Teacher's Preparatory Guide

Diagnostics for All (DFA)
Teaching relevance of science and engineering to solving societal problems

Overview This activity explores the societal impacts of engineering and science, specifically as it relates to the AIDS epidemic in developing countries. A series of videos and accompanying questions help students explore how engineers and scientists can contribute to various solutions related to diagnosing and preventing the spread of disease. The activity highlights the development of low-cost paper diagnostics for rapid and private diagnosis of AIDS and diseases related to AIDS (TB, other sexually transmitted diseases, etc.).

Purpose This activity is designed to help students understand the history of the disease, current efforts in educating the public, and the research and technology leading the way. It will motivate students to consider science and engineering as careers that help people, and show that science is a collaborative effort in the solution of problems. The module also addresses key points of the engineering design process, including awareness of patient needs and cultural and environmental constraints that feed in to the design process.

Time required: 2-3 class periods (25 minutes for 1st video, plus time for discussion, 17 minutes for 2nd video, plus time for discussion).

Level: Middle school or High school

Connection to Nanotechnology:
The activity highlights the development of paper diagnostics which are diagnostic tools that are inexpensive to make and simple to use. These devices are based on the widely expanding field of microfluidics which are micro or nano-electromechanical systems (MEMS/NEMS). Microfluidic devices move fluid through channels and include ink jet printer heads, needles, and Lab-on-a-chip. These devices are created using millimeter and nanometer components and are an important component of many nanotechnology and biotechnology research facilities.

Microfluidic devices move fluids by means of tiny pumps and other mechanisms to process the test material and chemicals. They can cost several hundred dollars. Paper diagnostic devices do not require the pumps but instead use the flow properties of paper to move the materials to be analyzed. These devices are expected to cost only a few cents to mass produce.

Paper diagnostics combine the advanced technology of microfluidics with something as basic as paper. This makes for inexpensive diagnostic tools that can be easily used and interpreted. They have the potential to help with diagnosis of diseases in poor nations. Paper diagnostics consist of small pieces of paper, usually about the size of a postage stamp. They require very small samples for testing – mililiter or nanoliter in size. The most familiar and commonly used version is the pregnancy test. However, researchers are moving beyond this and creating devices that can test for specific diseases or presence of drugs.

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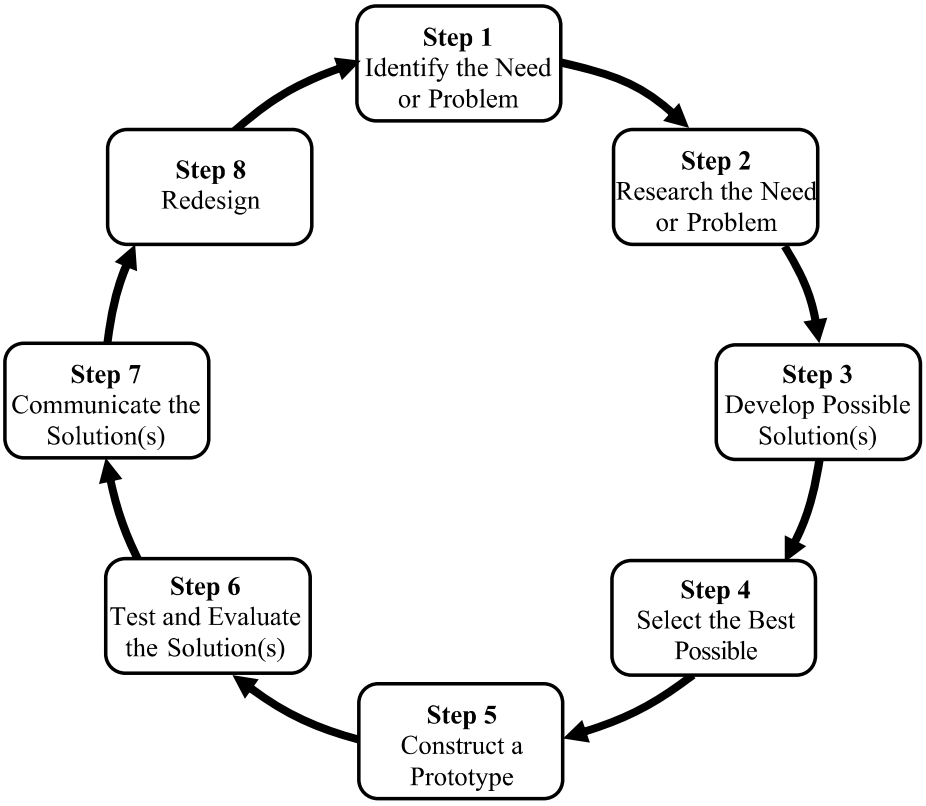
Steps in the Engineering Design Process



