Instructional Lesson Plan

Exposing High School Students to Sensors and Machine Learning

Raquel Diaz RET B.S.E.E., Jennifer Blain Christian PhD.

LESSON DETAILS

Subject Area(s): Algebra 3-4 Mathematics

Focus Grade Level: 11th Grade

Grade Level Range: 11th -12th

RESEARCH BACKGROUND

Students explore basic principles of sensors and machine learning (ML) in solving mathematical problems. Students develop a process to understand and apply the Linear Regression learning algorithm. They begin by using Desmos Graphic Calculator and use Linear Regression to graph several sets of data and identify their function family. Is it a Linear Equation or a Quadratic Equation? The student will need to determine the best fit model using a statistical parameter called r = correlation coefficient. Students will document their work with a mathematical equation and a diagram. After identifying the function 'manually' students learn to use the Python Linear Regression algorithm. The Linear Regression algorithm instantly finds the best fit for a data set and they will obtain the slope and intercept. Subsequent lessons will allow the students to apply the Linear or a Logistic ML algorithm once they learn about sensors and design their own experiment using a Cell Phone Application or an Arduino Circuit board.

LESSON SUMMARY

Students use the engineering design lab to generate data for assessing the design lab.

Students will work in groups and use several tables of data to complete linear and logistic regression. The students will first be exposed to the explanation of Function Families (Linear, Quadratic, Exponential and Cubic Functions). They will be given data and manually determine the best fit function family. We will also summarize the statistic parameters, correlation coefficient, accuracy, precision, and f-score.

Students will learn about sensors and real-world applications. Teacher will demonstrate how sensors are in your cellphone and have students download Arduino sensor App. Students will study 2-3 sensors and select 1 to collect data. Data will be exported from their cellphones to an Excel sheet.

Students will be introduced to Machine Learning and the teacher will demonstrate how Machine Learning is used in the real world sharing with students how Python code is utilized in the ML scripts.

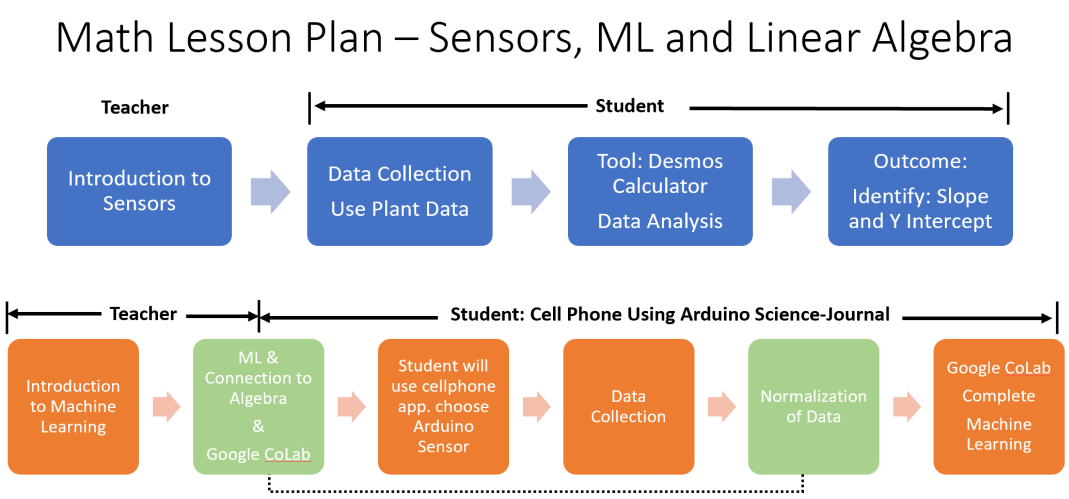
Students will use their own generated data and use Linear or Logistic Regression Machine Learning Algorithms to determine if we can predict future values.

Assessment questions that will be answered by the students: Importance of Sensors? Why do we measure data? Which applications in the Real-World interest you the most and why? Why would you need to use Machine Learning versus Graphic Calculators?

MATERIALS AND EQUIPMENT

- Blow dryer to change temperature
- Lamp that allows you to adjust light (on, off is best)
- Objects to determine the distance they are located from the sensor: Legos or Toys
- Objects to determine the direction they move from the sensor: Legos or Toys
- 3-4 page Mini Journal for Project
- 11 X 14 Poster Board OR Use Technology to Present Results
- Science Journal Link Arduino Sensors on your Cell Phone
- https://www.desmos.com/calculator
- Arduino Nano BLE33 Order Information (Accelerometer, Temp, Humidity, Light, Proximity Sensor, Gesture Sensor, Microphone, Bluetooth)
- Arduino Nano 33 BLE Sense Photo and data sheet
- Arduino Nano 33 BLE Sense Quick Start Guide

ATTACHMENTS



Lesson 1: MATH CONCEPT: FUNCTION FAMILY

Teacher Lesson Power Point: What are Function Families and their Equation Format?

