Carbon Capture and Storage - “Carbon capture and storage (CCS) has long been held as the salvation of coal-rich nations eager to guarantee energy security and limit climate change. But far from a homogeneous system, CCS is an intricate technology that is sparking intense competition, political divisions and public fear. In this seven-part report, E&E reporter Paul Voosen examines CCS in Germany and the Netherlands, leaders in researching and investing in CCS technologies.”

- Columbia University’s Dr. Klaus Lackner, PhD, the Maurice Ewing and J. Lamar Worzel Professor of Geophysics and Director of the Lenfest Center for Sustainable Energy at Columbia University’s Earth Institute and Allen Wright, a Senior Staff Associate, also at the Earth Institute are working on a collaborative project to study carbon capture with Global Research Technologies.
ADVANCE HEALTH INFORMATICS

Summary from N.A.E. Grand Challenge for Engineering:

When you dial 911 for a medical emergency, the outcome may very well depend on the 411 — the quality of the information available about your condition and ways to treat it.

No aspect of human life has escaped the impact of the Information Age, and perhaps in no area of life is information more critical than in health and medicine. As computers have become available for all aspects of human endeavors, there is now a consensus that a systematic approach to health informatics — the acquisition, management, and use of information in health — can greatly enhance the quality and efficiency of medical care and the response to widespread public health emergencies.

Health and biomedical informatics encompass issues from the personal to global, ranging from thorough medical records for individual patients to sharing data about disease outbreaks among governments and international health organizations. Maintaining a healthy population in the 21st century will require systems engineering approaches to redesign care practices and integrate local, regional, national, and global health informatics networks.

On the personal level, biomedical engineers envision a new system of distributed computing tools that will collect authorized medical data about people and store it securely within a network designed to help deliver quick and efficient care.

Basic medical informatics systems have been widely developed for maintaining patient records in doctor’s offices, clinics, and individual hospitals, and in many instances systems have been developed for sharing that information among multiple hospitals and agencies. But much remains to be done to make such information systems maximally useful, to ensure confidentiality, and to guard against the potential for misuse, for example by medical insurers or employers.

(Click here to read entire N.A.E. Grand Challenge.)
Examples of relevant questions:

- Can transparency between doctors and patients work, or will it end up worrying patients, muddling the patient-doctor relationship and adding more work to an already overburdened primary care work force?

- As Electronic Medical Records (EMR) use increases, how is the doctor-patient relationship affected?

- Who controls and has access to medical information, and for how long?

Possible Project Ideas:

- Can (and should) medical records be shared as interactive documents between patients and physicians?

- The collection of specific biomedical data on local, state, and national levels. Example: pending Congressional legislation to record BMIs for all children ages 2-18 and share that info with the federal government.

- How has the practice of documentation - written or electronic - shaped the ways in which current medical students and residents are learning to practice medicine?

Potential Target Neighborhoods:

- Citywide

Columbia University Resources:

- Columbia University Health Services
- St. Lukes Roosevelt Hospital
- Columbia University Medical Center

Background Materials:

- H.R 5209: “Healthy Choices Act” - to provide a comprehensive approach to preventing and treating obesity
Doctors have long known that people differ in susceptibility to disease and response to medicines. But, with little guidance for understanding and adjusting to individual differences, treatments developed have generally been standardized for the many, rather than the few.

Human DNA contains more than 20,000 genes, all of which are stored in our cells' nuclei. A gene is a strand of chemical code, a sort of blueprint for proteins and other substances necessary for life. Cells make those molecules according to the genetic blueprints.

Each person's overall blueprint is basically the same, made up of about 3 billion “letters” of code, each letter corresponding to a chemical subunit of the DNA molecule. But subtle variants in about 1 percent of our DNA — often the result of just a single chemical letter being different — give humans their individual identities.

Beyond physical appearance, genes give rise to distinct chemistries in various realms of the body and brain. Such differences sometimes predispose people to particular diseases, and some dramatically affect the way a person will respond to medical treatments.

Ideally, doctors would be able to diagnose and treat people based on those individual differences, a concept commonly referred to as “personalized medicine.” At its core, personalized medicine is about combining genetic information with clinical data to optimally tailor drugs and doses to meet the unique needs of an individual patient. Eventually, personalized medicine will be further informed by detailed understanding of the body’s distinct repertoire of proteins (proteomics) and complete catalog of biochemical reactions (metabolomics).

“Personalized medicine,” writes Lawrence Lesko of the U.S. Food and Drug Administration, “can be viewed . . . as a comprehensive, prospective approach to preventing, diagnosing, treating, and monitoring disease in ways that achieve optimal individual health-care decisions.” [Lesko p. 809]
Examples of Relevant Questions:

- What are some of the ethical considerations surrounding “personalized” medicine, and its reliance on (pharmo)genomics?

- What are some of the applications of tailored medicine to various industries such as pharmaceuticals and insurance?

- What are the implications for this technology in seemingly unrelated areas? Example: the collection of prisoner DNA.

