Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
2013 Volume IV: Asking Questions in Biology: Discovery versus Knowledge

Asking Questions about Enzymes

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I teach biology at Cooperative Arts & Humanities Magnet High School. This is a performing arts magnet school, located in the city of New Haven, CT. I teach the regular state required biology curriculum as well as Advanced Placement (AP) Biology. Being a magnet school we draw 30% of our students from surrounding districts that are a mix of urban and suburban school systems. In general our students perform well academically due to their desire to be in this school and to the rigor of school. We utilize a block schedule with four 90 minute periods a day. A day will be either even or odd, resulting in any given class occurring every other day for our students. The students study their art every day because 2 blocks are used for art instruction.

In New Haven biology is taught as a sophomore year course and must address the state's science framework objectives and content strands. The course is designed to cover all of the necessary content and skills that are tested on the Connecticut Academic Performance Test (CAPT) in April. The structure and function of enzymes is a topic covered in biology [S1] . The topic is only afforded one to two weeks of instruction and incorporates a compulsory laboratory activity provided by the state as an embedded task. Instruction time is limited therefore some creativity concerning the delivery of the content is something that must be addressed.

There is a discrepancy between the engagement of my AP Biology students and my biology students. The level of engagement is noted with the questions asked by the students indicating their level of interest in the content. Day after day in regular biology not a single question will be posed by the students. In contrast the typical AP Biology student is asking relevant questions daily, indicating an investment and interest in the content. This involvement by the higher achieving student facilitates a more active and positive classroom environment. Cleary the students are invested in their learning and engaged in the content. Their motivation is more intrinsic and I hope to encourage the same behaviors in the general biology course by presenting the compulsory content in a more interesting context. This unit will offer some general exposure to bioremediation using enzymes, a very relevant and fascinating use of enzymes. This modern and ground-breaking application can be brought into the class room to help inspire the un-engaged student and motivate them to take a more active role in the class. Students know that the world is being polluted by human activity and they are eager to learn about methods for cleaning up their world. Teaching enzymes through this modern application provides instant relevance for the students that will translate to increased buy-in and interest ultimately resulting in increased student performance.

I will also provide examples of enzyme instruction delivered through different content strands in the state biology curriculum. I will provide for you first some general information about enzymes. Secondly I will discuss specific information about enzymes that can be incorporated into the respiration content strand. Lastly current uses for enzymes in bioremediation will be addressed. Throughout the unit I will discuss the delivery of the content in a fashion that generates question-asking by students.

As teachers we are provided with a list of content strands and learning objectives. It is easy to structure a class to proceed in order through the objectives. This is an easy way to plan for the year and be certain that you, as a teacher, meet your responsibilities. This is functional for the teacher but unfortunately may not always be the best delivery method for the students to learn the information. For example, because enzymes are a required content strand, one may teach about enzymes as if enzymes were isolated molecules that perform a task for no other purpose than it being the function of the enzyme. When taught singularly as a content strand the true understanding of the unilateral importance of enzymes to facilitate reactions is lost. Although lessons can be constructed and delivered, that are focused narrowly on the definition of an enzyme, with fair results, this does not provide any context for the phenomenon that is enzymatic activity. Without context the idea of an enzyme becomes more abstract and thus harder to learn about and internalize. This makes it very difficult for students see relevance in the content and take enough interest to ask questions. Therefore this unit offers several examples of opportunities to teach the key understandings about enzymes. In addition this unit also demonstrates how an instructor can connect the seemingly isolated concept of enzyme activity to another tenth grade state content strand. Lastly, this unit will provide content to teach about what are some current applications of enzymes in bioremediation of herbicide pollution and petroleum product pollution.

Questions in the Classroom

The content presented in biology is extremely complicated, obscure, but relevant, and our students do not seem interested. Yes, the average AP Biology student is interested, and this intrinsic self-motivation has a lot to do with why the AP student is a successful student. I am talking about the majority of the other students that seem disinterested in the content. It is perplexing that students do not have questions nor obvious curiosity about the study of life. I do not believe that the content lacks intrigue, it must be that the presentation is flawed in some way. I believe that student interest will be piqued if the content is connected to their interests and lives.

