THE OHIO STATE UNIVERSITY

The table of indicators

The table of indicators provided below was picked from the full list of Science Academic Content Standards for Ohio as indicators that may be reinforced by the microbial fuel cell science experiment. Discussion and exam questions can be designed specifically for each grade depending on that grade's particular indicators. For example, in the "Discussion" section of this website, we have provided the following class project based on the indicators set for the 9th grade for Science and Technology:

"Some argue that a design should be continually assessed and the ideas of the design should be tested, adapted and redefined. Observe the MFCs in Figure 1 and Figure 2. Figure 1 illustrates the 1st generation of MFC design at OSU and Figure 2 the 2nd generation. Table 1 presents the maximum performance values of each fuel cell design. Why do you think changes were made in the first design? What kind of changes would you make to design the 3rd generation MFC? Draw a model of your proposed design. Build it and test it!"

The following indicators will be addressed by the above project:

- Identify a problem or need, propose designs and choose among alternative solutions for the problem.
- Explain why a design should be continually assessed and the ideas of the design should be tested, adapted and refined.

Visit the Ohio Department of Education Science Academic Content Standards web page

Table of Indicators set by the Ohio Department of Education

Subject	Level	Indicator
Life Sciences		
	Grade 10:	Explain the characteristics of life as indicated by cellular processes including: energy transfers and transformation and transportation of molecules
		Describe how matter cycles and energy flows through different levels of organization in living systems and between living systems and the physical environment.
		Explain how some energy is stored and much is dissipated into the environment as thermal energy (e.g., food webs and energy pyramids).
		Describe how cells and organisms acquire and release energy (photosynthesis, chemosynthesis, cellular respiration and fermentation).
		Explain that living organisms use matter and energy to synthesize a variety of organic molecules (e.g., proteins, carbohydrates, lipids and nucleic acids) and to drive life processes (e.g., growth, reacting to the environment, reproduction and movement).
		Relate how distribution and abundance of organisms and populations in ecosystems are limited by the ability of the ecosystem to recycle materials and the availability of matter, space and energy.
		Describe ways that human activities can deliberately or inadvertently alter the equilibrium in ecosystems. Explain how changes in technology/biotechnology can cause significant changes, either positive or negative, in environmental quality and carrying capacity.
		Illustrate how uses of resources at local, state, regional, national, and global levels have affected the quality of life (e.g., energy production and sustainable vs. nonsustainable agriculture).
		Analyze and investigate emerging scientific issues (e.g., genetically modified food, stem cell research, genetic research and cloning).
	Grade 11:	Describe how the maintenance of a relatively stable internal environment is required for the continuation of life, and explain how stability is challenged by changing physical, chemical and environmental conditions as well as the presence of pathogens.
		Recognize that chemical bonds of food molecules contain energy. Energy is released when the bonds of food molecules are broken and new compounds with lower energy bonds are formed. Some of this energy is released

		as thermal energy.
		Recognize that populations can reach or temporarily exceed the carrying capacity of a given environment. Show that the limitation is not just the availability of space but the number of organisms in relation to resources and the capacity of earth systems to support life.
		Give examples of how human activity can accelerate rates of natural change and can have unforeseen consequences.
	Grade 12:	Explain why and how living systems require a continuous input of energy to maintain their chemical and physical organization. Explain that with death and the cessation of energy input, living systems rapidly disintegrate toward more disorganized states.
		Describe advances in life sciences that have important, long-lasting effects on science and society (e.g., biotechnology).
Physical Sciences		
	Grade 9:	Trace the transformations of energy within a system (e.g., chemical to electrical to mechanical) and recognize that energy is conserved. Show that these transformations involve the release of some thermal energy.
	Grade 11:	Describe real world examples showing that all energy transformations tend toward disorganized states (e.g., fossil fuel combustion, food pyramids and electrical use).
	Grade 12:	Recognize that at low temperatures some materials become superconducting and offer little or no resistance to the flow of electrons.
Science and Technology		
	Grade 8:	Evaluate the overall effectiveness of a product design or solution.
	Grade 9:	Describe means of comparing the benefits with the risks of technology and how science can inform public policy.
		Identify a problem or need, propose designs and choose among alternative solutions for the problem.
		Explain why a design should be continually assessed and the ideas of the design should be tested, adapted and refined.
	Grade 10:	Cite examples of ways that scientific inquiry is driven by the desire to understand the natural world and how technology is driven by the need to meet human needs and solve human problems.
		Describe examples of scientific advances and emerging

		technologies and how they may impact society.
		Explain that when evaluating a design for a device or process, thought should be given to how it will be manufactured, operated, maintained, replaced and disposed of in addition to who will sell, operate and take care of it. Explain how the costs associated with these considerations may introduce additional constraints on the design.
	Grade 11:	Predict how decisions regarding the implementation of technologies involve the weighing of trade-offs between predicted positive and negative effects on the environment and/or humans.
		Investigate that all fuels (e.g., fossil, solar and nuclear) have advantages and disadvantages; therefore society must consider the trade-offs among them (e.g., economic costs and environmental impact).
		Research sources of energy beyond traditional fuels and the advantages, disadvantages and trade-offs society must consider when using alternative sources (e.g., biomass, solar, hybrid engines, wind and fuel cells).
	Grade 12:	Research how scientific inquiry is driven by the desire to understand the natural world and how technological design is driven by the need to meet human needs and solve human problems.
Scientific Inquiry		
	Grade 8:	Choose the appropriate tools or instruments and use relevant safety procedures to complete scientific investigations.
	Grade 9:	Construct, interpret and apply physical and conceptual models that represent or explain systems, objects, events or concepts.
	Grade 10:	Present scientific findings using clear language, accurate data, appropriate graphs, tables, maps and available technology.
	Grade 11:	Design and carry out scientific inquiry (investigation), communicate and critique results through peer review.
	Grade 12:	Formulate testable hypotheses. Develop and explain the appropriate procedures, controls and variables (dependent and independent) in scientific experimentation.