Possible Project Topics:

- Personalized medicine and race

- Debating DNA collection

Background Materials:

- Human Genome Project - “Completed in 2003, the Human Genome Project (HGP) was a 13-year project coordinated by the U.S. Department of Energy and the National Institutes of Health. During the early years of the HGP, the Wellcome Trust (U.K.) became a major partner; additional contributions came from Japan, France, Germany, China, and others. See our history page for more information. Project goals were to identify all the approximately 20,000-25,000 genes in human DNA, determine the sequences of the 3 billion chemical base pairs that make up human DNA, store this information in databases, improve tools for data analysis, transfer related technologies to the private sector, and address the ethical, legal, and social issues (ELSI) that may arise from the project. Let’s Get Personal: Science, Policy, and Ethics in Personalized Medicine” - Blog about issues in personalized medicine

- Mount Sinai School of Medicine Institute for Personalized Medicine - “The Institute for Personalized Medicine explores how genetic information and environmental exposure affect each person’s risk to develop certain diseases and response to medication. The Institute examines how this new model of genome-informed personalized healthcare may be translated in clinical settings to advance the practice, delivery and economics of health care.”

- Today’s Topics in Health Disparities: Race and Genetics - The Future of Personalized Medicine - “A webcast of the Kaiser Family Foundation's series, Today’s Topics In Health Disparities, which discusses the potential of race-based medical solutions for improving healthcare and reducing racial/ethnic health disparities. The webcast takes a closer look at efforts to study the interaction between race, genetics and health. Panelists discuss the efforts underway to develop medications to treat diseases that disproportionately affect certain racial and ethnic groups, as well as the benefits and drawbacks of using genetic markers for race in medical decisions. Other topics covered include which genetic factors are being used to personalize medicine and what pharmaceutical companies are doing to target the drugs and treatments they offer to certain groups.”
Using Simple Genome, Columbia Researchers Move Personalized Medicine Closer to Reality - Internet Article detailing Assistant Professor Dana Pe’er, in the department of biological sciences and head of Columbia’s Computational Systems Biology Lab research.
# REVERSE-ENGINEER THE BRAIN

Summary from [N.A.E. Grand Challenge for Engineering](#):

For decades, some of engineering’s best minds have focused their thinking skills on how to create thinking machines — computers capable of emulating human intelligence.

Why should you reverse-engineer the brain?

While some of thinking machines have mastered specific narrow skills — playing chess, for instance — general-purpose artificial intelligence (AI) has remained elusive.

Part of the problem, some experts now believe, is that artificial brains have been designed without much attention to real ones. Pioneers of artificial intelligence approached thinking the way that aeronautical engineers approached flying without much learning from birds. It has turned out, though, that the secrets about how living brains work may offer the best guide to engineering the artificial variety. Discovering those secrets by reverse-engineering the brain promises enormous opportunities for reproducing intelligence the way assembly lines spit out cars or computers.

Figuring out how the brain works will offer rewards beyond building smarter computers. Advances gained from studying the brain may in return pay dividends for the brain itself. Understanding its methods will enable engineers to simulate its activities, leading to deeper insights about how and why the brain works and fails. Such simulations will offer more precise methods for testing potential biotechnology solutions to brain disorders, such as drugs or neural implants. Neurological disorders may someday be circumvented by technological innovations that allow wiring of new materials into our bodies to do the jobs of lost or damaged nerve cells. Implanted electronic devices could help victims of dementia to remember, blind people to see, and crippled people to walk.

Sophisticated computer simulations could also be used in many other applications. Simulating the interactions of proteins in cells would be a novel way of designing and testing drugs, for instance. And simulation capacity will be helpful beyond biology, perhaps in forecasting the impact of earthquakes in ways that would help guide evacuation and recovery plans.

[Click here to read entire N.A.E. Grand Challenge.](#)
Sample Journey Seminar field of inquiry: consider the application of neuro- and cognitive science in the treatment of ADD and ADHD disorders in NYC elementary school children.

Examples of relevant questions:

- What are some of the ethical and legal questions raised by gains in scientific understanding of the brain?
- What are the standards of evidence and risk evaluation in the development of drugs in light of neurological and cognitive research?
- What are the diagnostic trends in ADD and ADHD over the last ten years in the USA?

Potential project topics:

- To what extent are ADD and ADHD medical conditions?
- Is there a connection between performance-oriented culture in college and graduate school and Ritalin use?
- Are problems of attention neurological or more broadly social in character?

Potential target neighborhoods/communities:

- Educators and students at NYC public schools in Morningside/Harlem area.
- College and graduate students at Columbia University.

Columbia University resources:

- Columbia Department of Psychiatry, Research on behavioral medicine (Richard Sloan, PhD, Chief): http://columbiapsychiatry.org/research/behavioral-medicine. “Research in the Division of Behavioral Medicine aims to understand the contribution of psychological, psychosocial, and behavioral factors to the onset, progression, and management of physical and mental disease, to identify the relevant pathophysiological mechanisms linking psychological states to disease, and to develop treatment interventions targeting these mechanisms. Projects range from the purely behavioral to the cellular, with new studies extending to gene expression.”

- Columbia Department of Psychiatry, Research on Integrative Neuroscience (Rene Hen, PhD, Chief): http://columbiapsychiatry.org/research/Integrative-Neuroscience. “The Division of Integrative Neuroscience is a research division aimed at understanding the pathophysiology underlying psychiatric illnesses using approaches that span multiple levels of neurobiological analysis.”

