Internet of Things (IoT) at UCF

UNIVERSITY OF CENTRAL FLORIDA

UCF RET Site: Collaborative Multidisciplinary Engineering Design Experiences for Teachers

8708110: Principles of Biomedical Science or AP/Honor’s Biology

Mohammed Patel

8708110: Principles of Biomedical Science

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READ THIS FIRST

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- Remember to do your 3R reflection include an updated copy of your lesson plan, developed assessment tools, presentation materials, to the evaluator. See implementation plan instructions developed by the evaluator. Send within a week after completing the lesson to bonnie.swan@ucf.edu

<table>
<tr><td colspan="2">RET Site: Diagnosing Diabetes Lesson/Unit Plan

Subject Area(s): Biological Science/Biomedical Science
Course(s): Principles of Biomedical Science and/or AP Biology/Honor’s Biology
Grade Level: 9-12
Suggested Length of Lesson: 2 x 45 mins lessons</td></tr>
<tr><td colspan="2">Lesson Summary: In this lesson, students will be introduced to the concept of feedback loops. Students will use an array of detection techniques to determine if a patient is diabetic or not. The teacher will begin the lesson with a short video on diabetes. The students will then complete a card sort activity to demonstrate how the human body is able to regulate blood sugar levels after which they will draw a feedback loop. Students will</td></tr>
<tr><td colspan="2">Prerequisite Knowledge: Students should be familiar with the basics of cellular respiration i.e. glucose is a reactant that is utilized by cells as an energy source. Students should also understand that glucose is a macromolecule that cannot passively diffuse through the cell membrane unaided. Students may need to recall the relationship between independent and dependent variables with respect to plotting data on a graph.</td></tr>
<tr><td>Materials/Technology Needed:
• Neon Expo Markers
• Card Sort
• “Diagnosing Diabetes Lab”
• Projector
• Chart Paper
• Microsoft Excel/Google Sheets</td><td>Where this Fits/Lesson Dependency:

▪ In the PLTW Principles of Biomedical Science course this lesson can be taught in the diabetes unit as an introductory lesson to relate it back to the case study. Patient B (Type I Diabetic) can be replaced with the patient from the course.
▪ In an Honor’s Biology or AP Biology course this lesson can be taught as part of homeostasis or as an example of cellular signaling.
▪ This lesson can also be modified for Honor’s Chemistry or AP Chemistry where the primary focus can shift to unit conversion, data collection, concentration, and tonicity.

Content Connections:

• Feedback Loops
• Cellular Signaling
• Homeostasis
• Endocrine System
• Feedback Loop
• Biochemistry
• Unit Conversion/Dimensional Analysis
• Tonicity/Concentration</td></tr>
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Lesson Objective(s)/Learning Goal(s):

- Students will be able to describe the relationship between insulin and blood sugar levels.
- Students will be able to identify the differences/similarities between Type 1 and Type 2 diabetes.
- Students will be able to diagram a cell signaling pathway found in the human body and can describe how it helps maintain homeostasis.
- Students will be able to describe how technological tools can be utilized in the detection and treatment of diabetes.
- Students are able to differentiate between sensor selectivity and sensor sensitivity.
- Students are able to propose a technological solution for diabetes diagnosis and treatment and relate their device to the layers of the Internet of Things "IoT."

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Standard(s)/Benchmark(s):

CTE Standards

- 13.01: Explain how many systems, living or non-living, operate using feedback mechanisms and that information put into a system causes a reaction within the system.
- 13.02: Understand that there are two different types of feedback systems, positive and negative.
- 13.03: Summarize how insulin regulates the transfer of glucose into the body cells and its role as part of the feedback system.
- 13.04: Compare Type 1 & Type 2 Diabetes.

NGSS Standards

- DCI - LS1.A - From Molecules to Organisms: Structures and Processes - Structure and Function: Systems of specialized cells within organisms help them perform the essential functions of life.
(HS-LS1-1)
- DCI - LS1.A - From Molecules to Organisms: Structures and Processes - Structure and Function: Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.
(HS-LS1-3)

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Standards for Mathematical Practice

