Ages 14 - 19 | Design Thinking | Empathize | Programming & Coding | Problem Solving

Mathematics | 120 min | Educator's Guide

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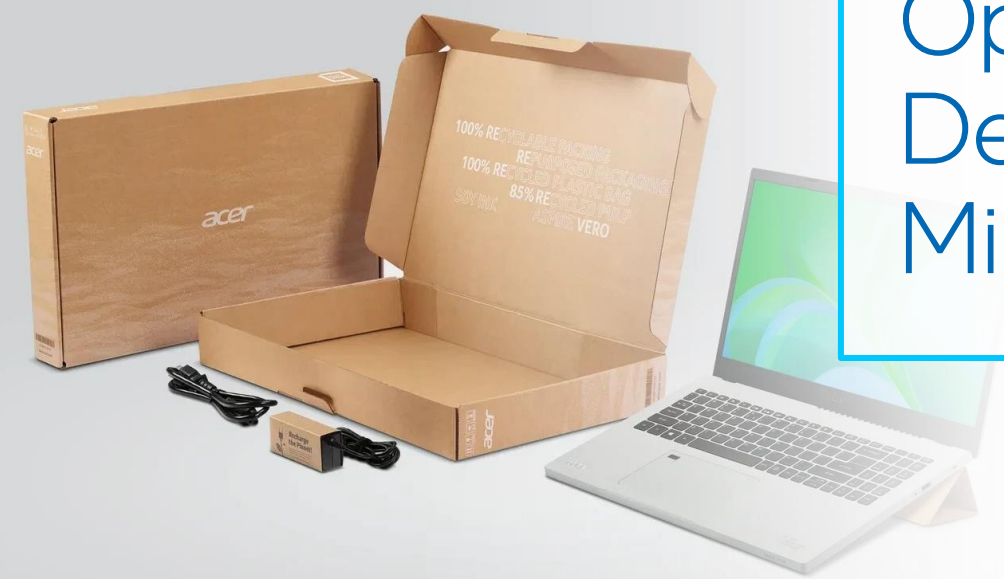

Optimize, Design, and Minimize

Intel® Core™ processors

Summary: Learners will use Linear Programming to optimize the number of boxes cut from a sheet, and apply derivatives to maximize box volumes, enhancing efficiency and reducing waste in packaging design.

Key Concepts

Optimization

Linear Programming

Derivatives

Software

Jupyter Notebook

Instructional Objectives

Learners will be able to:

1. Understand the principles of packaging design and optimization using Linear Programming (LP).
2. Apply LP to calculate the optimal number of boxes that can be cut from a large cardboard sheet.
3. Apply derivatives to solve the problem of optimization.

Learning Outcomes

- Apply LP using Jupyter Notebook to determine the optimal number of boxes that can be cut from a cardboard sheet.
- Effectively use derivatives to maximize the volume of a box for shipping laptops.

Real World Application

Empower learners to use derivatives and LP to design sustainable, efficient packaging that reduces material waste in product design and logistics.

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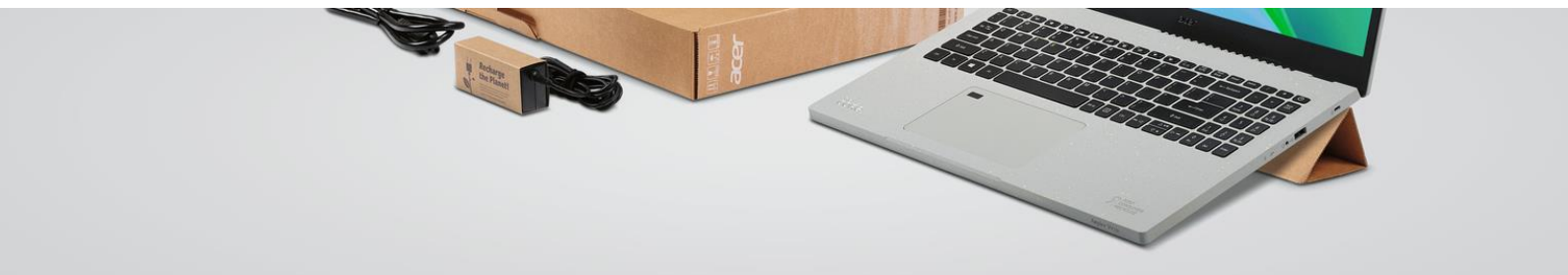
1. Lesson Overview