The students are not asking questions because they cannot see the connection between enzymes and their everyday lives. Once the connection is established the questions will come. We need to motivate students to pose questions because it is in their nature to. With questioning comes interest and investment in the class. With increased investment we will have better performing students. As teachers we really cannot do anything more than to generate a desire to learn and then support the learning. We cannot make a student learn. Focusing on generating that desire we must present our content in a context that has relevance to the students.

Enzymes: Overview

This overview is intentionally general and brief because this is content that is normally covered and thus general knowledge for any biology teacher. It is provided in this unit more as a supply of general content. This will be helpful to refer to when discussing making connections between other biology content strands and enzymes as well as when discussing teaching enzymes through bioremediation.

Importance and Production

Most enzymes are proteins that facilitate reactions. They are large molecules that fall into the general category of macromolecules. Enzymes act on substrates to create products. A reaction may be the combining substrate units to create a product or the breakdown of a substrate molecule into products. This action occurs within cells to support many different cellular processes. Enzymes may be releasing energy, building energy storage molecules, translating DNA, building proteins, as well as other functions. Although the reactions that enzymes facilitate will eventually happen spontaneously, enzymes make reactions happen at rates high enough to support life. Reaction rates are in the tens of thousands per second, allowing cells to do work and consequently support life.

The human body requires tens of thousands of different enzymes to function, each with specific functions. Functions will be discussed later in this unit. Even a simple bacterium, such as Escherichia coli, requires thousands of enzymes to live its unicellular existence.

Importance and Production: Coding

The majority of discovered enzymes are proteins. Cellular function is regulated by enzymes that are produced in house by the cell itself. When considering a multi-cellular organism, cells of different tissues may have markedly different enzymes from one another in order to perform their tissue specific function. This can be useful when determining the function of different cells. The instructions for making the requisite enzymes are coded into the DNA of the cell. Each different type of enzyme is produced by the cell's translation of a specific genetic code of DNA into a protein product. Translation of DNA is also carried out by enzymes. DNA code provides the specific sequence of amino acids needed to produce a specific product protein. DNA code is universal to all organisms. The sequence of DNA that codes for a given amino acid is the same no matter the organism. All organisms use the same genetic language to translate their DNA.

Importance and Production: Production

Enzymes are produced using amino acid building blocks. The DNA code sequence will dictate the type and sequence of amino acids thus dictating the enzyme produced by a given code. The process of translation of genetic code into protein product is performed out by organelles called ribosomes. The ribosomes are either free in the cytoplasm of the cell or embedded in the membrane of the endoplasmic reticulum. Depending on the function of the enzyme or activity of the cell enzymes may be produced for immediate use. Enzymes may also be produced and stored for later use.

Structure of Enzymes

Structure of Enzymes: Enzymes are Proteins

Most enzymes are proteins but not all proteins are enzymes. Proteins are made of any combination of the twenty amino acids. Protein structure is dictated by combination, number, and sequence of the amino acids that constitute it as coded by DNA. Some proteins, and hence enzymes, are combinations of multiple proteins folded together to form a single structure. Although enzymes do perform work, they are simply just macromolecules and must not be thought of as living or even as organelles. The action of the enzyme is to facilitate a reaction. In general an enzyme contains or creates an ideal micro-environment for a specific reaction to occur, this micro-environment is called the active site of the enzyme.

Structure of Enzymes: Structure Leads to Function

The final structure of an enzyme allows for binding of a specific substrate(s) in order to catalyze a reaction. The structure of importance is the active site wherein the substrate(s) bind. This active site will facilitate the reaction by providing the conditions to catalyze a specific reaction. Enzyme action may be to break a substrate down into smaller parts (catabolic reactions) or to bind two substrates together to form a single molecular product (anabolic reactions). Commonly the binding of the substrate to the active site will change the shape of the enzyme or the substrate resulting in the breaking of bonds or forming of new bonds. The enzyme provides the conditions for the reaction to take place by having a very specific shape that will stress the bonds of a single substrate, resulting in separation into products or aligning two substrates in such a way that they will bond forming a single product.