- New York State Psychiatric Institute: http://nyspi.org/director.html. “Columbia University Department of Psychiatry, New York State Psychiatric Institute, and the Psychiatric Services at NewYork-Presbyterian Hospital form an extraordinary convergence of scientific expertise, clinical talent, and technological resources.”
• Columbia Department of Pharmacology: http://asp.cpmc.columbia.edu/pharm/faculty_list.asp. “molecular genetics and structural biology together are beginning to identify specific and novel targets that offer great potential to change the manner by which chemical agents can be used to modify the function of living systems.”

• Columbia Department of Biomedical Engineering: http://www.bme.columbia.edu/index.html. “Our Department is home to world-class researchers in the fields of cell and tissue engineering, biomechanics, and biomedical imaging.”

Background materials:


• Steve Clarke, S. Matthew Liao and Mark Sheehan,” The Duty to Disclose Adverse Clinical Trial Results”, The American Journal of Bioethics 9 (8), 2009, pp. 24-32: http://www.smatthewliao.com/2008/06/30/the-duty-to-disclose-adverse-clinical-trial-results/


PREVENT NUCLEAR TERROR

Summary from NAE Grand Challenge for Engineering:

Long before 2001, defenders of national security worried about the possible immediate death of 300,000 people and the loss of thousands of square miles of land to productive use through an act of terror.

From the beginnings of the nuclear age, the materials suitable for making a weapon have been accumulating around the world. Even some actual bombs may not be adequately secure against theft or sale in certain countries. Nuclear reactors for research or power are scattered about the globe, capable of producing the raw material for nuclear devices. And the instructions for building explosive devices from such materials have been widely published, suggesting that access to the ingredients would make a bomb a realistic possibility.

“It should not be assumed,” write physicists Richard Garwin and Georges Charpak, “that terrorists or other groups wishing to make nuclear weapons cannot read.”

Consequently, the main obstacle to a terrorist planning a nuclear nightmare would be acquiring fissile material — plutonium or highly enriched uranium capable of rapid nuclear fission. Nearly 2 million kilograms of each have already been produced and exist in the world today. It takes less than ten kilograms of plutonium, or a few tens of kilograms of highly enriched uranium, to build a bomb.

Fission, or the splitting of an atom’s nucleus, was discovered originally in uranium. For a bomb, you need a highly enriched mass of uranium typically consisting of 90 percent uranium-235, a form found at levels of less than 1 percent in uranium ore. Fuel for nuclear power reactors is only enriched 3 percent to 5 percent with respect to this trace form of uranium, and so is no good for explosions. Highly enriched bomb-grade uranium is, however, produced for some reactors (such as those used to power nuclear submarines and for some research reactors) and might be diverted to terrorists.

Besides uranium, another serious concern is the synthetic radioactive element plutonium. Produced by the nuclear “burning” of uranium in reactors, plutonium is a radioactive hazard in itself and also an ideal fuel for nuclear explosives. Worldwide, more than 1,000 reactors operate nowadays, some producing electric power, others mostly used for research. Plutonium produced in either reactor type could be extracted for use in weapons.

Nuclear security therefore represents one of the most urgent policy issues of the 21st century. In addition to its political and institutional aspects, it poses acute technical issues as well. In short, engineering shares the formidable challenges of finding all the dangerous nuclear material in the world, keeping track of it, securing it, and detecting its diversion or transport for terrorist use. (Click here to read entire N.A.E. Grand Challenge.)
Sample Journey Seminar field of inquiry inspired by this challenge: improvements to homeland security in New York City since 11 September 2001.

Examples of relevant questions:

- Who is in charge of homeland security in New York City?
- What weapons protect the city?
- Why haven’t there been more attacks on New York after continuous war since 9/11/2001?
- How significant is the security risk to Columbia undergraduates relative to other threats.

Possible project topics:

- Could a 9/11-style attack happen again.
- How well has outsourcing worked.
- What role do animals play in New York City’s security.
- Are candy bars a greater threat than terrorists to the well-being of New Yorkers.

Potential target neighborhoods:

- Wall Street: the keep of New York’s castle.
- Morningside Heights/West Harlem: security on the east and west sides of Morningside Park.
- Cadman Plaza, Brooklyn: home of the city’s Office of Emergency Management

Columbia University resources:

- Computers: Network Security Lab at Columbia University’s Computer Science Department. “Dedicated to performing cutting-edge research in critical areas of network and systems security. This research includes new methods for efficient encryption, system and network reliability, autonomic security, reactive security systems, automated patching, host-based intrusion prevention, applications of peer-to-peer networks, security and availability policy, and network intrusion detection and anomaly analysis.”

- School of International and Public Affairs: Faculty with expertise in security studies include: Austin Long, Harpreet Mahajan, Michael Doyle, Richard K. Betts See “Columbia University Experts on Terrorism Available for Media Interviews.”

- University: Department of Public Safety. “The Mission of the Columbia University Department of Public Safety is to enhance the quality of life for the entire Columbia community by maintaining a secure and open environment where the safety of all is balanced with the rights of the individual. The Department strives to accomplish its mission while adhering to its core values of Pride, Professionalism, and Service.”
Background materials:

- **New York City Office of Emergency Management**. “Established in 1996, the New York City Office of Emergency Management (OEM) plans and prepares for emergencies, educates the public about preparedness, coordinates emergency response and recovery, and collects and disseminates emergency information.”