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Instructional Strategies

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▪ N.Q .1 - Quantities: Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. ▪ N.Q .3 – Quantities: Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. ▪ S.ID.1 - Interpreting Categorical and Quantitative Data ▪ Represent data with plots on the real number line (dot plots, histograms, and box plots). ▪ S.IC.6 - Making Inferences and Justifying Conclusions ▪ Evaluate reports based on data. ▪ *Florida NGSS Standards:* ▪ MAFS.912.F-IF.2.4 For a function that models a relationship between two quantities, interpret key features of graphs	<u>General Instructional Strategies</u> ○ Case Study ○ Guided Inquiry ○ Scaffolding ○ Strategic Grouping ○ Concept Mapping ○ Cooperative Learning ○ Incorporating Technological Aids ○ Critical Thinking & Problem Solving ○ Whole Class Instruction ○ Modeling/Scaffold Instruction ○ Chunking: Pacing of Instruction ○ Formative Checkpoints ○ Providing Verbal Immediate Feedback ○ Providing Non Verbal Cues ○ Circulation & Monitoring for Understanding ○ Review of Material ○ Practicing Skills, Strategies, and Processes <u>ELL Strategies</u> ○ Paired Reading ○ Concept Mapping ○ Non-verbal Cues ○ Text Features ○ Group Activity ○ Preferred Seating ○ Strategic Grouping ○ "Hands-on" Activity ○ Digital Tools (Google Translate) <u>ESE Strategies</u> ○ Guided Inquiry ○ Concept Mapping ○ Preferred Seating ○ Strategic Grouping ○ Clarified and Repeated Instructions ○ Check for Understanding ○ Extension Tasks for Gifted Students ○ Strategic Scaffolding Embedded
Evidence of Learning (Assessment Plan) ▪ Pre-Test ▪ Card Sort (Formative Assessment) ▪ Diagram Feedback Loops (Formative Assessment/ Concept Map) ▪ Conduct Lab (Formative Assessment) ▪ Record Lab Data (Formative Assessment) ▪ Analyze Lab Data (Correct Diagnosis) ▪ Post- Test	

	○ Other strategies listed in individual student’s IEP/504

Description of Lesson Activity/Experiences

1. Students complete the pre-test online prior to attending class. This can be done via a google form (link to be attached)
2. Students are introduced to the concept of feedback loops via a guided card sort.
3. Students draw and label the glucose regulation feedback loop.
4. Students watch this short video and are introduced to the “oral glucose tolerance test.”
5. Students watch a demonstration of how blood plasma can be isolated.
6. Students determine independent and dependent variable for the test.
7. Students conduct a lab to simulate oral glucose tolerance test results for 3 different patients.
8. Students record the glucose and insulin data in a data table and represent it graphically, utilizing simulated glucose sensors and a java program which converts color input to a numerical value so they can obtain data.
9. Students analyze their recorded results (Excel, Google Sheets etc. or drawn by hand) to determine the appropriate diagnosis for each patient.
10. Students are introduced to the basics of MEMS and propose “Smart” solutions utilizing the “Internet of Things” to potentially diagnose diabetics sooner and also provide treatment solutions. The students can present their diagnosis and treatment plan via a mini-poster presentation. (Optional extension activity)
11. Post Test (Online)

Recommended Assessment(s) and Steps

- Students will take a pretest online which will test their understanding of feedback loops, diabetes, computer generated data, sensor function, sensor fabrication, and technological solutions for the diagnosis and treatment of diabetes.
- Students will be completing a card sort in pairs on their tables to demonstrate understanding of the glucose regulation feedback loop in the human body. This activity will lead to two feedback loops being created. 1 feedback loop represents low blood sugar (hypoglycemia) regulation and the other feedback loop will represent high blood sugar (hyperglycemia). This is an opportunity to circulate and monitor for correct understanding and engage students with questions regarding their placement of cards.
- Students will rearrange their cards to demonstrate understanding of hypoglycemic conditions and hyperglycemic conditions.
- Students will then draw a simplified feedback loop which combines both high and low blood sugar. This is an opportunity to check for understanding and to clarify any misconceptions.
- Students will conduct a lab to simulate oral glucose tolerance testing using simulated blood plasma and simulated sensors. As students are constructing their data tables and setting up their graph axes and titles, it is a good time to test their understanding of independent and dependent variables. Students will also be drawing circuits on to their pH sensors to demonstrate the relationship between glucose concentration and an electrical signal.

- Students will record their data electronically or physically, as they are recording data they should be questioned regarding any trends they see and if the data is reliable and valid. Students will be utilizing a predetermined key which converts observable color change data into an electrical signal value for glucose which they will then input into a java program to get back the glucose reading. For the insulin measurement students will simply put the color reading into the program and it will generate an insulin value. This is an opportunity to discuss the validity of the measurements and the implications of using a computer to recognize an electrical signal (glucose data) versus sensing insulin without an electrical signal.
- Students will present a diagnosis which they should be able to defend using patient data and background information.
- Students will research current technological solutions in diagnosing diabetes and the treatment of diabetes and present their findings to the class via a mini-poster presentation.
- Students will complete a post-test.