	Activity	Innovation Skill
Introduction (20 min) **Slides 1 – 7**	Introduction to the problem of packaging waste.	Design Thinking (Empathize)
	Introduction to optimization.	
Development (90 min) **Slides 7 – 29**	Explore the various mathematical methods of optimization.	
	Introduction to Python & Jupyter Notebook.	
	Explore and solve various optimization problems related to the packaging of laptops, focusing on maximizing space utilization, minimizing waste, and improving shipping efficiency.	Programming & Coding (Problem Solving)
Conclusion (10 min) **Slides 30– 31**	Lesson summary.	



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2. Session Preparation

Logistics

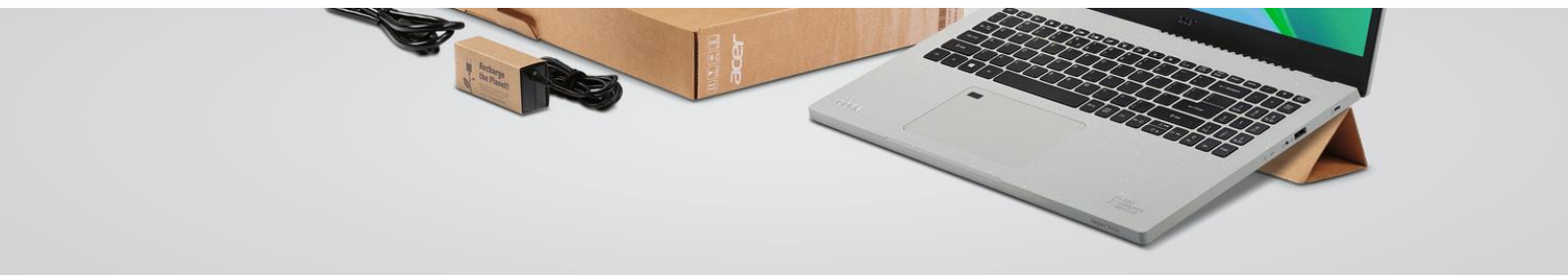
Items
Laptop, Desktop or Chromebook (Recommended: 2 learners per laptop)
Worksheet

Installation

1. Refer to this link (http://bit.ly/SFISP-Jupyter) for the Jupyter Notebook installation guide and follow the instructions provided.
2. Download and extract files found in the 'Working Files' folder.
3. Other things to note:
    - For hardware requirements, please refer to the minimum hardware requirements from the software provider.

Working files contain:

- Worksheet
- Jupyter Notebook Worksheet (.ipynb file)
- Worksheet: Answer key
- Beginner's Guide



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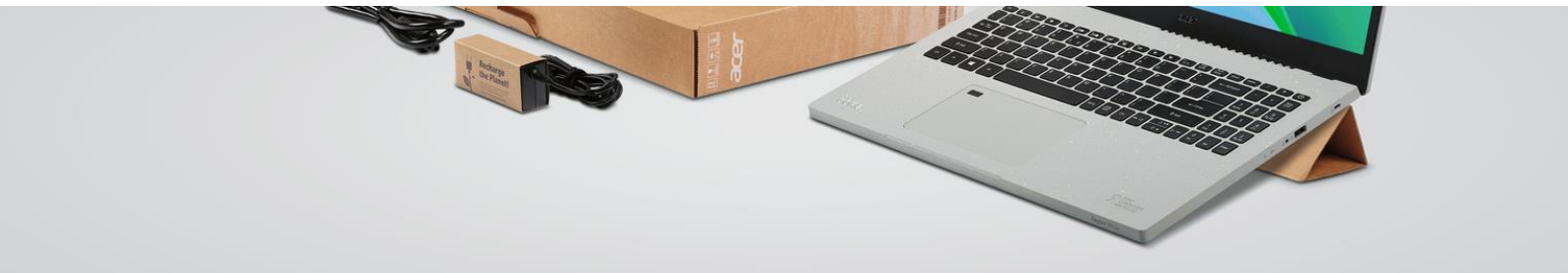
3. Activity Guide