- **Department of Homeland Security: Counterterrorism**. “Protecting the American people from terrorist threats is the founding purpose of the Department and our highest priority. The Department’s efforts to battle terrorism, include detecting explosives in public spaces and transportation networks, helping protect critical infrastructure and cyber networks from attack, detecting agents of biological warfare, and building information-sharing partnerships with state and local law enforcement that can enable law enforcement to mitigate threats.”


- **International Counter-Terrorism Officers Association**. “A Non-Profit association founded by members of the New York City Police Department. The ICTOA is comprised of law enforcement personnel, firefighters, military, first responders, private/corporate security, and other related professionals.”
SECURE CYBERSPACE

Summary from N.A.E. Grand Challenge for Engineering:

Personal privacy and national security in the 21st century both depend on protecting a set of systems that didn’t even exist until late in the 20th — the electronic web of information-sharing known as cyberspace. Electronic computing and communication pose some of the most complex challenges engineering has ever faced. Networks of electronic information flow are now embedded in nearly every aspect of modern life. From controlling traffic lights to routing airplanes, computer systems govern virtually every form of transportation. Radio and TV signals, cell phones, and (obviously) e-mail all provide vivid examples of how communication depends on computers — not only in daily life, but also for military, financial, and emergency services. Utility systems providing electricity, gas, and water can be crippled by cyberspace disruptions. Attacks on any of these networks would potentially have disastrous consequences for individuals and for society. In fact, serious breaches of cybersecurity in financial and military computer systems have already occurred. Identity theft is a burgeoning problem. Viruses and other cyber-attacks plague computers small and large and disrupt commerce and communication on the Internet.

The problems are currently more obvious than the potential solutions. It is clear that engineering needs to develop innovations for addressing a long list of cybersecurity priorities. For one, better approaches are needed to authenticate hardware, software, and data in computer systems and to verify user identities. Biometric technologies, such as fingerprint readers, may be one step in that direction. A critical challenge is engineering more secure software. One way to do this may be through better programming languages that have security protection built into the ways programs are written. And technology is needed that would be able to detect vulnerable features before software is installed, rather than waiting for an attack after it is put into use. Another challenge is providing better security for data flowing over various routes on the Internet so that the information cannot be diverted, monitored, or altered. Current protocols for directing data traffic on the Internet can be exploited to make messages appear to come from someplace other than their true origin.

More research is needed on how people interact with their computers, with the Internet, and with the information culture in general. Cultural and social influences can affect how people use computers and electronic information in ways that increase the risk of cybersecurity breaches. Laws and regulations concerning cybersecurity need to be evaluated for their influence on how people use or misuse electronic information. And perhaps most important, political forces need to be marshaled to support and fund the many lines of research that will be needed to accomplish the complex task of protecting cyberspace from attack.

(Click here to read entire N.A.E. Grand Challenge.)
Examples of relevant questions:

- What is the role of hackers in testing the limits of cybersecurity?
- How can the cybersecurity needs of individuals, businesses and public institutions be balanced with the economic, political, and creative value of preserving cyberspace as a free and open domain?
- What specific cybersecurity threats are faced by users of social media sites?
- What is “jailbreaking” and how will federal protection of this practice reconfigure both the creative potential and the security issues associated with iphone use?
- How can copyright infringements be tracked?
- Is online communication more or less private than the ordinary world?
- Is online culture fundamentally opposed to the 500-year old nation-state paradigm?
- Has anyone ever actually been hurt by cyberterrorism? Is it even a genuine threat, or just a way to justify law enforcement budgets.

Columbia University Resources

- Department of Computer Science, Columbia University
- Columbia University Information Technology (CUIT)
- Professor Steven M. Bellovin, a member of the Committee On Improving Cybersecurity Research In The United States, whose findings are published in: Seymour E. Goodman and Herbert S. Lin, editors. Toward a Safer and More Secure Cyberspace. National Academy Press, 2007.

Background Information

- The Department of Homeland Security’s National Strategy to Secure Cyberspace, “The purpose of this document is to engage and empower Americans to secure the portions of cyberspace that they own, operate, control, or with which they interact. Securing cyberspace is a difficult strategic challenge that requires coordinated and focused effort from our entire society—the federal government, state and local governments, the private sector, and the American people.”
- New York State Office of Cyber Security
- WIRED: Threat Level – Privacy, Crime and Security Online, A blog from Wired magazine that tracks cybersecurity issues, politics, court cases and technical innovations.
- DEF CON: The Hacker Community’s Foremost Social Network, includes updates on conferences, resources, news, and community organizing forum.
To most people, virtual reality consists mainly of clever illusions for enhancing computer video games or thickening the plot of science fiction films. Depictions of virtual reality in Hollywood movies range from the crude video-viewing contraption of 1983's "Brainstorm" to the entire virtual universe known as "The Matrix."

But within many specialized fields, from psychiatry to education, virtual reality is becoming a powerful new tool for training practitioners and treating patients, in addition to its growing use in various forms of entertainment. Virtual reality is already being used in industrial design, for example. Engineers are creating entire cars and airplanes "virtually" in order to test design principles, ergonomics, safety schemes, access for maintenance, and more.