Steps in the Engineering Design Process

1. Identify the need or problem
2. Research the need or problem
   - Examine the current state of the issue and current solutions
   - Explore other options via the Internet, library, interviews, etc.
3. Develop possible solution(s)
   - Brainstorm possible solution(s)
   - Draw on mathematics and science
   - Articulate the possible solution(s) in two and three dimensions
   - Refine the possible solution(s)
4. Select the best possible solution(s)
   - Determine which solution(s) best meet(s) the original need or solve(s) the original problem
5. Construct a prototype
   - Model the selected solution(s) in two and three dimensions
6. Test and evaluate the solution(s)
   - Does it work?
   - Does it meet the original design constraints?
7. Communicate the solution(s)

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- Make an engineering presentation that includes a discussion of how the solution(s) best meet(s) the initial need or the problem
- Discuss societal impact and tradeoffs of the solution(s)

8. Redesign
   - Overhaul the solution(s) based on information gathered during the tests and presentation

Materials:

This module uses a series of videos and inquiry-based questions to spur guided discussion about engineering design.

- Zinhle Thabethe POPtech video (24 minutes) www.poptech.org/popcasts/zinhle_thabethe__poptech_2006
- George Whitesides TED video (17 minutes) www.ted.com/talks/lang/eng/george_whitesides_a_lab_the_size_of_a_postage_stamp.html
- Computer with internet access (or request CD), Quicktime, Keynote or Powerpoint
- Projector

Safety Information: None

Advance Preparation: Secure a computer lab, mobile lab and overhead projector.

Teacher Background: Awareness of engineering design process, be familiar with the basic concepts of low-cost diagnostics, be familiar with concepts of science and engineering concepts used to solve societal problems. Basic knowledge of the use of Quicktime, PowerPoint, and basic video editing tools.

Teaching Strategies: This activity has three distinct parts: videos, discussion, and the creation of a Public Service Announcement about AIDS.

Video strategies: Play the videos for the whole class, and pause occasionally to clarify new terminology or confusing concepts. See the "Guided Dialog" below for definitions of terms used in some of the videos that may be new to students.

Discussion Strategies: There are multiple ways to effectively facilitate discussion about the two videos. The Pop!Tech video is less technical than the Whitesides video, so a whole group discussion may be helpful for the Whitesides video to guide students in understanding the technical content. As there are two videos, you may choose to facilitate the discussion a different way for each video, or use the method of discourse that is familiar to your students.

Possibilities include:
Think-Pair-Share: Pose one of the discussion questions about the video to the students, give them a few minutes to write down a response, and have them share their response with a partner. Then have pairs share out their ideas to the class.
Whole Group Discussion: Pose a question to the entire group and allow students to agree or disagree with each other's responses. For questions with many answers, two students may be chosen to act as "Recorders" and put student responses on the board to be considered.

Small Group Discussion: Small groups may be posed the same or different questions, and have the big ideas from their discussion shared with the whole class, either verbally or on a transparency or poster.
Public Service Announcement Strategies: This would be easiest to do in small groups. In a small class or as a longer-term project, the whole class may do it together. This may be done in a low-tech or high-tech way, depending on the resources and desires of the school. The public service announcement can be a written task, with optional paper illustrations to set the scenes, or it can be scripted and recorded using video cameras or the cameras included on many laptops or desktop computers.