Introduction (slides 1 – 7)		
Duration	**Slide**	**Activity**
20 min	1	Introduction to lesson.
	2	Educators provide learners with an overview of the lesson: ▪ Understand the role of packaging design in sustainable product development and its impact on material efficiency. ▪ Apply Linear Programming to determine the optimal number of laptop boxes that can be cut from large cardboard sheets. ▪ Learn how to use differentiation in order to solve optimization problems.
	3	Educators begin by asking learners what happens to all that packaging after unboxing a new gadget? Educators may extend the discussion by asking: What packaging materials have you seen when unboxing gadgets? If learners struggle, ask them to think about unboxing videos or gadgets they've received.
	4-5	Educators explain the impact of packaging materials. Describe the common materials found in packaging, such as foam, cardboard, and plastic, and how they can negatively affect the environment. Educators present the question to the learners: What can be done to solve this problem? Some expected responses may include: ▪ Use more recyclable or biodegradable materials ▪ Increase consumer awareness
	6	Learners watch a video on how Acer is tackling the problem through sustainable packaging. Source: https://www.youtube.com/watch?v=YGnTprEWek0&
	7	Educators summarize Acer's approach - Share how Acer uses recyclable materials instead of plastic and foam in their packaging, balancing protection with eco-friendly design. Introduce the idea of optimizing cardboard usage to further reduce waste and cost while ensuring laptops of various sizes remain protected.



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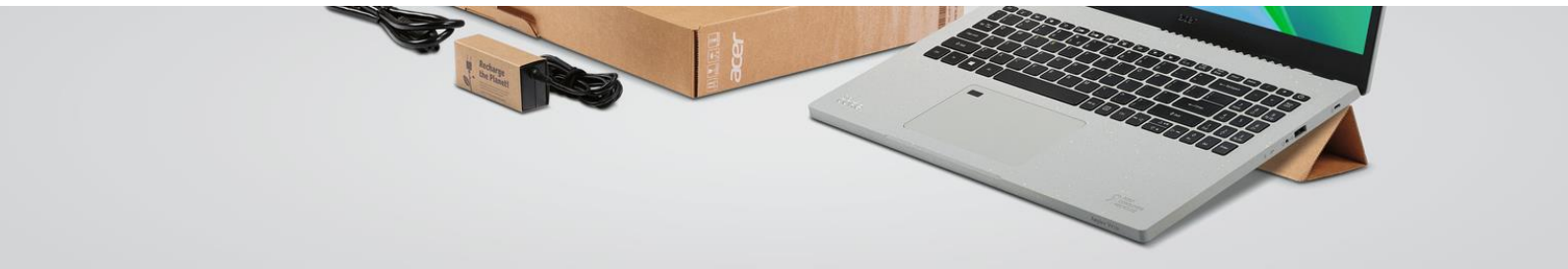
Development (slides 8 – 29)		
Duration	**Slide**	**Activity**
90 min	8-9	Educators introduce the problem to the learners. Educators ask the learners how to cut squares of different sizes from a 200 cm x 200 cm sheet to maximize the number of squares while minimizing waste. Expected responses may include: ▪ Experiment with different layouts to find the most efficient arrangement. ▪ Use a mix of sizes to better utilize the sheet and fill gaps.
	10	Educators discuss the concept of optimization. ▪ Optimization involves finding the best solution from many options while meeting specific constraints. ▪ Optimization aims to maximize or minimize objectives such as profit, efficiency, or cost. ▪ It uses mathematical models to determine the best outcome. ▪ Linear programming and derivatives are some methods used in solving optimization problems.
	11-12	Educators introduce Linear Programming (LP) ▪ Linear Programming is a method for finding the best outcome, such as maximum profit or minimum cost, using linear relationships in a model. ▪ The Objective Function specifies what needs to be optimized (maximized or minimized). ▪ Constraints define the limits within which the solution must be feasible and practical.
	13-14	Educators explain the Objective Function and constraints in detail. The Objective Function is a linear equation representing what needs to be optimized, such as $z = c_1x_1 + c_2x_2 + \ldots + c_n\,x_n$ where c_1, c_2 are coefficients representing the contribution of each decision variable to the objective function. Constraints are linear inequalities or equations that define limits, such as $a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n \leq b_1$ where a_ij are coefficients that define the relationship between the decision variables x_j and the i-th constraint.