Basically, virtual reality is simply an illusory environment, engineered to give users the impression of being somewhere other than where they are. As you sit safely in your home, virtual reality can transport you to a football game, a rock concert, a submarine exploring the depths of the ocean, or a space station orbiting Jupiter. It allows the user to ride a camel around the Great Pyramids, fly jets, or perform brain surgery.

True virtual reality does more than merely depict scenes of such activities — it creates an illusion of actually being there. Piloting a Boeing 777 with a laptop flight simulator, after all, does not really convey a sense of zooming across the continent 5 miles above the surface of a planet. Virtual reality, though, attempts to re-create the actual experience, combining vision, sound, touch, and feelings of motion engineered to give the brain a realistic set of sensations.

And it works. Studies show that people immersed in a virtual reality scene at the edge of a cliff, for instance, respond realistically — the heart rate rises and the brain resists commands to step over the edge. There are significant social applications as well. It has been shown that people also respond realistically in interactions with life-sized virtual characters, for example exhibiting anxiety when asked to cause pain to a virtual character, even though the user knows it's not a real person and such anxiety makes no rational sense. It is clearly possible to trick the brain into reacting as though an illusory environment were real.

(Click here to read entire N.A.E. Grand Challenge.)
Sample Journey Seminar field of inquiry: improving access of NYC public school students to educational virtual reality games.

Examples of relevant questions:

- What virtual reality applications are designed for use in educational settings?
- How have educators reacted to the integration of virtual reality technology in the classroom?
- What is the impact of virtual reality use on the developing brains of children?
- Are there examples of virtual reality applications that enable children with particular challenges (cognitive, physical, emotional) to learn more effectively?
- How are games currently integrated into elementary, middle and high school curriculums of the NYC public school system?

Potential project topics:

- Needs assessment/survey of virtual reality technology desirability among school administrators.
- Proposal for training educators to use virtual reality technology in their classrooms.
- Identification of a curriculum area that would benefit substantially from the integration of virtual reality in the classroom.

Potential target neighborhoods/communities:

- Educators and/or students at NYC public schools in Morningside/Harlem area.
- Graduate students at Teachers College.
- A virtual community of students.

Columbia University resources:

- Center for Technology and School Change, Teachers College. “CTSC is committed to using technology as a catalyst to transform teaching and learning in ways that are consistent with larger school improvement themes. The Center contributes to a growing professional knowledge base in technology use through research and evaluation activities.” [CTSC website]
- Harlem Schools Partnership for STEM (Science, Technology, Engineering and Mathematics) Education: a collaborative effort of Teachers College, and the Fu Foundation School of Engineering and Applied Science (SEAS) in association with the New York City Department of Education (NYC DOE) and with support from the General Electric Foundation.[Project website]
Institute for Learning Technologies, Teachers College. “As organizations struggle to find the most powerful uses for new technologies in education, there is a pressing need for research that can guide effective program design and project implementation. ILT’s Research and Evaluation team supports and extends the institute’s mission of developing, testing, and implementing new pedagogical approaches to transforming education in both K-12 and higher education, and in both site-based and online environments.” [ILT website]

Visual Media Center (VMC), Department of Art History and Archaeology. “The VMC explores design and pedagogy in the broadest sense to connect faculty research and student learning through the creative application of technology. Our goal is to examine and extend the ways of interpreting images, objects, buildings, and sites and to reinforce Columbia’s historic strengths in core education for undergraduate students, graduate student training, and faculty research. Our specialized facilities and personnel serve the closely related fields of Art History, Archaeology, Architecture and Historic Preservation, but we invite all Columbia University faculty interested in new media and visual culture to visit us with their ideas.” [VMC website]

Games Research Lab, Teachers College. “Through an understanding of play, the Games Research Lab seeks to gain knowledge of human cognition, collaboration, media effects, modern culture, creativity, improvisation and other factors within games that have implications for education. Faculty and students involved with the Games Research Lab have broad-ranging interests, and the lab has resources allowing the study of video games, traditional board and card games, role-playing games, games for teaching and learning, “serious” games, media literacy, the psychology of games, and related topics.” [Dept. of Mathematics, Science and Technology website]

Background materials:

Q2L: Quest to Learn, a New York City Public School located in Manhattan. “Designed to support the digital lives of young people and their capacity for learning, Quest to Learn is a school committed to graduating strong, engaged, literate citizens of a globally networked world. Through an innovative pedagogy that immerses students in differentiated, challenge-based contexts, the school acknowledges design, collaboration, and systems thinking as key literacies of the 21st century.” [Q2L website]


Johns Hopkins University Center for Technology in Education (Partnership of the Maryland State Department of Education). “The Center for Technology in Education strives to improve the quality of life of children and youth, particularly those with special needs, through teaching, research, and leadership in the use of technology. We conduct research to contribute to the field in our areas of specialty and to address issues that are crucial to our mission: equal access to the general education curriculum for all students, evidence-based instructional strategies that transform instruction, online learning and communities of practice, leadership that utilizes data to make sound instructional decisions, and application of new technologies in education.”
• Get a Life: Students Collaborate in Simulated Roles: Virtual reality provides a shared online universe in which students can play to learn. www.edutopia.org. 3/4/2008.