Structure of Enzymes: Active Sites

Active sites are specific to the substrates and as the name implies, this is where the enzymatic reaction takes place. It is popular to describe the active site and substrate relationship as that of a lock and key. Although this is not longer the accepted model it is still a functional way to present the concept within a high school classroom. In this model, the active site is thought of as a lock and the substrate as a key. Therefore each key will only fit in a single lock. This analogy also assumes that the both lock and key are static and rigid. This model helps create a visual first for the students to frame their view of enzymes. Note that the model is imperfect because enzymes and substrates are not rigid and inflexible. Some enzyme active sites will bend and stress the bonds of a bonded substrate in order to break bonds. In contrast some enzyme-substrate relationships rely on the manipulation of substrates in order to create bonds. Other active sites function as being true micro-environments for the substrates. It may be the case that the active site has a pH or temperature that differs from the surrounding medium. This condition is ideal for the reaction, thus facilitating the reaction in an otherwise non-reactive environment for the substrate.

Structure of Enzymes: Multienzyme Complexes

Reactions are not necessarily independent and reaction events are often steps in complex processes that require multiple enzymes. Enzymes can be found in complexes comprised of multiple copies of the several different enzymes that all perform a specific task that is part of a reaction sequence. This results in more efficient processes for the cell. In essence this is an aggregate of macromolecules, a complex that catalyze a reaction sequence using proximity to increase efficiency.

Regulation

Enzymes cause reactions to happen at rates fast enough to support life; therefore, the control of the activity of the enzyme can regulate the functions of the cell. Regulation can be fostered by directly inhibiting or activating an enzyme. Enzyme rates are also affected by temperature and pH. Cells must regulate their enzymes but it is not always the case that the cell has any control of the conditions that it is exposed to. As we learn more about enzyme regulation we can begin to see the importance of understanding what affects enzymatic rate.

Regulation: Temperature and pH

Enzymes have specific ranges of temperature and pH that they will function in. Optimal ranges of pH are specific to enzymes. Understanding the relationship between temperature and reaction rate is more intuitive. If one considers kinetic energy as it relates to movement of particles it makes sense, that within limits, higher temperatures correlate with higher reaction rates. This is due to higher kinetic energy and an increase of molecular movement and thus collision. The more the substrate and enzymes are moving the more likely it is that they come in contact with the each other. Often, the upper limit of the relationship between temperature and increased reaction rate, is dictated by the temperature threshold of the enzyme. At this point the enzymatic rate will cease to increase and will sharply decline. Enzymes, being proteins, are denatured by when exposed to extreme temperatures. Denaturation will result in a shape change for the enzyme, thus loss of structure equals loss of function.

Temperature and pH are an indirect way that enzymes are regulated. Indirect because often is the case that the temperature or pH that a given enzyme is subjected to is being manipulated by an extracellular event. This can be an interesting quest for a high school biology class to help gain understanding about how important homeostasis is to the human body and why it is so dangerous for the body to have to operate outside of its normal temperature range, i.e., when the body experiences fever.

Regulation: Inhibition

Decreasing or stopping the function of an enzyme is called inhibition. Think of an enzyme being naturally active in order to regulate the action it must be inhibited. As an analogy this would be a car with not gas pedal and only a brake pedal. The car will constantly run automatically unless the brake is applied to stop it. Many enzymes can be regulated in this way. Consider an enzymatic pathway that results in a product that is needed in finite amounts. The product in this case may also be the inhibitor. The way this would work is that when the product is in excess of what the cell needs it is will bind to the inhibition site, preventing further production of a molecule that is not needed. It may also be the case that the inhibitor molecule is produced via different pathway in response to a trigger. Whatever the case is, the enzymatic activity is being regulated by a negative control.

The enzyme may have a binding site that allows an inhibitor molecule to bind causing a shape change in the enzyme and resulting in a deformation of the enzyme's active site. In this case, while the inhibitor is bound to the enzyme, the deformed active site is rendered inoperable. Upon release of the inhibitor the active site regains shape and may begin catalyzing reactions again. Another inhibition method may involve the binding of an inhibitor molecule to the active site. The active site will thus be occupied by the inhibitor effectively blocking the substrate.