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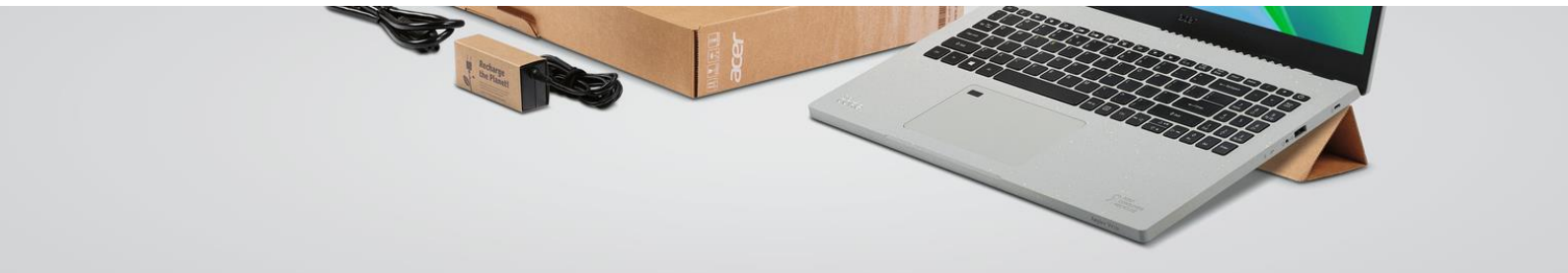
Development (slides 8 – 29)		
Duration	**Slide**	**Activity**
90 min	15-16	Educators guide learners through a detailed example of Linear Programming, applying the concepts of Objective Function and Constraints. Educators ask the learners to calculate the maximum value of the objective function by looking at the graph. The maximum value of is Z = 30 It is obtained for the values of $X_1 = 0$ and $X_2 = 5$
	17	Educators describe a real world example of optimization using LP ▪ United Parcel Service (UPS) used Linear Programming: to minimize fuel costs for optimizing package delivery routes. ▪ This optimization led to potential annual savings of $180,000 in fuel expenses, while also contributing to reduced carbon emissions and improved delivery times.
	18-19	Educators introduce the First Derivative $f'(x)$ ▪ The first derivative measures how a function changes with respect to x. ▪ Critical Points: Where $f'(x) = 0$ or $f'(x)$ is undefined. These points are potential candidates for local maxima or minima. Local Maxima/Minima: Points where the function reaches a peak or trough within a specific interval. Global Maxima/Minima: The highest or lowest points over the entire domain of the function.
	20	Educators explain the process of optimizing a function with derivatives. ▪ Define the Function: Identify the function $f(x)$ you want to optimize. ▪ Compute the First Derivative: Find $f'(x)$. ▪ Solve for Critical Points: Set $f'(x) = 0$ to find points where the function's slope is zero. ▪ Evaluate the Function: Compare the values of the function at these critical points to determine the optimal solution.



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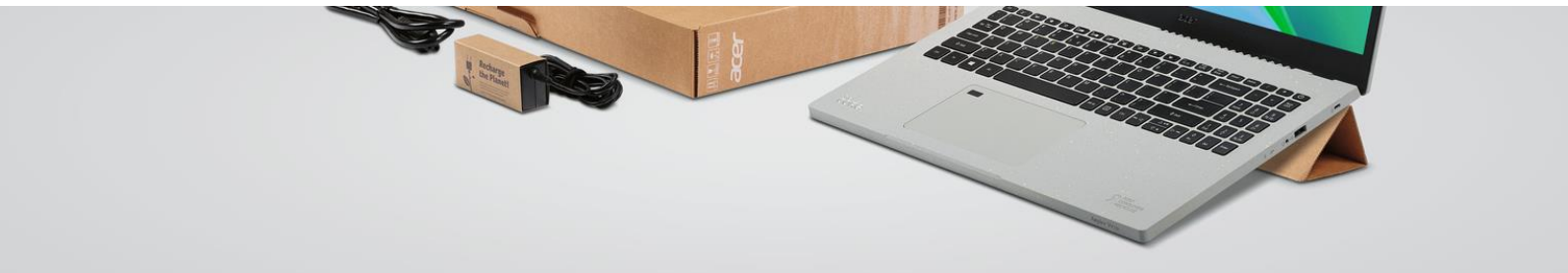
Development (slides 8 – 29)		
Duration	**Slide**	**Activity**
90 min	21-22	Educators guide learners through a detailed example of optimization using derivatives.
	23	Educators present the question to the leaners: Solving a few equations by hand is manageable, but what happens when you have dozens of equations? Some expected responses may include: ▪ Expected responses: Utilize specialized software like MATLAB, Python or Excel for complex calculations. ▪ Apply optimization algorithms to handle large data sets and find solutions quickly.
	24	Educators explain the role of programming in solving complex problems. ▪ When dealing with a large number of equations, manual calculation becomes impractical. Programming languages, like Python, streamline this process by automating calculations and handling large datasets. ▪ Python's libraries, such as NumPy, SciPy, and PuLP, offer built-in functions that make solving linear equations and optimization problems more efficient.
	25-26	Educators introduce the demonstration of Python and Jupyter Notebook. Python, combined with Jupyter Notebook, provides an interactive platform for coding and visualization. Jupyter Notebook allows users to write and execute Python code in a flexible, user-friendly environment, making it ideal for demonstrating complex calculations and optimization tasks. Educators ask the learners to go through the user interface of Jupyter Notebook