• Institute of Play. “Institute of Play promotes gaming literacy: the play, analysis, and creation of games, as a foundation for learning, innovation, and change in the 21st century. Through a variety of programs centered on game design, the Institute engages audiences of all ages, exploring new ways to think, act, and speak through gaming in a social world.”
Summary from N.A.E. Grand Challenge for Engineering:

For years, researchers have debated whether phonics or whole-word recognition is the best way to teach children how to read. Various experts can be found who will advocate one approach or the other.

Ask an astute first-grade teacher, though, and the answer is likely to be that it depends on the kid. Some pupils respond more favorably to the whole-word approach; others learn faster with phonics. Young brains (and older brains, for that matter) are not all alike. Learning is personal.

Throughout the educational system, teaching has traditionally followed a one-size-fits-all approach to learning, with a single set of instructions provided identically to everybody in a given class, regardless of differences in aptitude or interest. Similar inflexibility has persisted in adult education programs that ignore differences in age, cultural background, occupation, and level of motivation.

In recent years, a growing appreciation of individual preferences and aptitudes has led toward more “personalized learning,” in which instruction is tailored to a student’s individual needs. Personal learning approaches range from modules that students can master at their own pace to computer programs designed to match the way it presents content with a learner’s personality.

Why is personalized learning useful?

Some learners are highly self-motivated and self-driven, learning best by exploring a realm of knowledge on their own or at least with very little guidance. Other learners prefer some coaching and a more structured approach; they are typically self-motivated when the subject matter appeals to their interests. Still another type is more often motivated by external rewards and may learn best with step-by-step instruction. Some may resist learning altogether and have little motivation or interest in achieving goals established by others.

These general categorizations provide a base for developing personalized instruction, but truly personalized learning could be even more subtly individualized. Within the basic types of learners, some prefer to learn by example, others by finding answers to questions, and others by solving problems on their own. Under different conditions, people might even switch their preferences, preferring examples in some contexts but questions in others.

Not surprisingly, many efforts to take this into account make use of computerized instruction, often in the classroom or via the Internet. Among the many projects attempting to meet the personalized education challenge are “intelligent” Web-based education systems, development of “recommender” systems that guide individual learning using Web-based resources, and creation of algorithms that adjust recommendations to the abilities of the student.

(Click here to read entire N.A.E. Grand Challenge.)
Sample Journey Seminar field of inquiry: Improve personalized learning in public schools in NYC.

Examples of relevant questions:

- Do Morningside Heights/Harlem public elementary schools meet the New York State performance standards for reading?
- What are the main obstacles to literacy in NYC public schools?
- What are the studied effects of poor literacy i) on individuals; ii) on communities?

Potential project topics:

- Basic feasibility study of instituting advanced personalized learning systems in a typical NYC public school.
- Comparative study of technology and human centered solutions to literacy problems.
- Analyze the effectiveness of current personalized learning technologies.
- How do the use of portable electronic devices effect the literacy i) of young children; ii) of teenagers?

Potential target neighborhood/communities:

- Morningside Heights: public, private and charter schools.
- Washington Heights
- East Harlem

Columbia University resources:

Center for Computational Learning Systems: http://ccls.columbia.edu/about-us/mission. “CCLS was created as a Center where research scientists can apply their computational disciplines and resources of a great University to real-world challenges – and, in the process, develop new, efficient algorithms and innovative problem formulations that will also support and advance the University’s own research and teaching departments.”

- Jennifer Manly Associate Professor of Neuropsychology (in Neurology, the Sergievsky Center and the Taub Institute): http://www.cumc.columbia.edu/dept/sergievsky/cnd/manly.html. Works on the relationship between, among other things, literacy and memory.
- Literacy Specialist at Teachers College: http://www.tc.edu/c%26t/Literacy/ . “This program is designed to immerse the literacy educator in an intense study of practice, theory, and research. The eventual goal is to prepare each participant to assume a leadership role in literacy education.”
• The Teachers College Reading and Writing Project: http://rwproject.tc.columbia.edu/, “The Teachers College Reading and Writing Project is a research and staff development organization housed at Teachers College, Columbia University. The teacher-educators who staff the Project are involved in long-lasting collaborations with teachers across the world. The Project has a lasting and deep affiliation with our 600 schools, and develops ideas that are foundational to literacy instruction across the globe.”

• EdLab at Teachers College, Columbia University: http://edlab.tc.columbia.edu/index.php?q=node/411 EdLab is a research, design, and development unit at Teachers College, Columbia University. EdLab envisions and pilots knowledge projects for a fundamentally different education sector that is attuned to the emerging post-industrial world. EdLab engages in work that has the potential to contribute to the improvement of educational institutions today and the broader evolution and reconfiguration of future educational services.


Background materials:


• New York city performance standards: http://schools.nyc.gov/offices/teachlearn/documents/standards/ELA/index.html. “This volume contains the first New York City edition of the New Standards TM Performance Standards for English Language Arts. The standards set out in this volume establish the same high expectations for student performance as those published by New Standards—the standards are unchanged from those published by New Standards. What distinguishes this edition is the collection of student work samples included to illustrate the meaning of standard-setting work. The collection has been revised extensively to reflect work produced by students studying in New York City’s public schools.”