List of Materials/Resources Used

- Neon Markers (to write on class table)
- Card Sort (with accompanying PowerPoint with instructions)
- pH Paper (simulated glucose sensor)
- Simulated Blood Plasma - pH solutions (pH 3, pH 6, pH 7, pH 9)
- Universal pH indicator – (insulin indicator)
- Java Program – (to get numerical data)
- Microsoft Excel or Google Sheets (if recording data electronically)
- Internet (to research current and future technological solutions)

Engineering Connection (60-100 words/3 sentences)

The pancreas functions like a sensor to detect blood sugar levels and responds to a high or low blood sugar signal by sending out specific hormones which help regulate blood sugar levels via negative feedback loops. Students will be utilizing technological tools to help determine if a patient is diabetic. The connection is that the external sensor has to detect glucose or insulin and convert the chemical concentration into an electrical signal which a computer can interpret. Furthermore, the students can extend their understanding by comparing this feedback loop to known feedback loops in everyday smart devices. For example, they can examine how Nest thermostat regulates temperature and compare the elements that make up the Internet of Things (IoT) to the elements that control blood sugar levels.

Engineering Category (choose one) – I'm not sure which category is best for this lesson

✓	relating science and/or math concepts to engineering (primarily science & math with some engineering)
	engineering analysis or partial design (primarily engineering with some science/math)
	engineering design process (full engineering design)

Key Words: homeostasis, cellular signaling, pancreas, diabetes, patient case study, insulin, glucose, sensor, endocrine system, feedback loop

Introduction/Motivation (written as if talking to students):

Diabetes is a widespread disease which affects over 400 million people in the world today compared to 100 million people in the 1980's and this number continues to increase. According to the World Health Organization (WHO), diabetes was the seventh leading cause of death in 2016. High glucose levels lead to even more deaths than diabetes and half of all diabetic deaths before the age of 70 are linked to high glucose levels. Other complications of diabetes related to uncontrolled blood glucose are blindness, kidney failure, heart attacks, stroke and lower limb amputation. This is why it is necessary to have better and earlier detection protocols to prevent, detect, and diagnose diabetes.

We will first complete a card sort to demonstrate the relationship between glucose and insulin. Our body utilizes glucose (sugar) as the primary source of energy in cellular respiration. Without sugar, our cells are eventually unable to undergo cellular respiration which will eventually lead to cellular death and a host of metabolic problems which can lead to death. Can you think of some complications that would arise from being unable to utilize glucose? For example, if glucose is building up in the blood stream this could create a hyperglycemic environment which would lead to cells losing water ultimately leading to cellular death. If glucose is unable to enter a cell, a cell may have difficulty in continuing ATP production which would lead to an inability to perform cellular functions which could lead to cellular death, necrosis of tissues/organ, and eventually organ failure. Will a person feel thirsty and dehydrated? Where will all the excess glucose go? Why will there be excess glucose in the urine of a diabetic patient? What areas of the body do you think would be affected first? Recall that blood vessels further from the heart are thinner and therefore would be most susceptible to necrosis. Which areas would be affected last? Recall that it is important for vital cells such as brain cells and red blood cells to be able to take in glucose without insulin.

The pancreas is our primary organ which detects high or low blood sugar via alpha cells and beta cells. In response to high blood sugar (hyperglycemia), the beta cells in the pancreas release insulin, a peptide hormone. Most body cells are unable to take in glucose passively as they do with simple gases and small nonpolar molecules because glucose is a fairly large molecule (macromolecule). Therefore, in order to cross the hydrophobic bilayer membrane glucose diffuses down its concentration gradient into cells via a special protein that is embedded through the membrane. This glucose channel proteins are only able to open when the cell receives a chemical signal from insulin. It is important to note that the insulin hormone is received by the insulin receptor which is also on the cell membrane. This signal is what opens the glucose channel which is embedded in the membrane. Think of a scenario in which a doorbell is pushed by an Amazon delivery driver to alert the recipient of a package at their door. The Amazon driver would be analogous to the insulin molecule and the doorbell would be the insulin receptor on the cell membrane (just the exterior). The package is analogous to glucose that is trying to get into the cell (house) – one distinction is that glucose would already be present due to digestion not due to the action of insulin. The recipient (cell) opens up a door (glucose channel) on the membrane which goes all the way through both interior and exterior. If the driver does not ring the doorbell the recipient will not open the door. If the driver never arrives the doorbell will not ring. In type I diabetes the beta cells that produce insulin no longer function. Typically this is diagnosed early. In type II diabetes the insulin receptors may not recognize insulin or become resistant too insulin even though insulin is being produced by the beta cells. Create a diagram also known as a feedback loop on your tables which demonstrates how the body responds to high blood sugar to bring a person back down to normal blood sugar. Excess sugar that is not needed by the cells is stored in the liver where it is converted to glycogen. Can you create a diagram for smart devices that work in a similar fashion? Take for example a smart thermostat that is connected to the internet. What sensor(s) would it need to have? How would it respond to fluctuations in temperature? What kind of feedback loop is it utilizing? How is the pancreas like a sensor? How is the insulin molecule like a signal? How is the opening and closing of the glucose channel like an actuator?

