Lesson Plan: Teaching Introductory Calculus (Differentiation) using Atmospheric CO_2 Data

As a **high school** or **undergraduate Mathematics** teacher, you can use this set of computer-based tools to help you in teaching topics such as **differentiation**, **derivatives of polynomials**, and **tangent line problems** in **Introductory Calculus**.

This lesson plan allows students to perform polynomial differentiation and solve tangent line problems using climate data such as atmospheric CO_2 concentrations data since 1950.

Thus, the use of this lesson plan allows you to integrate the teaching of a climate science topic with a core topic in Mathematics.

Use this lesson plan to help your students find answers to:

- *Plot a graph and find the polynomial equation to model the average yearly atmospheric CO_2 levels from 1950 to 2017 (using data records provided).*
- *Compare and analyze the rate of change of atmospheric CO2 levels by applying polynomial differentiation*
- *Based on observed trends, what will the atmospheric CO_2 level be in 2100?*

About the Lesson Plan

Grade Level	High school, Undergraduate
Discipline	Mathematics
Topic(s) in Discipline	Introductory Calculus, Differentiation, Derivatives of Polynomials, Tangent Line Problem
Climate Topic	Climate and the Atmosphere, The Greenhouse Effect

Location	Global
Access	Online, Offline
Language(s)	English
Approximate Time Required	120 – 130 min

1 Contents

1. **Reading (30 – 45 min)** — A reading that introduces the topics of differentiation and derivatives of polynomials. The resource also includes exercises.

   http://web.mit.edu/wwmath/calculus/differentiation/polynomials.html

2. **Micro-lecture (video) (~10 min)** — A micro-lecture (video) that explains polynomial differentiation with examples and practice questions. It also includes a tutorial on tangents of polynomials.

   https://www.khanacademy.org/math/ap-calculus-ab/ab-derivative-rules/ab-poly-diff/v/derivative-properties-and-polynomial-derivatives

3. **Classroom/Laboratory activity (~60 min)** — A classroom/laboratory activity to learn and apply polynomial differentiation and solve tangent line problems for global average CO_2 data from 1950 to 2017.

   http://sustainabilitymath.org/calculus-materials/

4. Suggested questions/assignments for learning evaluation

- Plot a graph and find the polynomial equation to model the average yearly atmospheric CO_2 levels from 1950 to 2017 (using data records provided).
- Based on observed trends, what will the atmospheric CO_2 level be in 2100?

2 Step-by-step User Guide

Here is a step-by-step guide to using this lesson plan in the classroom/laboratory. We have suggested these steps as a possible plan of action. You may customize the lesson plan according to your preferences and requirements.

1. Introduce the topic through a reading and exercises

- Introduce the topic of differentiation.
- Explain derivatives of polynomials with the help of the reading and exercises, "Derivatives of Polynomials", from World Web Math, Massachusetts Institute of Technology.

  The reading can be accessed at: http://web.mit.edu/wwmath/calculus/differentiation/polynomials.html.

2. Play a micro-lecture (video)

Next, play this micro-lecture (approx. 10 min), "Differentiating polynomials", to help students further understand polynomial differentiation through examples and exercises.

The micro-lecture "Differentiating Polynomials", from Khan Academy, is available at https://www.khanacademy.org/math/ap-calculus-ab/ab-derivative-rules/ab-poly-diff/v/derivative-properties-and-polynomial-derivatives.

3. Conduct a classroom/laboratory activity	Then, help your students apply the learned concepts through a hands-on classroom/laboratory activity, "Mauna Loa Yearly Average CO2", by Thomas J. Pfaff at Sustainability Math. This activity uses atmospheric CO_2 data from the Mauna Loa site for the period 1950 to 2017. This activity will help students to • observe the trend in increasing atmospheric CO_2 levels • infer the approximate year when atmospheric CO_2 levels could cause global temperatures to increase by 2°C (leading to serious climate change-related problems) • determine the desired trends in atmospheric CO_2 levels that could help in avoiding or mitigating such climate change-related consequences Go to http://sustainabilitymath.org/calculus-materials/. • Download the material in the project, "Mauna Loa Yearly Average CO2", under Calculus I – Differentiation Related Projects. • Students can plot the time-series graph of atmospheric CO_2 by using the data in the Excel file or can directly use the graph provided in the Word file. • Conduct the exercises 1-6 to predict atmospheric CO_2 levels in the future. (Optional: exercises 7 and 8). • Discuss the possible impact of these trends on global temperature and climate.
4. Questions/Assignments	Use the tools and the concepts learned so far to discuss and determine answers to the following questions: • *Plot a graph and find the polynomial equation to model the average yearly atmospheric CO_2 levels from 1950 to 2017 (using data records provided).*

- *Based on observed trends, what will the atmospheric CO_2 level be in 2100?*

3 Learning Outcomes

The tools in this lesson plan will enable students to:

- calculate the derivatives of polynomials
- interpret and compare the slope of a curve at different points
- compare and analyze the rate of change of atmospheric CO2 levels by applying polynomial differentiation
- predict future atmospheric CO2 levels based on current levels, and discuss the corresponding effect on climate

Further questions that have been listed as associated with the main activity:

This activity will help students to:

- observe the trend in increasing atmospheric CO2 levels
- infer the approximate year when atmospheric CO2 levels could cause global temperatures to increase by 2°C (leading to serious climate change-related problems)
- determine the desired trends in atmospheric CO2 levels that could help in avoiding or mitigating such climate change-related consequences

4 Additional Resources

If you or your students would like to explore the topic further, these additional resources will be useful.

1. **Visualization** — An interactive visualization, "Interactive Graph showing Differentiation of a Polynomial Function" from Interactive Mathematics:

   https://www.intmath.com/differentiation/derivative-graphs.php

5 Credits/Copyrights

All the teaching tools in our collated list are owned by the corresponding creators/authors/organizations as listed on their websites. Please view the individual copyright and ownership details for each tool by following the individual links provided.
We have selected and analyzed the tools that align with the overall objective of our project and have provided the corresponding links. We do not claim ownership of or responsibility/liability for any of the listed tools.

1. **Reading, "Derivatives of Polynomials"** — World Web Math, Massachusetts Institute of Technology
2. **Micro-lecture (video), "Differentiating polynomials"** — Khan Academy
3. **Classroom/laboratory activity, "Mauna Loa Yearly Average CO2"** — Thomas J. Pfaff, Sustainability Math

4.	**Additional Resources**	Interactive Mathematics