Regulation: Activation

Enzymes may also exist in a non-active form unless an activator molecule binds them to activate them. As analogy, this car would have only a gas pedal and will naturally be stationary unless activated by applying the gas pedal. This is a positive regulation of an enzyme, wherein the binding results in activity. Enzymes that are regulated by activators will have a binding site for the activator. When the activation molecule is bound to the enzyme the enzyme becomes functional.

Consider that a cell may not need all of its enzymes to be functioning at all times. Cells may only need certain enzymes when the cell is exposed to a certain conditions. When certain conditions are met the cell may quickly turn on or off the enzymes as a response. It is important to stress that enzyme rates are controlled by cells and that these rates may be controlled via different strategies. Furthermore cellular function is controlled by manipulation of enzymatic rates.

Making Connections: Enzymes & Cellular Respiration

Cellular respiration is critical content to cover in biology. This is a wonderful opportunity for a teacher to weave in instruction about enzymes in order to provide a relevant context for students.

If you were to query your students at the beginning of a unit they will know that sugar provides energy for humans. They will know that we need to ingest the sugar to get the energy that it stores. They will also know that we must inhale oxygen and that we exhale carbon dioxide. This is of course an important understanding, but severely limited. At this point we can ask our students what questions they have about the process, starting with a "Chalk Talk" around the word respiration. I use "Chalk Talks" throughout the year to focus the class and to help them realize what they may or may not know about a topic. This effective at the beginning of a unit, but is also very effective at the summation of a unit.

Chalk Talk

For a "Chalk Talk" the teacher chooses a word or phrase and writes it on the board. Then the students are expected to make connections and associations with the word. The rules are simple: no talking and students are free to get up and write on the board without asking permission. You want to encourage them to keep what they write brief because it will be discussed when the writing period is over. The no talking rule achieves two ends, number one it helps maintain order and number two it reduces or eliminates judging. It is important that the students feel safe to write whatever is on their mind to connect to the topic and not be judged in the process. After the energy has simmered out and the ideas are not flowing anymore the teacher takes the lead again and discusses each and every idea. It is important that with each idea the teacher offers the author a chance to explain but also that the teacher asks the class how the idea ties to the topic. Some students will not want to talk about their ideas; what matters is that they were given the chance to share and be a part of the class in a way that was comfortable for them.

The "Chalk Talk" will generate many questions because it demonstrates to the students that not only do they already know about the topic but that they also have associations with the topic that they may not be able to make much sense of. After discussing each idea, it is time to generate a list of questions with the students. Typically we pull on the main themes of the discussion and generate a list of questions around this.

This approach is very popular with my students. The first time is a little difficult because they are generally not used to having such freedom. Subsequent "Chalk Talks" always run much more smoothly. I find that it is not only easy and quick, but really helps to focus the students on the topic and give them some freedom to ask questions. Most importantly this allows the students a time to get up and move around during class.

Questions: Cellular Respiration

Cellular respiration is the process of breaking down glucose, or other substrates, in order to generate energy in the form of adenosine triphosphate (ATP). This is complex process involving three separate pathways: glycolysis, the citric acid cycle, and oxidative phosphorylation. Each of these separate pathways involves multiple enzymes specific to the intermediates produced and used within the pathways.

The equation for cellular respiration is: $C_6H_{12}O_6 + 6\ O_2 \text{-->} 6\ CO_2 + 6\ H_20$ + Energy

Our cells are taking in glucose and oxygen and releasing carbon dioxide and water constantly in the effort to keep the body alive and functioning. The process of gylcolysis, one of the three pathways involved, requires ten different enzymes to convert one molecule of glucose into two molecules of pyruvate. This also yields a net gain of two ATP's for the cell.

The pyruvate is the substrate for the citric acid cycle which also yields two ATP per glucose. The citric acid cycle uses a multienzyme complex, the pyruvate dehydrogenase complex, to achieve the process in a fast and efficient manner.

Both glycolysis and the citric acid cycle also reduce molecules of NAD^+ and FAD to NADH and $FADH_2$ that will supply electrons to the third process, oxidative phosphorylation. Through an electron transport chain and chemiosmosis this third pathway will generate between 32 and 34 ATP per glucose for the cell.