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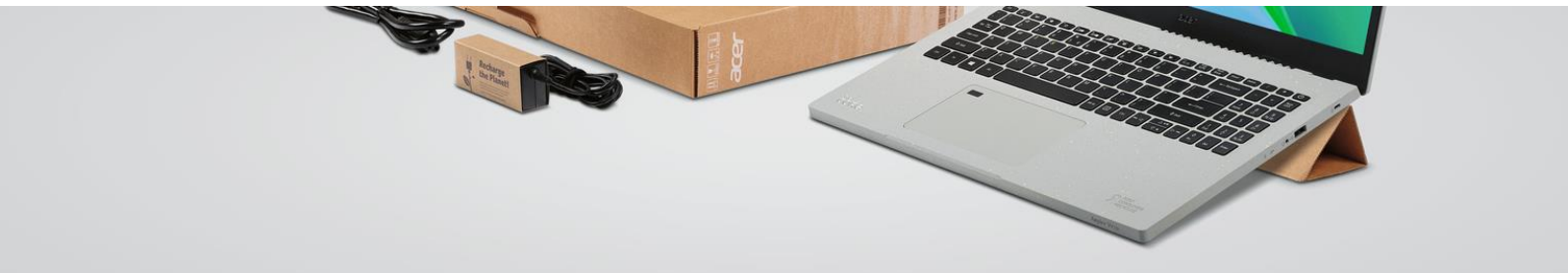
3. Activity Guide

Development (slides 8 – 29)

Duration	Slide	Activity
90 min	27	Learners work in pairs to complete the mission. Go through the mission with the groups: ▪ Optimal Laptop Boxes - Determine how many 13-inch laptop boxes can be cut from 8x5 feet cardboard sheets to maximize box count and minimize waste. ▪ Cardboard Sheet Optimization - Use Linear Programming to find the best arrangement for different-sized boxes on large cardboard sheets to reduce waste and maximize material use. ▪ Maximizing Box Volume - Optimize the dimensions of a box made by cutting squares from a flat sheet and folding it, aiming to maximize the box's volume for efficient packaging. Skillset: Programming & Coding | Problem Solving Learners employ computational thinking, alongside experimentation and inquiry-based learning, to solve problems in programming and coding.
	28	Educators explain the concept of a dieline in packaging. A dieline is a detailed template used in the packaging industry to ensure that a package design fits precisely on the material, like cardboard. It outlines where the package will be cut, folded, and assembled, ensuring the final product matches the intended design.
	29	Educators instruct learners to complete their independent hands-on practice by: ▪ Referring to instructions on the worksheet. ▪ Ensuring that working files have been downloaded and extracted