Resources: You may wish to use these resources either as background or as a resource for students to use in their inquiry-based design. There are many other resources on the web that can be found using various search engines. These are but a few:

- Paper Diagnostics http://www.technologyreview.com/biomedicine/22113/
- Paper Diagnostics http://inhabitat.com/stamp-sized-paper-chip-diagnoses-diseases-for-just-a-penny/paper-diagnostic-chip/
- Global Infectious Disease Surveillance and Detection: Assessing the Challenge http://pubs.acs.org/cen/science/87/8711sci1.html
- The Whitesides Group http://gmwgroup.harvard.edu/
- Lab-on-a-chip devices for global health: past studies and future opportunities (C. Chin, V. Linder, and S. Sia) http://www.ncbi.nlm.nih.gov/pubmed/17180204 (free article)
- Point of Care Diagnostics Idea Lab UC Berkeley http://idealabs.berkeley.edu/pocdx (with videos, links, and other resources
- Develop an Inexpensive (and Cost-Effective) Diagnostic Test (free article Keck Future Institute) http://www.keckfutures.org/conferences/genomics/pdf/NAKFI_Gen_3_summary_online.pdf
- Inexpensive Diagnostics http://www.robaid.com/tech/cheap-and-disposable-paper-strips-could-be-used-for-chemical-analysis.htm
- Video on paper diagnostics http://www.google.com/url?sa=t&source=video&cd=1&ved=0CDUQtwIwAA&url=http%3A%2F%2Fwww.youtube.com%2Fwatch%3Fv%3DndekmIJMFXU&ei=01aoTfjTFcmftgfGrKDeBw&usg=AFQjCNEHaZIH3o20LnP0jpWC5kzsHfJ-Og
- Overview of aids http://www.howstuffworks.com/search.php?terms=HIV+Aids

Instructional Procedure: Brief introduction: This activity explores the societal impacts of engineering and science, specifically as it relates to the AIDS epidemic in developing countries, the key challenges of the epidemic and why these ideas are important today. Students will be asked to create a public service announcement (PSA) to educate their peers about the facts and misconceptions about this disease.

Watch Z. Tabethe video (problem)
Watch George Whitesides video (solution, using engineering to solve a societal dilemma)
Guided brainstorming of what needs to be done. Pick student responses that have potential to be solved with engineering technology.
(George Whitesides video)– follow up with guided questions

Day 1: Warm-up question: [5 minutes writing, 5-10 minutes discussing]
In what ways do science, technology, and engineering help society? What are some problems you know of that science has yet to solve/improve?

Possible student answers include: Improving our lives through computers, medicine, travel, cell phones, Internet, movies. Problems yet to be solved might include cancer, homelessness, poverty, teleportation, time travel – possible answers are endless.

Alternate warm-up questions:

Have you ever known someone affected by a sexually transmitted infection? Are there currently treatments for all STIs? How might getting an STI affect someone's life?
Possible student answers include: Yes or no – students may have known someone with an STI or they might not. Similarly, they may think that all STIs are curable or they will not affect your life. They may think that an STI could make you sterile, kill you, make you an undesirable partner, may make you a bad person or mean you are a promiscuous one.

Pop!Tech Video: [25 minutes]

Post-video discussion: [15 minutes]
Questions for discussion/for a handout after the Pop!Tech video:

- What did Zinhle think of the Boston Globe article in which a US government official said that Africans are unable to keep time in order to take their medications?
- Have you ever seen evidence of the idea "we are not the same" in our community or in what you know of people around the country or world (past or present)? What are some examples you know of other than AIDS in Africa?
- What are the problems with treating AIDS and TB in South Africa?

-End of 1st 50-minute period

Day 2: Warm-up Question: [5 minutes writing, 5-10 minutes discussion]
What are some of the problems with treating AIDS and TB in South Africa?