Again, provided is just a brief synopsis of the content in order to discuss the topic of inspiring students to generate questions by providing a context for them to learn the abstract concepts of enzymes.

Teaching enzymes through cellular respiration the teacher has numerous ways to tie relevance and meaning into the unit. As the body needs more energy there are mechanisms that will ramp up the process and vice versa if the body does not need the energy and is storing instead. This can be linked to instruction about enzyme activation and inhibition.

The intent is to motivate students to ask questions about the impacts of enzymes on the entire process of cellular respiration both as a whole and on a specific level. Students can pose questions about the impact of each enzyme on the process. Students may pose questions about the loss of a particular enzyme and how that will impact the process. Students may pose questions about the effect of temperature on the different enzymes. Students can pose questions about how the multienzyme complex involved in the citric acid cycle facilitates a more efficient process. Students can ask what happens when not enough glucose is available or if there is too much. Students can investigate how the body removes the waste products of carbon dioxide and water.

Making Connections: Enzymes & Population Dynamics

The state embedded task involves factors that affect the fermentation by Saccharomyces cerevisiae of molasses as a sugar source. This task is assigned to be carried out by our students in New Haven during the winter months in the midst of a unit on population dynamics. Students investigate the effect of temperature or food supply (molasses concentration) on the carbon dioxide production of the yeast. The amount of carbon dioxide produced is supposed to reflect the activity of the yeast population. This lab investigation would be more useful if carried out during a unit on enzymes because it clearly demonstrates the effects of temperature on enzyme activity.

Students find that yeast incubated at temperatures higher than room temperature result in faster and greater carbon dioxide production. Conversely samples incubated below room temperature will have decreasingly lower production correlated with the decrease in temperature. Students also find that there is a positive correlation between molasses concentration and enzyme activity.

Making Connections: Enzymes and Bioremediation

Bioremediation is the use of biological processes to overcome environmental problems. Enzyme activity is a biological process that can be used to modify chemicals that are harmful to the environment, converting them to inert molecules. Two areas of interest wherein enzymes can be used as bioremediators are with the clean-up of petroleum spills and herbicide run-off.

Specific enzymes can be harvested from microorganisms that produce them in order to be used for bioremediation. A benefit of using an enzyme is that it has a singular function: to act upon a target substrate molecule. In the case of bioremediation the target is a pollutant. An enzyme will catalyze the reaction, detoxifying the pollutant, thousands of times a second. The enzyme, in most cases, is just a protein and will be otherwise innocuous. Other methods of bioremediation utilize bacteria, fungi, algae and plants. These organisms are either identified for their special useful biochemical activity or genetically modified to achieve a desired action.

Releasing live organisms as a method of bioremediation has a host of possible problems. Laboratory simulations can be effective but knowing all of the consequences of introducing a new organism into an ecosystem is not possible. Once released, particularly in the case of a microorganism it is impossible to re-capture and destroy the organism should unintended effects occur. Consider releasing a strain of bacteria to clean-up a pollutant. Although the bacteria may be effective, its actions also may be disruptive to other microorganisms. In this case there would be no viable way of recovering and destroying every released bacterium, particularly if they were to enter a water way. Live organisms are also not proving to be as effective in the field as they are in the lab. Often it is the case that the microorganism performs well in laboratory conditions but once released the productivity is reduced. Living organisms have a specific acceptable range of temperature, pH, oxygen, and other factors that they thrive in. The environment may not consistently have these conditions. Organisms also need other nutrients to survive and if they are not present in the location in need of bioremediation this will pose a problem.

Bioremediation of Triazine Herbicides

Atrazine, the most commonly used triazine herbicide, has been in use since 1958. The chemical is synthesized and distributed by Syngenta, an international company. Atrazine is used in the production of corn, sorghum, and sugarcane, around the globe, to increase crop yields. Atrazine is most effective against broadleaf plants. Atrazine is a Restricted Use Pesticide (RUP) meaning that it can only be used by registered professionals. Atrazine is used heavily by corn farmers in the US, but is also used as roadside weed control and golf course turf management. The action of the chemical is to block the photosynthetic pathway ultimately killing the affected organism. There are triazine resistant crops that have been developed, one of which is canola. Corn is naturally resistant to the chemical. Other triazine pesticides include methoxytriazines (atraton), methylthiotriazine (ametryn), propazine, and simazine.