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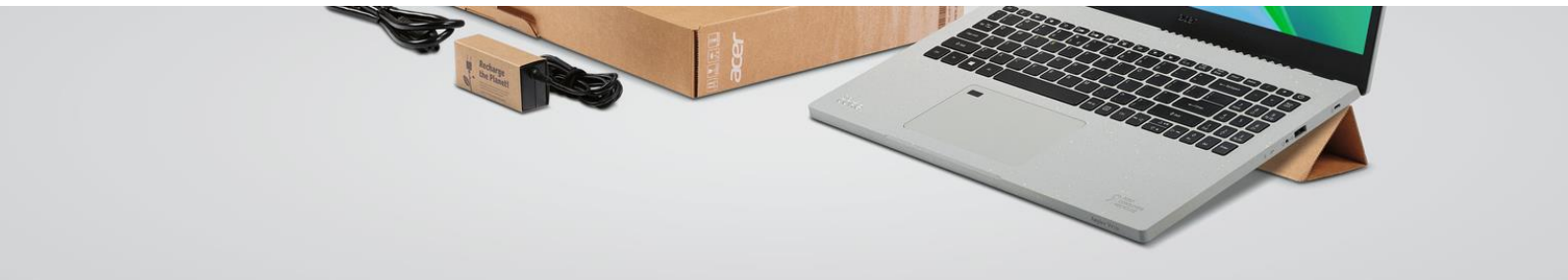
Conclusion (slides 30– 31)		
Duration	**Slide**	**Activity**
10 min	28	Educators conclude the lesson with summary of what has been learned: ▪ Understood the role of packaging design in sustainable product development and its impact on material efficiency. ▪ Applied Linear Programming to determine the optimal number of laptop boxes that can be cut from large cardboard sheets. ▪ Applied derivatives to calculate the dimensions of a box with maximum volume.
	29	End of lesson.



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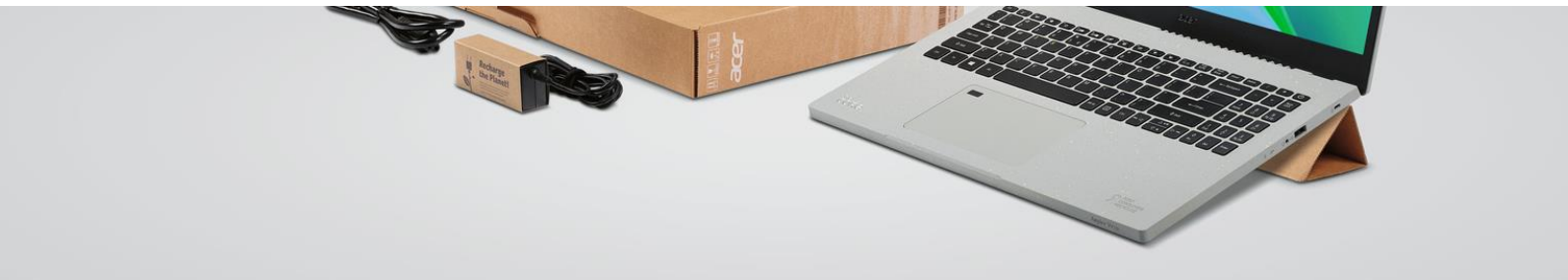
4. Troubleshooting Tips

Common Mistakes & Issues

	Issue	Possible Reasons	Resolution
1	Jupyter Notebook not able to run code (an asterisk appears instead of a number In[*] and kernel circle is filled.	Antivirus software installed on the computer may be interfering with the connection to Jupyter Notebook.	Stop the antivirus software and restart the kernel.
2	Module Not Found Error.	The library has not been installed.	Use !pip install followed by the library name to install it.
3	Not Found/Not Defined Error.	Missed execution of certain code cells.	Use shift + enter to execute the code cells. Ensure you run all of the cells before proceeding to the next cell.



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5. Assessment Rubric

Focus	Learning Outcome	Approaching Expectation	Meeting Expectation	Exceeding Expectation
 Design Thinking (Prototype)	Understand the role of packaging design in sustainable product development	Demonstrates some awareness of challenges posed by strong winds and waves in coastal skyscraper design	Demonstrates clear understanding of how packaging design affects product sustainability and material efficiency	Exhibits in-depth knowledge of packaging design's role in sustainability, including its environmental, economic, and social impacts
 Programming and Coding (Problem Solving)	Apply Linear Programming to optimize laptop box cutting	Can set up a basic Linear Programming model but struggles with constraints or objective function	Successfully applies Linear Programming to determine the optimal number of laptop boxes from cardboard sheets	Can modify the code to change constraints and analyze the impact on results
	Use differentiation to solve box volume optimization problems	Understands the concept of differentiation for optimization but has difficulty applying it to the box volume problem	Correctly applies differentiation to solve the box volume optimization problem	Can modify the code to change constraints and explore different optimization scenarios