Lack of funding, trouble with timekeeping, poor infrastructure, ill equipped health care system, poor roads, reliable transportation, lack of education about how to take medications, improper diagnosis, lack of medication, lots of people are sick.

Introduce to students the Whitesides TEDxBoston video to students: [3 minutes]
This video describes one solution to the problem of diagnosing the correct ailment for people in places such as South Africa. Remind students of Zinhle's mother, who was coughing up blood and was sent home with a cold. This video shows one scientific approach to improving the issue of diagnosing what is wrong with a person.

Watch Whitesides Video [17 minutes]

Review Important Terms & Ideas (See Guided Dialog, below) [15 minutes]

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-End of 2nd 50-minute period

Day 3: Warm-up: [5 minutes writing, 5 minutes discussion]
What has been the impact of engineering and science on South Africa with regards to the AIDS epidemic there? What impact would you like to see in the future?

Introduce the activity to students: [5 minutes]
Students will be creating a Public Service Announcement, like those they have likely seen on television, describing to a target audience the challenges facing South Africa and why they relate to an American teen audience. They will then perform this PSA, either on camera or in front of the class.

Activity: [rest of period, 35 minutes]
Students use the Student Guide to help create a script for a PSA.

Day 4: Students complete and present their PSAs, either by recording them on camera or performing them for the class, depending on the resources available and desires of the teacher.

Guided Dialog Before beginning the lab, review the meaning of these terms:

Paper Diagnostics: is a versatile, disposable test that can diagnose a tiny amount of urine or blood for evidence of infectious diseases or chronic conditions, designed to be made of paper.

Microfluidics: is a multidisciplinary field intersecting engineering, physics, micro/nano-technology and biotechnology, with practical applications to the design of systems in which small volumes of fluids will be used (milliliters and nanoliters). Microfluidics emerged in the beginning of the 1980s and is used in the development of inkjet print heads, DNA chips, lab-on-a-chip technology, micro-propulsion, and micro-thermal technologies.

Ethics / Social Responsibility: Strive to promote social good and prevent or mitigate social harms through research, public education, and advocacy.

Antiretroviral Treatment (ARVs): Medications for the treatment of HIV.

Ask students questions to provoke thought and review what they already know:
Ex. What is a lab on a chip? A lab on a chip is a device that integrates one or several laboratory functions on a single chip of only millimeters to a few square centimeters in size.
What is a pandemic? *A pandemic is an epidemic of infectious disease* that is spreading through human populations across a large region; for instance a continent or even worldwide.
Why is ethics important in science and engineering: ethics is important in science and engineering because it strives to promote social good and prevent or mitigate social harms through research, public education, and advocacy.
Capillary action or wicking: The movement of liquids through thin tubes or the flow of liquids through a porous media such as the follow of water through soil.
Math questions
In terms of population size of South Africa or other African countries, how many diagnostic tests would be needed? What would be the cost to mass-produce diagnostic tests? What would be the methods of delivery to a large population? What would this cost?

What percent of Africa's population is affected? What would that look like projected on our town or school?

English/social studies questions

Reflection paper on how you envision your career intersecting with society
History of disease in African and in the US.
How does the stigma of the disease prevent diagnosis and treatment, and contribute to spread of disease?
How does culture contribute to spread of disease?
How do Western beliefs and misconceptions, or unawareness of cultural norms/beliefs hinder effective treatment paradigms?
What role does ethics play in science and engineering?

Chemistry, Physics and Biology

Students could developed chemistry and biology research paper on paper diagnostics.
Students could research antibodies/antigens, biological molecules, etc.
Students could explore photolithography, microfluidics and their application to low-cost diagnostic tools.

Engineering

How do engineers definine/determine customer needs?
Students could research how engineering constraints inform design (low cost, mass production, temperature, easy to read, privacy, stability of reagents, etc.)
How do engineers determine the need to solve a societal problem?