Triazine herbicides are of particular interest as environmental pollutants because of their wide-spread use, persistence, and mobility. Atrazine remains stable and active for 4 to 57 weeks after application. It has been found in soils, groundwater, lakes, and even oceans. Atrazine is a threat to lakes, wetlands, and reefs. The chemical disrupts photosynthetic action of corals, phototrophic bacteria, freshwater algae, and mangrove trees. These are all non-target organisms of the application process. The product is applied to a crop, but run-off carries the atrazine to a multitude of down-river destinations. The Great Barrier Reef off the coast of Australia is one of the un-intended targets.

An enzyme that metabolizes atrazine was first discovered by chance. A bacterium, Pseudomonas sp. ADP, was isolated from an herbicide spill. This strain of Pseudomonas was dubbed ADP because of it metabolized atrazine as a nitrogen source. This bacterium used atrazine as it sole nitrogen source, metabolizing it remarkably fast, at a rate of "9 x 10^{9} cells per ml degraded 100 ppm of atrazine in 90 minutes" [1] . The enzyme responsible for the metabolism was isolated and named atrazine dechlorinase (AtzA), an atranine dechlorinase. The enzyme dechlorinates atrazine transforming it from an effective herbicide to an innocuous non-herbicide molecule. The gene that codes for this enzyme has since been isolated. With this isolated gene scientists have been able to produce transgenic E. coli, as well as plants, in order to field trial them as bioremediation devices. For reasons discussed above it is more promising to use the enzyme alone for bioremediation. Currently this is an area of research that is gaining ground. The enzyme has been improved upon; triazine hydrolase (TrzN), is a recent iteration that shows promise because it can act on a broader range of triazines and not just the chlorinated ones.

Fostering Relevance, Connections, and Questions

Herbicide pollution is of paramount importance to this generation. "Organic" is a common household word that students will have some familiarity with because it used in daily conversations and advertisements. High school students are at the age where they are starting to make decisions about their lives and bodies and it is not uncommon to meet a student that chooses to eat organic foods. This is the connection that helps to garner buy-in from the students, because they are already invested in the concept. Organic foods are not grown with synthetic herbicides such as atrazine.

Studying genetically modified organisms, especially the methods of creation and the use of them in the food industry, is required state content. One can easily put together a mini curriculum that focuses on both genetic engineering and the subsequent use of pesticides. Genetically modified foods (GMOs) are developed to be resistant to pesticides and herbicides. Although this may not result in the increased application of pesticides, the fact remains the same: the pesticides are used and therefore released into the environment affecting non-target organisms. A unit that connects bioremediation methods with production of GMOs will be much richer and more interesting than a unit that focuses just on one of the two topics.

Students need to be convinced of the relevance of what they are being taught. Connecting content objectives, such as enzymatic action, to current events is an effective way to demonstrate importance to the students. An added benefit is that these are also controversial topics and will elicit increased interest from high school students who are eager to define themselves.

Bioremediation of PAHs

Polycyclic aromatic hydrocarbons (PAHs) are semi-volatile organic compounds (SVOCs). These compounds are present in crude oil that has spent time in the ocean and is thus a concern when oil spills occur. PAHs come from other sources as well such as the incomplete combustion of gas, coal, garbage, wood, and from motor vehicle exhaust. There are a number of PAHs the Environmental Protection Agency (EPA) will test for, following an oil spill and clean-up efforts.

PAHs are environmental pollutants that may also be detrimental to humans. It is possible that they cause cancer, adversely affect reproduction, and disrupt the immune system. "The Department of Health and Human Services (DHHS) has determined that some PAHs may reasonably be expected to be carcinogens. Some people who have breathed or touched mixtures of PAHs and other chemicals for long periods of time have developed cancer. Some PAHs have caused cancer in laboratory animals when they breathed air containing them (lung cancer), ingested them in food (stomach cancer), or had them applied to their skin (skin cancer)" [2] .

