Lesson Plan Title:

Technological Innovation, Invention and Problem-Solving

Overview:

Students will first browse the historical timeline in the CHM online exhibition, "The Silicon Engine: A Timeline of Semiconductors in Computers," located at http://www.computerhistory.org/semiconductor/timeline.html, to learn about the process and evolution of a series of significant semiconductor-related inventions. Students will be led to realize that innovations and inventions are created when problems or challenges are encountered and solutions have to be found. Needs that aren't being met - that would make life easier or better - inspire creative individuals to tackle problems and find new and unique ways to solve them.

Students will be asked to try and figure out the connections, creative problem-solving steps and inter-related innovations, inventions and developments that occurred from one historical stage to the next, in the development of semiconductors. In other words, how did one person's 'invention' become the stepping stone for the next creative innovation or development?

Finally, they will be asked to think about the 19th-20th century world before the theory, invention and eventual widespread use of semiconductors. They will be asked to think how the development of semiconductors has had a significant impact on the present day world. Students will be asked to briefly think of new technologies and to envision future technologies.

Objective:

To help students think about the creative process of invention, and the individuals who used problem-solving skills to become inventors.

Materials:

- Online exhibit timeline, "The Silicon Engine: A Timeline of Semiconductors in Computers," located at http://www.computerhistory.org/semiconductor/timeline.html
- Also, online exhibit glossary, "The Silicon Engine: A Timeline of Semiconductors in Computers," located at http://www.computerhistory.org/semiconductor/glossary.html, to look at additional vocabulary words, such as crystal, current, electrolyte, rectifier, etc.
- Online Exhibit people, "The Silicon Engine: A Timeline of Semiconductors in Computers," located at http://www.computerhistory.org/semiconductor/people.html , to look at important individuals, including Ferdinand Braun, William Shockley, Alan Wilson, among others
- Web browser
- Index cards, or word-processing computer program

Website References:

Online exhibition: "The Silicon Engine: A Timeline of Semiconductors in Computers". The following list of five milestones from the timeline highlights or summarizes some of the most important developments and processes that led to the widespread use of semiconductors.

- **1874: Semiconductor Point-Contact Rectifier Effect is Discovered**
  In the 1870s, German physicist and inventor Karl Ferdinand Braun was studying the electrical conductivity of metal salts in solution (electrolytes), and the study of mineral-metal sulfide crystalline solids that conducted, even when not dissolved in solution. In 1874, he reported that for many metal sulfides, the electrical resistance varied with the magnitude and polarity of the applied voltage. This was especially true if one of the electrodes was a pointed metal wire. He had discovered that some mineral metal sulfides conduct electricity, or allow current to flow, in one direction only.

  This was the important discovery of the point-contact rectifier effect, although it had no immediate practical application at the time. He found out that conduction and rectification in metal sulfide crystals occurred when the crystal was probed by a metal point. Two years later, he demonstrated this rectification effect of a metal-semiconductor contact to an audience, but his work was not recognized until the advent of radio in the early 1900s when it was used as the basis for the crystal radio receivers.

- **1901: Semiconductor Rectifiers Patented as "Cat's Whisker" Detectors**
  Radio pioneer Jagadis Chandra Bose applied for a patent for the use of a semiconductor crystal rectifier to detect radio waves. He demonstrated the use of galena (lead sulfide) crystals contacted by a metal point (a small wire, often known as a 'cat's whisker') to detect small electromagnetic waves. In 1901 he filed a U.S patent for a point-contact semiconductor crystal rectifier for detecting radio signals, and was awarded the patent in 1904. Presumably, this was the first patent awarded for a semiconductor detector, although it was not recognized as such (the word semi-conductor hadn't been commonly used yet).

- **1931: "The Theory of Electronic Semi-Conductors" is Published**
  "Translated into English as "semiconductor," the German word "halbleiter" was first used in 1911 to describe materials with electrical conductivities between those of metals (conductors) and insulators. But a good explanation of semiconductor behavior eluded scientists for decades…."

  In 1931, Cambridge University physicist Alan Wilson wrote two papers titled "The Theory of Electronic Semi-Conductors", which attempted to explain the distinction between metals, insulators, and semi-conductors. He also tried to describe the mechanism of conduction in semi-conductors. He proposed that their peculiar properties were due to the "presence of impurities" in otherwise pure crystals of these materials. His explanation eventually was proven wrong, although his ideas led to further developments in micro-electronics and the invention of the transistor. Wilson's two papers were pivotal in establishing the existence of semiconductors as a separate, unique class of materials.