In response to low blood sugar (hypoglycemia), the alpha cells in the pancreas release glucagon. (Helpful hint: glucagon sounds like glucose is gone). Glucagon then goes to the liver which begins to convert the stored glucose (now in glycogen form – a polymer of glucose) back into glucose (monomer) to be released into the bloodstream. This results in blood glucose levels increasing. Make a feedback loop to demonstrate what happens when the body has low blood sugar. Can the cells absorb this glucose? No! They still need insulin to be released by the beta cells in the pancreas. Can you now combine both feedback loops into one feedback loop that satisfies all parameters?

Today, you will be performing a popular diabetic test known as the oral glucose tolerance test utilizing blood plasma collected from three patients over a period of 3 hours. The patient is advised to go on a fast of 8+ hours to establish a baseline of fasting glucose levels. When the patient arrives to the doctor’s office they are given an 8 ounce (237 milliliters) glucose solution containing 3.5 ounces (100 grams) of sugar. Their blood plasma is analyzed at the one hour mark, two hour mark, and three hour mark. You will also be provided with additional blood plasma to test for insulin levels at these time intervals. (This would be a good opportunity to review the plasma layer of the blood and if a centrifuge is available you can demonstrate with red colored milk and oil mixed together.)

You will collect the glucose data using the glucose paper sensors. A sensor is a device that can be used to determine the presence or absence of an object. These sensors have to have an electrical circuit in order to function. We will need a negative electrode, a positive electrode, and a reference electrode. Can you think of why we need at minimum three different electrodes? Utilizing the diagram shown in the PowerPoint draw the circuits on to your glucose paper sensors. When you are ready using the labeled blood glucose bottles (0 min, 60 min, 120 min, 180 min) place 1-2 drops on the testing sheet for each corresponding time. Next, place your glucose sensor directly on top of the blood plasma. Observe the color change and using the provided data reference sheet input convert the color change into an electrical value and then input the electrical value into the Java program. Record the result provided in mg/dL as your glucose concentration value. Repeat until you have completed glucose results for each patient. Complete your data tables, and graphs displaying glucose concentration over time. What are some trends you notice? What are your current thoughts on each patient? Are they diabetic? If so, type I or type II? (Note: This is a simulated process and the actual underlying chemistry is pH change).

We will also measure insulin values to serve as an additional control to help validate our diagnosis. Typically, this is not done as part of the oral glucose tolerance test. Place 1-2 drops of the labeled blood glucose (for insulin testing) on to your testing sheet. Next, place 1 drop of insulin indicator solution directly on top of the blood plasma. Input the observed color change into the Java program and record the insulin value. Complete your data tables, and graphs displaying insulin concentration over time. Record the results in pmol/L. Can a computer detect glucose or insulin without first converting it into an electrical signal? Why, or why not? If we wanted to display both insulin and glucose trends over time how could we display that? Are you able to convert mg/dL into mmol/L? Why are units important? You will be creating a mini poster to communicate your results to share out with the class on the chart paper.

Lesson Closure (written as if talking to students):

Typically the sensors would arrive to the lab with the circuits drawn utilizing a variety of technologies such as photolithography, screen printing, and direct transfer depending on the size of the application. Extremely tiny sensors can now be created with this technology are these small sensors are known as micro-electro-mechanical systems (MEMS). Can you research examples of how this technology can be used to create sensors for the purpose of glucose monitoring? What are some examples you have found? Notice how in our lab, we needed the glucose to first react with our sensor (color change) and then we were able to detect the color change to an electrical signal which was interpreted as a glucose concentration value. Typically biosensors are coated with a biological agent which will selectively react (ideally) to our intended substrate and convert that change to an electrical signal. Can you think of why reasons why sensor selectivity is important? What if our sensor registered only registered changes at high concentrations? Can you think of reasons why sensor sensitivity is important? Could a light sensor be used to accurately determine glucose concentration? How would a wearable glucose sensor benefit in diabetes detection?