Assessment: Assessment on Function Familias

Lesson 2: LINEAR AND LOGISTIC REGRESSION

Teacher Lesson Power Point: Introduction to Linear and Logistic Regression

Desmos Graphic Calculator Link: https://www.desmos.com/calculator

Assessment: Can I Identify Linear vs Logistic Regression?

Lesson 3 SENSORS: Where are they? Why are they Important?

Teacher Lesson Power Point: https://docs.google.com/presentation/d/1gvzNSPlNfQ2_UhfPebADNy7Y-KE4cbV7/edit?usp=sharing&ouid=105364705071120506836&rtpof=true&sd=true Intro to Sensors

Guest Speaker: Jennifer Blain Christian

Lesson 4 INSTRUCT HOW TO SETUP SENSORS - Cellphone Arduino Application

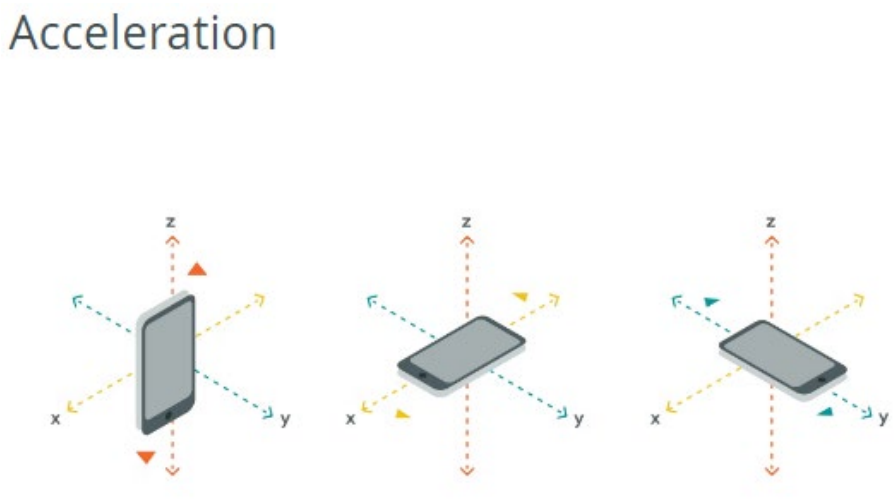
Teacher Lesson: Instructions Load Arduino Instructions on Uploading Arduino onto Cellphone (Science Journal Setting Up Experiments)

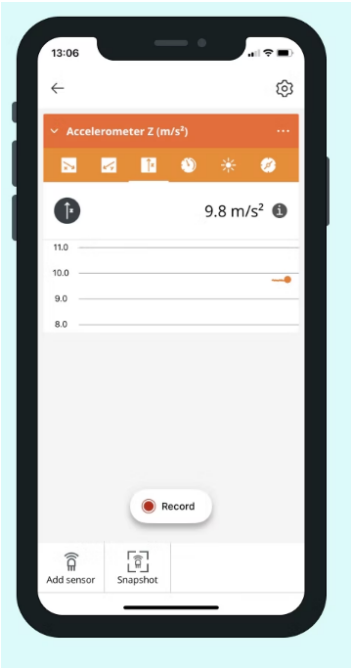
Guest Visitor: Jean Larson

Lesson 5 MACHINE LEARNING

Teacher Lesson Power Point: https://canvas.asu.edu/courses/81492/pages/ml-intro?module_item_id=5787289 **Intro to Machine Learning**

Guest Speaker: *Kristen Jaskie to Present ML*





EDUCATIONAL STANDARDS

K-12 TEACHERS

Next Generation Science Standards (NGSS)