Gaseous PAHs contaminate soils and aquifers as they deposit from the atmosphere. The widespread contamination, magnitude of the pollution, and effect on humans makes remediation of PAHs a very important and necessary activity. Bioremediation with enzymes may be the answer.

A phenoloxidase called laccase can be harvested from Trametes versicolor, a species of mushroom. This enzyme catalyzes the oxidation of PAHs when a mediator is present to act as an electron shuttle. Not only is the enzyme needed to remediate PAHs but enzymes mediator is also required. Mediators have been developed to couple with the enzyme. Oxidation of the PAHs degrades the molecule into inert products.

Fostering Relevance, Connections, and Questions

Oil spills are current hot topics. Unfortunately oil spills are all too common as well. Your students will have questions about these tragedies. What better way to harness their innate interest than to focus on a learning objective that must be taught? Teaching about enzymatic bioremediation of PAHs can be coupled with an ecology unit. Teaching about enzymes in this tangible, meaningful, forum will motivate students to take more interest in the topic. Students want to connect their learning to something that they care about. The environmental damage caused by oil spills interests students because they are such devastating events. This will be in contrast to teaching enzymes through the state embedded task wherein one uses pectinase to produce apple juice from apple sauce: an activity that is so obscure and strange that I have a hard time justifying the loss of class time it takes to perform the activity.

If students are interested they will ask questions. If students are asking questions they care about the content; they have a desire to understand. If students are asking questions they are acting like scientists, this is the point of science instruction, is it not?

As science instructors we are failing our students if our focus is so narrow that it presents only content. We must teach students what science is and the impetus of science is posing questions. Presenting students with real-world problems in the context of the content that they will be held responsible for garners their interest effectively. Encouraging students to study the application of biological phenomena to solve human problems will bridge the gap between their interests and the state requirements. Once they are hooked and interested in the class the questions will come. It is our job to define and support the question process, validating the action for the students. We validate the action of question posing by allowing our students to investigate their questions and essentially act as scientists.

Activities

Question Formation Technique

See Make *Just One Change: Teach Students to Ask Their Own Questions* by Dan Rothstein and Luz Santana. Rothstein and Santana describe a deliberate and easily replicable technique that a teacher can employ at the beginning of a unit. There is a well-described question formation technique described in this book that will be useful for generating questions from your students. The hidden benefit is that activities such as these foster student interest in the class because students are given a voice. With the questions generated you structure the class instruction to answer their questions, creating instant purpose and relevance for the students. This allows the students to have a say in how the unit is framed and gives them control of what they will be learning.

Penny Enzyme Activity

This is a great hands-on activity that is engaging, active, fun, and cheap. Students learn the concepts of enzyme structure, active site, competitive inhibitors, temperature effects, denaturation, reaction rates and substrate-enzyme relationships.

The premise is that a penny is the substrate and the hand is the enzyme. The reaction is the picking up of one penny from a bowl and placing it on the table "heads" up. The fingers are the active site. Depending on the length of the class one can modify this activity in many ways. I use the activity in a 90 minute block.

The students are paired, one being the enzyme and the other counting and validating the enzymatic activity. The supplies per pair are: plastic bowl, 100 pennies, masking tape, access to ice, access to clock with a second hand, and 100 paper clips. The students will run multiple trials for each of several scenarios in order to model enzymatic activity. The data that are collected can be used to determine averages, create graphs, and calculate rates. The data can also be aggregated for the whole class for analysis.

The following reaction simulations can be run in fifteen-second trials. The reaction is the picking up of one penny from the bowl and placing it on the table "heads up."

1. "Normal Enzyme Activity" - this is to collect baseline data

2. "Denatured Enzyme" – the student must tape his/her four fingers together

3. "Competitive Inhibition" – the students add 100 paper clips to the bowl of pennies

4. "Temperature Effect" – the student first cools his/her hand with ice for a minute

Notes

[11] Mandelbaum, Raphi T., Deborah I. Allan, and Lawrence P. Wackett. "Isolation and Characterization of a Pseudomonas sp. That Mineralizes the s-Triazine Herbicide Atrazine."