MAKE SOLAR ENERGY ECONOMICAL

Summary from N.A.E. Grand Challenge for Engineering:

As a source of energy, nothing matches the sun. It out-powers anything that human technology could ever produce. Only a small fraction of the sun’s power output strikes the Earth, but even that provides 10,000 times as much as all the commercial energy that humans use on the planet.

Already, the sun’s contribution to human energy needs is substantial — worldwide, solar electricity generation is a growing, multibillion dollar industry. But solar’s share of the total energy market remains rather small, well below 1 percent of total energy consumption, compared with roughly 85 percent from oil, natural gas, and coal.

Those fossil fuels cannot remain the dominant sources of energy forever. Whatever the precise timetable for their depletion, oil and gas supplies will not keep up with growing energy demands. Coal is available in abundance, but its use exacerbates air and water pollution problems, and coal contributes even more substantially than the other fossil fuels to the buildup of carbon dioxide in the atmosphere.

For a long-term, sustainable energy source, solar power offers an attractive alternative. Its availability far exceeds any conceivable future energy demands. It is environmentally clean, and its energy is transmitted from the sun to the Earth free of charge. But exploiting the sun’s power is not without challenges. Overcoming the barriers to widespread solar power generation will require engineering innovations in several arenas — for capturing the sun’s energy, converting it to useful forms, and storing it for use when the sun itself is obscured.

Many of the technologies to address these issues are already in hand. Dishes can concentrate the sun’s rays to heat fluids that drive engines and produce power, a possible approach to solar electricity generation. Another popular avenue is direct production of electric current from captured sunlight, which has long been possible with solar photovoltaic cells.

(Click here to read entire N.A.E. Grand Challenge.)
Sample Journey Seminar field of inquiry: facilitating access to solar energy technology for New York City Housing Authority (NYCHA) residents

**Examples of relevant questions:**

- Does the NYC Housing Authority have any regulations pertaining to the use of alternative energy sources?
- Which household appliances (e.g. stove, washer, television) can be powered by solar energy? Which cannot?
- Would a change to solar power incur any costs to individual families?
- What skills/training is needed to install solar energy technology?

**Potential project topics:**

- Basic feasibility study of installing solar technology on an average-size NYCHA building.
- Development of a manual for NYCHA residents about how to acquire solar technology.
- Proposal for a small business plan: training of NYCHA residents as educators and installers of solar technology.

**Potential target neighborhood/communities:**

- Ulysses S. Grant Building, 3170 Broadway
- Frederick Douglass 1 Buildings, 825 Columbus Avenue
- A community center that services youth residing in NYCHA buildings.

**Columbia University resources:**

- Lenfest Center for Sustainable Energy. The mission of LCSE is to develop innovative technologies to ensure a sufficient supply of environmentally sustainable energy for all humanity. To meet this goal, LCSE supports research programs in energy science, engineering and policy across Columbia University to develop technical and policy solutions that will satisfy the world’s future energy needs without threatening to destabilize the world’s natural systems. LCSE focuses primarily on the three energy sources sufficient to support the world’s projected population in 2100 without increased carbon emissions: solar energy, nuclear power, and fossil fuels used in combination with carbon capture and storage.
- Center for Life Cycle Analysis. “The Center for Life Cycle Analysis (LCA) of Columbia University was formed in the spring of 2006 with the objective of conducting comprehensive LCAs of energy systems. LCA provides a framework for quantifying the potential environmental impacts of material and energy inputs and outputs of a process or product from "cradle to grave". The mission of the Center is to guide technology and energy
policy decisions with data-based, well balanced and transparent descriptions of the environmental profiles of energy systems.” [CLCA website]


- **Bridging Gaps: Energy Efficiency Research in New York City Area Engineering and Technology Schools**, SIPA, May 2010

- **H.R. 1945: Energy for our Future Act: “To improve energy efficiency in the United States”**, Columbia University, School of International and Public Affairs (SIPA), Program in Environmental Science and Policy, Summer 2007,


- **“Rob’s Solar Energy Page”**, An invaluable list of information sources from Robert Cartolano, Director, Libraries Information Technology Office,

**Background materials:**

- Pratt Center for Community Development. The Pratt Center works for a more just, equitable, and sustainable city for all New Yorkers through work in public policy, community planning, building and advocating for infrastructure and teaching citizens and professionals the skills to improve New York’s neighborhoods. [Pratt Center website] A webpage provides information on how to finance a solar electric system.


- US Dept. of Energy: Energy Efficiency and Renewable Energy. Webpage on Solar American Cities/New York, NY provides example on current use of solar energy in NYC and future solar expansion projects. “The City of New York hopes to foster a solar-electric market that will be a competitive and economically sustainable industry while providing the City with clean, reliable, affordable electricity. It will do so using a three-part strategy that will: 1) Lay the foundation to support a growing industry by reducing barriers and educating the labor pool; 2) Use the City’s resources to spur the market and create economies of scale to lower prices; 3) Create the institutions to plan and monitor future growth.” [Solar American Cities website]

- New York City Housing Authority.