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

Arizona State Standard

Functions - F		
Interpreting Functions (F-IF)		
A2.F-IF.B **Interpret functions that arise in applications in terms of the context.**	**A2.F-IF.B.4**	For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. Include problem-solving opportunities utilizing a real-world context. Key features include: intercepts; intervals where the function is increasing, decreasing, positive, or negative; relative maximums and minimums; symmetries; end behavior; and periodicity. Functions include linear, quadratic, exponential, polynomial, logarithmic, rational, sine, cosine, tangent, square root, cube root and piecewise-defined functions.
	A2.F-IF.B.6	Calculate and interpret the average rate of change of a continuous function (presented symbolically or as a table) on a closed interval. Estimate the rate of change from a graph. Include problem-solving opportunities utilizing real-world context. Functions include linear, quadratic, exponential, polynomial, logarithmic, rational, sine, cosine, tangent, square root, cube root and piecewise-defined functions.
A2.F-IF.C **Analyze functions using different representations.**	**A2.F-IF.C.7**	Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases. Functions include linear, quadratic, exponential, polynomial, logarithmic, rational, sine, cosine, tangent, square root, cube root and piecewise-defined functions.
	A2.F-IF.C.8	Write a function defined by an expression in different but equivalent forms to reveal and explain different properties of the function. b. Use the properties of exponents to interpret expressions for exponential functions and classify those functions as exponential growth or decay.

LEARNING OBJECTIVES

- Create and represent a Linear Equation and define mathematical structure.
- Create and manually represent Linear Regression.
- Create and manually represent Logistic Regression.
- Describe what a Sensor and Student will choose 1 Sensor for this Project
- Basic knowledge of Linear Regression in Machine Learning
- Execute Google CoLab to experience Python Code using Linear Regression.
- Students will be able to classify variables (light, heat, vibration, noise) using Machine Learning.
- Demonstrate understanding of Sensors and Machine Learning in a Final Report

VOCABULARY (BILINGUAL)

Linear Equation	**Y = mx + b**
Slope and Intercept	M = slope of the line b = y intercept is the where the line intercepts the y axis
Linear Regression	Used to solve regression problems. Data is linear or continuous. Used to model the linear relationship between a dependent and independent variable.
Logistic Regression	Data is separated so the categories become distinct. Reference Article
Sensor	A sensor is a device that detects and responds to some type of input from the physical environment. The specific input could be light, heat, motion, moisture, pressure, or any one of a great number of other environmental phenomena.
Machine Learning	Machine learning algorithms have shown great promise in providing solutions to complex problems. Some of the applications we use every day from searching the Internet to speech recognition are examples of tremendous strides made in realizing the promise of machine learning.[1]
Correlation Coefficient	The correlation coefficient is a statistical measure of the strength of the relationship between the relative movements of two variables.
Accuracy	Accuracy is how close or far off a given set of measurements (observations or readings) are to their true value,
Precision	Precision is how close or dispersed the measurements are to each other. In other words, precision is a description of random errors, a measure of statistical variability.
f-score	In statistical analysis of binary classification, the F-score or F-measure is a measure of a test's accuracy. It is calculated from the precision and recall of the test, where the precision is the number of true positive results divided by the number of all positive results, including those not identified correctly, and the recall is the number of true positive results divided by the number of all samples that should have been identified as positive.

LESSON PROCEDURE

INTRODUCTION/MOTIVATION

Share my experience in SenSip RET program. Presentation on Project. How I learned about the Baby Boot Project.

SenSip RET Summer Internship Experience for Ms. Diaz Algebra 3-4 acher at Trevor Browne Presentation

Connect to Culture, experience a baby bootie. How many of you made one of these? Or do you know of someone that did?

LEARNING ACTIVITIES/STRATEGIES

Prior Knowledge: Algebra 1-2

Lesson 1: MATH CONCEPT: FUNCTION FAMILY

Objective: Students will work in groups and use several tables of data to complete linear and logistic regression. The students will first be exposed to the explanation of Function Families (Linear, Quadratic, Exponential and Cubic Functions). They will be given data and manually determine the best fit function family. We will also summarize the statistic parameters, correlation coefficient, accuracy, precision, and f-score.

Teacher Lesson Power Point: What are Function Families and their Equation Format? (Linear, Quadratic, Exponential, Cubic) Refresh on dependent and independent variables. y=mx + b

VIDEO: Find Equation of a Straight Line in Desmos

Desmos Graphic Calculator Link: https://www.desmos.com/calculator

Assessment: Assessment on Function Familias

Lesson 2: LINEAR AND LOGISTIC REGRESSION

Objective: Students will use their own generated data and use Linear or Logistic Regression Machine Learning Algorithms to determine if we can predict future values.

Teacher Lesson Power Point: Introduction to Linear and Logistic Regression

Assessment: Can I Identify Linear vs Logistic Regression?

VIDEO: Do a Linear Regression using Desmos https://youtu.be/zcZaI-xfiFE

HANDOUT: Instructions on doing linear regression using Desmos Graphic Calculator.

Assignment 2: Students will complete linear regression using Desmos Calculator

Data: Data for Assignment 2

Desmos Graphic Calculator Link: https://www.desmos.com/calculator

Assignment 2: Student Example

Lesson 3 SENSORS: Where are they? Why are they Important?