Extension Activity: *Can you devise a detection and treatment protocol utilizing technology? You may use the image displayed which identifies layers of a typical Internet of Things (IoT) smart technology to guide you. Be sure to identify each layer of your protocol. You may also research using the internet, a list of resources have been provided to get you started.*

Lesson Background & Concepts for Teachers

- Insulin/glucagon glucose feedback loops (google images has plenty of examples)
- The role of glucose in cellular respiration.
- The role of insulin in cell signaling.
- Be familiar with basic circuit design (positive, negative, reference).
- Be familiar with the general use of sensors in biological applications (in-situ, in-vivo, and ex-vivo) as well as other non-biological examples (detection of lead in water, sensors in phone, sensors to detect blood pressure, sensors to detect glucose etc.)

Important Vocabulary

Term	Definition
Glucagon	A protein hormone secreted by pancreatic endocrine cells that raises blood glucose levels; an antagonistic hormone to insulin.
Glucose Tolerance Test (GTT)	A test of the body’s ability to metabolize glucose that involves the administration of a measured dose of glucose to the fasting stomach and the determination of blood glucose levels in the blood or urine at intervals thereafter and that is used especially to detect diabetes.
Homeostasis	The maintenance of relatively stable internal physiological conditions (as body temperature or the pH of blood) in higher animals under fluctuating environmental conditions.
Hormone	A product of living cells that circulates in blood and produces a specific, often stimulatory, effect on the activity of cells that are often far from the source of the hormone.
Insulin	A protein hormone secreted by the pancreas that is essential for the metabolism of carbohydrates and the regulation of glucose levels in the blood.
Positive Feedback	Feedback that tends to magnify a process or increase its output.
Negative Feedback	A primary mechanism of homeostasis, whereby a change in a physiological variable that is being monitored triggers a response that counteracts the initial fluctuation.

Type 1 Diabetes	A disease that usually develops during childhood or adolescence and is characterized by a severe deficiency of insulin, leading to high blood glucose levels.
Type 2 Diabetes	A disease that develops especially in adults and most often obese individuals and that is characterized by high blood glucose resulting from impaired insulin utilization coupled with the body’s inability to compensate with increased insulin production.
Sensor	A device which can detect or record to a physical stimulus and convert it into an electrical signal
Biosensor	A device that can convert a biological signal into an electrical signal.
Sensitivity (Sensors)	The measure of accuracy of the desired output (for example is our glucose sensor giving us reliable measurable electrical data)
Selectivity (Sensors)	The measure of the accuracy to discern between desired output and other potential disruptions (for example glucose sensor is responding to testosterone levels also)

Troubleshooting Tips

It is important that students only use the labeled dropper for each bottle. Otherwise, if there is contamination the entire lab will not work. The students should be cognizant of this. A way to avoid this from happening is to provide disposable pipets and have students throw them away after extracting the simulated blood plasma. Each bottle should have its own pipet. If you are running short on time you can provide students with a completed key so they do not have to input data into the Java program.

Other Helpful Information

Google forms is a great way to deliver informal assessments and will be utilized for the pre-test and post-test. A website like www.tinyurl.com can be utilized to shorten the link to the google form to ease in dissemination. There is a link provided to the pre-test which you may copy and modify to your needs.

This pre-test is also the post-test. The provided PowerPoint attachment can be displayed on the day of the lab to aid in guiding students through the card sort and the lab. The presenter notes have been filled out with helpful tips and guiding questions to aid in Socratic seminar and formative questioning while circulating. There are also two Word attachments with student and teacher files. The student files contain templates for data tables and the charts. It is advisable to have students create their own to understand the lab better. The student files also contain the diagnosing diabetes test sheet. This sheet should be printed out and laminated ahead of time as they will conduct their tests on this sheet. The student files also contain the card sort activity. It is advisable to print and number the backs (1 for group 1, 2 for group 2…) before laminating to cut out for repeated student use and to avoid mixing them up if a student drops one.

You can have a chemistry teacher at your school help you in creating the desired pH for each solution and to obtain pH papers and universal indicator. It's best to have 4 big bottles of starting solution which can be aliquoted out using the key into student test kits ahead of time. Alternatively, you can order a diagnosing diabetes refill kit from Science Take-Out for PLTW – this kit will provide pre-prepared solutions, pH paper, and universal indicator. You will have to adjust the values on the teacher key provided to match the pH solutions provided by this kit.

Attachments

- PowerPoints for Lesson w/teacher notes
- Student Files
- Teacher files with keys and link to Java program

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Authors

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Contact information

Mohammed Patel – mohammed.patel@ocps.net