- New York City Solar Summit 2010. The City University of New York, through Sustainable CUNY, annually convenes the New York City Solar Summit. During the day long event, on June 8, 2010, the NYC Smart Solar City plan was rolled out along with preview screenshots of a NYC ‘Solar Map’. The Summit also presented details on the NYC Smart Grid, solar policies and incentives and the latest in supporting technologies and battery storage and
announced the creation of three ‘Solar Empowerment Zones’. The initial Zones: ‘Staten Island East, ‘Downtown Brooklyn’ and ‘Greenpoint-Gateway’.


- European Photovoltaic Industry Association. With more than 200 Member companies drawn from across the entire solar electricity sector, the European Photovoltaic Industry Association (EPIA) is the world’s largest photovoltaic industry association and represents about 95% of the European photovoltaic industry and 80% of the worldwide photovoltaic industry

- Solar Energy International. “Founded in 1991 as a nonprofit educational organization to help others to use renewable energy resources and sustainable building technologies through education and technical assistance.”

- U.S. Department of Energy Solar Energy Technologies Program: The Solar Energy Technologies Program leads the U.S. effort to research, develop, and deploy cost-effective technologies toward growing the use of solar energy.

- Science. “Special Section: Scaling Up Alternative Energy.” “Science explores worldwide efforts to develop clean, renewable alternatives to fossil fuels. News stories highlight some of the challenges associated with making this energy transition, Perspectives take an in-depth look at how researchers hope to scale up biofuels development, and a Review discusses a two-stage approach for expanding nuclear power generation.” 13 August 2010: ScienceMag.org.
ENGINEER THE TOOLS OF SCIENTIFIC DISCOVERY

Summary from N.A.E. Grand Challenge for Engineering:

In the popular mind, scientists and engineers have distinct job descriptions. Scientists explore, experiment, and discover; engineers create, design, and build.

But in truth, the distinction is blurry, and engineers participate in the scientific process of discovery in many ways. Grand experiments and missions of exploration always need engineering expertise to design the tools, instruments, and systems that make it possible to acquire new knowledge about the physical and biological worlds.

In the century ahead, engineers will continue to be partners with scientists in the great quest for understanding many unanswered questions of nature.

Biologists are always seeking, for instance, better tools for imaging the body and the brain. Many mysteries also remain in the catalog of human genes involving exactly how genes work in processes of activation and inhibition. Scientists still have much to learn about the relationship of genes and disease, as well as the possible role of large sections of our DNA that seem to be junk with no function, leftover from evolution.

To explore such realms, biologists will depend on engineering help — perhaps in the form of new kinds of microscopes, or new biochemical methods of probing the body's cellular and molecular machinations. New mathematical and computing methods, incorporated into the emerging discipline of “systems biology,” may show the way to better treatments of disease and better understanding of healthy life. Perhaps even more intriguing, the bioengineering discipline known as “synthetic biology” may enable the design of entirely novel biological chemicals and systems that could prove useful in applications ranging from fuels to medicines to environmental cleanup and more.

Turning to the mysteries of our own minds, new methods for studying the brain should assist the study of memory, learning, emotions, and thought. In the process, mental disorders may be conquered and learning and thinking skills enhanced. Ultimately, such advances may lead to a credible answer to the deepest of human mysteries, the question of the origin and nature of consciousness itself.

(Click here to read entire N.A.E. Grand Challenge.)
Sample Journey Seminar field of inquiry: Lay out a research program for pressing environmental problems in the NYC area.

Examples of relevant questions:

- What is a scientific discovery?
- How is a discovery different from an invention?
- How do science and engineering contribute to the discovery process?
- What motivates scientific discovery?
- How do practical needs, eternal questions, monetary incentives and other factors promote research in some areas and inhibit the production of knowledge in others?
- Which questions should be prioritized in scientific and engineering research and why?
- How do new technologies, for example, techniques of visualization, data analysis, and new materials, generate new questions and avenues of enquiry?
- What conditions, technical, social, economic, are conducive to innovative scientific research?

Potential project topics:

- Air pollution in NYC.
- Food waste in NYC.
- Water supply in NYC.
- The heating and cooling of NYC buildings
- Offseting the carbon footprint of the metropolis

Potential target neighborhoods:

- West Side Highway.
- Columbia University buildings.
- Hudson / East River waterfront.
- NYC markets and supermarkets.

Columbia University resources:

- The Earth Institute, Columbia University: http://www.earthinstitute.columbia.edu/sections/view/9
• Professor Phillip Kitcher, Department of Philosophy: http://www.columbia.edu/cu/philosophy/fac-bios/kitcher_philip/faculty.html

• Department of Earth and Environmental Engineering. “Strives to develop effective solutions to complex and multidisciplinary environmental problems, reconciling a deep concern for the environment with the needs of our global industrialized society. Our central theme is the conscientious stewardship of our finite natural resources, namely minerals, fuels, energy, water, and land.” [EEE website]


Background materials:


• Helen Longino, “Reply to Phillip Kitcher, Philosophy of Science 69(4), 2002, 573-577.


• Science. “Special Section: Scaling Up Alternative Energy.” “Science explores worldwide efforts to develop clean, renewable alternatives to fossil fuels. News stories highlight some of the challenges associated with making this energy transition, Perspectives take an in-depth look at how researchers hope to scale up biofuels development, and a Review discusses a two-stage approach for expanding nuclear power generation.” 13 August 2010: ScienceMag.org.