Objective: Students will learn about sensors and real-world applications.

Teacher Lesson Power Point: https://docs.google.com/presentation/d/1gvzNSPlNfQ2_UhfPebADNy7Y-KE4cbV7/edit?usp=sharing&ouid=105364705071120506836&rtpof=true&sd=true Intro to Sensors
Guest Speaker: Jennifer Blain Christian

Assessment/Assignment 3: 1 Page Summary of Sensors – Student select Sensors (at least 2)

Assignment 3: Student Example

Lesson 4 USE CELLPHONE APP – INSTRUCT HOW TO SETUP SENSORS

Objective: Teacher will demonstrate how sensors are in your cellphone and have students download Arduino sensor App. Students will study 2-3 sensors and chose 1 sensor to collect data. Data will be exported from their cellphones to an excel sheet.

Teacher Lesson: Instructions Load Arduino Instructions on Uploading Arduino onto Cellphone (Science Journal Setting Up Experiments)

Instructions Using a sensor and collecting the Data **Link to Each Type of Sensor Experiment**

Activity 4: Design Sensor Experiment and Collection of Data (Form TBD)

Activity 4: Review Lesson on Sensor: Acceleration – Link to Lesson

Lesson 5 MACHINE LEARNING

Objective: Students will be introduced to Machine Learning and the teacher will demonstrate how Machine Learning is used in the real world sharing with students how python code is utilized in the ML scripts.

Teacher Lesson Power Point: https://canvas.asu.edu/courses/81492/pages/ml-intro?module_item_id=5787289 **Intro to Machine Learning** **(Invited Kristen Jaskie to Present ML)**

Assessment: What is Machine Learning? (Form TBD)

Demonstrate Linear Regression ML Google Colab Link

Activity 5: Students will use their Sensor Data and Run a Linear Regression or Logistic Regression Machine Learning Algorithm.

Final Report to be turned in at end of Project

Student will create a report of Data Collection, Sensor, and ML Project (Form TBD)

Student Example (Form TBD)

CLOSURE

Use Exit Tickets

Guest Speakers: Mentor will be invited to the class virtually.

Hands On Activity: Student will build graphs and determine the key features of the function.

Sensor Lab: Students will use sensors to learn about how a sensor works. Students will set up a sensor experiment and collect data. Finally, the students will use the data to perform linear regression using Google CoLab.

Final Report: Students will present their learnings/findings.

ASSESSMENT

FORMATIVE ASSESSMENT

Time in Class: Provide time for students to work on Lesson for the day. Review responses to "Check-In Quizzes".

Notebooks: Students will use a mini science notebook/journal and graphic organizers, a vocabulary index to track their learning from the beginning, middle and end of the lesson.

Coaching: Meet with each student to monitor progress, especially those who were absent for any of the lessons.

Lesson 1: Learning about Function Family's Assessment on Function Familias

Lesson 2: **LINEAR AND LOGISTIC REGRESSION** Assessment: Can I Identify Linear vs Logistic Regression?

Lesson 3: What are Sensors? (Microsoft Forms Quiz - TBD)

Lesson 4: Student will demonstrate they know how to use sensor and log data using the cellphone app. If a student does not have a cellphone, they will have the option of using an Arduino Uno or Nano Board.

Lesson 5: Assessment: What is Machine Learning (Microsoft Forms Quiz - TBD)

SUMMATIVE ASSESSMENT

After Lesson 5: Students will present their Results of Sensor Experiment

1) Everyone will turn in Turn in 3-4 page Mini Journal for Project
2) Presentation to Class Use a 11x14 Poster

OR

Online Tool (PowerPoint…)

Expectations: Review the Deadline and Rubric.

Rubric for Assignment (TBD)

CONTRIBUTORS

INDIVIDUALS

Jennifer Blain Christian PhD: Mentor, Sensor, Signal and Information Processing Center (SenSIP)

Dan Gulick: Mentor, Science Technologist

Jean Larson: Education Director, Center for Bio-mediated and Bio-inspired Geotechnics (CBBG)

Kristen Jaskie PhD: Mentor Machine Learning

Mike Stanley Director LightSense: Mentor Machine Learning

Karl Ernsberger: SenSip RET Science Teacher Lumos Arts Academy

SUPPORTING PROGRAM

RET Site: Sensor, Signal and Information Processing Algorithms and Software
Sensor, Signal and Information Processing Center (SenSip), in partnership with Arizona State University and the National Science Foundation.

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Photo Image Source: IBM