- **1947: Invention of the Point-Contact Transistor, the First Type of Solid-State Electronic Transistor Ever Constructed**
  In early 1945, William Shockley organized a solid-state physics research group at Bell Labs to pursue research into solid state replacements for bulky, unreliable and energy-wasteful vacuum tubes used in Bell Telephone Systems phone equipment. A year later, theoretical physicist John Bardeen suggested that electrons on the semiconductor surface might be blocking penetration of electric fields into the material, negating any effects. With experimental physicist Walter Brattain, Bardeen began researching the behavior of these "surface states."

  Their research culminated 18 months later with the invention of the first successful semiconductor amplifier, on December 16, 1947. In part, it consisted of two metal contacts (two strips of gold foil) only a hair's-width apart and a wafer of germanium (a chemical element, a crystalline substance and also a semi-conductor when small amounts of impurities were added) placed on a metal plate. It functioned as an amplifier, because when a bit of current came through one of the gold contacts, another even stronger current came out the other contact.

Named the "transistor" by electrical engineer John Pierce, Bell Labs publicly announced the revolutionary solid-state device at a press conference on July 1, 1948. This was perhaps the most important electronics invention of the 20th century or modern history. It is the key active component in practically all modern electronic devices. Its invention led to the development of the integrated circuit and microprocessor, all of which could be mass produced (or fabricated) using an automated process.

Point-contact transistors were only manufactured for a few years before being superseded in 1954 by the junction transistor, invented by a Texas Instruments employee. Silicon transistors – and the entire semiconductor industry – would soon follow.

- **1953: Transistorized Computers Emerge**
  In 1950, the SEAC (National Bureau of Standards Electronic Automatic Computer) was constructed – the first stored program computer in the US, marking the beginning of high-level computer programming. It was the first computer to use diode logic - more reliable than vacuum tubes. Transistorized computers demonstrated the small size and low-power advantages of semiconductors compared to vacuum tubes.

  During the 1950s, semiconductor devices gradually replaced vacuum tubes in digital computers, and by 1960, new designs were fully transistorized. In 1951, the UNIVAC-1 was released – it was the world's first commercially-available computer, and was first used by the US Census Bureau. In 1953, IBM's first electronic computer was the IBM 701. Bell Laboratories built the first transistorized digital computer, TRADIC, in 1954. The first transistor radio available to US consumers, the Regency TR-1, was available in US stores in October 1954 at a price of $49.95. In 1955, the SAGE (Semi Automatic Ground Environment) computer became operational, the first to be used for military air defense purposes. And in 1956, M.I.T. introduced the TX-0, the first fully programmable, transistorized computer.

  In 1964, IBM introduced the System / 360, one of the first general-purpose mainframe computers to be widely used by corporations.

Teaching Strategy/Procedure:

1. Create five small teams of students. Assign each team to one of the five milestones mentioned above. Have each team of students thoroughly research their important milestone on the timeline and be prepared to discuss with the rest of the class. Students may have to browse the web or do further searches to investigate their timeline item.

2. Discuss with them that they must explore the idea that it takes many people over several decades to find solutions to various challenges. They must think about this question as they perform their research: how did one milestone, development, or 'invention' become the stepping stone for the next creative innovation or development?

3. Students will also be asked to demonstrate how innovations and inventions are usually created when problems or challenges are encountered and solutions have to be found. Also, if appropriate, ask them how previous milestones contributed to the development of the next milestone. Ask them for examples.

4. Ask teams to discuss and brainstorm today's emerging technologies. What technologies do they see as changing the world we live in, as we move forward? What technologies do they envision for the future? Ask students from different groups to share their ideas with the class.

5. After each group has presented, have the students work individually to capture the nature of the discussion in writing. This exercise will allow students to think independently about the information they have heard in their own group and the contributions of others in the class.

6. Refocus the students' attention on the nature of invention, theory, and solutions, and how it takes many people to build on the ideas of each other in order for there to be real progress.

For Further Study:

- Have students research their favorite present-day technological tool: cell phone, iPod, iPhone, etc. What extensions of these technological devices do you think may be developed over the next decade?