2

US Department of Health and Human Services. "Polycyclic Aromatic Hydrocarbons (PAHs)"

Resources

[1] Mandelbaum, Raphi T., Deborah I. Allan, and Lawrence P. Wackett. "Isolation and Characterization of a Pseudomonas sp. That Mineralizes the s-Triazine Herbicide Atrazine."Applied and Environmental Microbiology61 (1995): 1451-1457.

[2] US Department of Health and Human Services. "Polycyclic Aromatic Hydrocarbons (PAHs)." ATSDR Agency for Toxic Substances and Disease Registry. www.atsdr.cdc.gov/tfacts69.pdf (accessed July 2, 2013).

[3] "Polycyclic Aromatic Hydrocarbons (PAH) on Gulf Coastline | EPA Response to BP Spill in the Gulf of Mexico | US EPA." US Environmental Protection Agency. http://www.epa.gov/bpspill/pahs.html (accessed July 1, 2013).

[4] Behal, R H, D B Buxton, J G Robertson, and M S Olson. "Regulation Of The Pyruvate Dehydrogenase Multienzyme Complex."Annual Review of Nutrition13, no. 1 (1993): 497-520.

[5] Karigar, Chandrakant S., and Shwetha S. Rao. "Role of Microbial Enzymes in the Bioremedation of Pollutants: A Review."Enzyme Research2011 (2011): 1-11.

[6] Scott, C., C. J. Jackson, C. W. Coppin, R. G. Mourant, M. E. Hilton, T. D. Sutherland, R. J. Russell, and J. G. Oakeshott. "Catalytic Improvement And Evolution Of Atrazine Chlorohydrolase."Applied and Environmental Microbiology75, no. 7 (2009): 2184-2191.

[7] Phone. "Syngenta - United States." Syngenta - United States. http://www.syngenta-us.com/home.aspx (accessed July 2, 2013).

[8] "Photosynthesis Inhibitors." Purdue Agriculture. www.btny.purdue.edu/weedscience/moa/Photosynthetic_Inhibitors/text.html (accessed July 2, 2013).

[9] EPA. "Atrazine Chemical Summary." EPA United States. www.epa.gov/teach/chem_summ/Atrazine_summary.pdf (accessed July 2, 2013).

[10] Roush, R. T. . "GMOs IN FOOD PRODUCTION - THE PERCEPTIONS AND THE REALITY."Animal Production Australia24 (2002): 512-517.

[11] Datta, Sumitra, L. Rene Christena, and Yamuna Rani Sriramulu Rajaram. "Enzyme immobilization: an overview on techniques and support materials."3 Biotech3, no. 1 (2012): 1-9. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3563746/ (accessed July 2, 2013).

[12] Tomlinson, Carol A., and Jay McTighe. Integrating Differentiated Instruction & Understanding by Design: Connecting Content and Kids. Alexandria, VA: Association for Supervision and Curriculum Development, 2006. Print.

[13] Roberts, Royston M. Serendipity: Accidental Discoveries in Science. New York, NY: Wiley, 1989. Print.

[14] Hughes, Laurel. How to Raise Good Children: Encouraging Moral Growth. Nashville, TN: Abingdon, 1988. Print.

[15] Rothstein, Dan and Luz Santana Make Just One Change: Teach Students to Ask Their Own Questions. Cambridge, MA: Harvard Education Press, 2011. Print.

[16] Campbell, Neil A., Jane B. Reece, Lisa A. Urry, Michael L. Cain, Steven A. Wasserman, Peter V. Minorsky, and Robert B. Jackson.AP Edition Biology. 8th ed. New York: Benjamin/Cummings, 2008. Print.

[17] Mason, Kenneth A., Jonathan B. Losos, and Susan R. Singer.Biology AP Edition. 10th ed. New York: McGraw-Hill, 2014. Print.

Implementing District Standards

S1. D.29 Describe the general role of enzymes in metabolic cell processes.

S2. D.34 Describe, in general terms, how the genetic information of organisms can be altered to make them produce new materials.

S3. D.35 Explain the risks and benefits of altering genetic composition and cell products of existing organisms.

S4. D.14 Describe combustion reactions of hydrocarbons and their resulting by-products.

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