Cleanup: None

National Science Education Standards

Science and Technology [Grades 5-12]

Content Standard E

- (4E) Science and Technology are pursued for different purposes. Scientific inquiry is driven by the desire to understand the natural world, and technological design is driven by the need to meet human needs and solve human problems and fulfill human aspirations.

Science in Personal and Social Perspectives [Grades 5-12]

Content Standard F

- (1F) Science influence society through its knowledge and worldview.
- (2F) Societal challenges often inspire questions for scientific research, and society often influences research priorities through the availability of funding for research.
- (7F) Scientist and engineers cannot answer all questions and technology cannot solve all problems or meet all human problems or meet all human needs.

Science and Technology in Local, National, and Global Challenges

Content Standard F

- (1F) Understanding basic concepts and principles of science and technology should precede active debate about the economics, policies, politics, and ethics of various science- and technology-related challenges.

Massachusetts State Curriculum Frameworks

1. Engineering Design

Central Concepts: Engineering design involves practical problem solving, research, development, and invention/innovation, and requires designing, drawing, building, testing, and redesigning. Students should demonstrate the ability to use the engineering design process to solve a problem or meet a challenge.

1.1 Identify and explain the steps of the engineering design process: identify the problem, research the problem, develop possible solutions, select the best possible solution(s), construct prototypes and/or models, test and evaluate, communicate the solutions, and redesign.

1.2 Understand that the engineering design process is used in the solution of problems and the advancement of society. Identify examples of technologies, objects, and processes that have been modified to advance society, and explain why and how they were modified.

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Student Guide

Public Service Announcement: AIDS in South Africa

Introduction

Together we have explored some of the challenges facing people in South Africa, where 1 in 2 adults is HIV positive. It is your job now to try to educate people about this issue! You'll be doing this by writing a Public Service Announcement, either a TV segment or a radio segment, telling people what YOU think are the most important issues!

Materials

- Paper
- Markers, crayons, or colored pencils
- Access to the videos from previous classes or your notes about those videos
- Optional: a camera or computer

You will join a group of your peers to answer the following two questions:

1. What are the important challenges facing the South Africa continent as it relates to the AIDS epidemic?
2. Why are these challenges relevant to America's youth?

Once you are in your groups, complete the following steps:

1. Discuss and agree on what are the most important ideas conveyed in the videos. Write down the ideas you agree on. :

_____

_____

_____

_____

2. Discuss and agree on why these ideas are important to our lives today. Write down the ideas you agree on.

_____

_____

_____

_____

4. Check your answers for Questions 1 & 2. Are the messages accurate, clear and

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important? If not, edit those questions. These answers will be the message of your PSA.

3. Choose the format for your PSA: 30- second video spot, 30-second radio spot, etc.
Your format: _____ Length of time: _____

4. Write a script for a PSA to educate others on your answers from Questions 1 & 2. You want to explain to a group of your peers who might be watching/listening about the facts and why they're important. Your PSA should:
• Catch your audience's attention.
• Convince your peers that the information presented is important.

Everyone in your group should work together. You should consider the point of view of:

Students: Check for high interest. Is our presentation interesting and creative? Will it catch your peers' attention? Will they remember it?
Scientists: Check for clarity and persuasiveness. Is the meaning clear? Are the facts correct?

5. (Optional) If you have chosen to produce a television segment, use the materials provided to create one or two illustrations of the scenes of the segment. If you have chosen to do a radio commercial, think of any sound effects that would need to be added and how you could create them.

6. Prepare to present your PSA to others. Be prepared to explain how your group decided what the most important ideas of the AIDS epidemic were and why these ideas are important today. Be prepared to answer questions about your decisions.

Assessment
Students can be assessed by evaluating their presentations. This can be done by other students, teachers, or both. The rubric below can be used to evaluate these presentations.

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Rubric for PSA Presentations

Science Accuracy: Did the presentation include correct facts about the issue? ___/10

Persuasiveness: Did the presentation make you believe that the issue is important and related to your life? _____/10

Clarity: Was the meaning and message of the PSA evident? _____/10

Creativity: Was the segment innovative and new? _____/10

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