Project 4.1 Puzzle Design Challenge

Introduction

Have you ever looked at a product that has been well-designed? Do you find yourself asking questions such as, “How did the designer think of that idea?” or “What is involved in the creation of that product?” The more you study and learn about design and how designers create items, you begin to learn certain skills and knowledge that you can only acquire through experience. Design challenges provide opportunities to apply skills and knowledge in unique and creative ways.

Taking an idea you have and transferring it from a concept to a sketch, to working drawings, to models, and then to a working prototype is exciting and fun. It also entails several steps. When you are a one-person design and build team, the task of effective communication is rather simple. However, what happens when you must communicate your ideas to others, or when the responsibility for building a team’s solution falls on someone else’s shoulders? This increases the level of responsibility significantly and requires the development of a complete set of design documentation in order to communicate effectively.

This project will provide you the opportunity to exercise your creativity and develop your sketching and modeling skills, as well as your ability to use the computer as an efficient communication tool.

Equipment

- Engineering notebook
- Pencil
- 27 – ¾ in. hardwood cubes
- 27 – interlocking plastic centimeter cubes (optional)
- Paper towels
- Isometric grid paper
- Orthographic grid paper
- Markers (colored pencils or paint are optional)
- Wood glue
- Sandwich-sized Ziploc® bag for storage
- 220 abrasive paper
- Computer with 3D CAD solid modeling software

Procedure

1. The entire project procedure is included below as an overview. Your teacher will guide you as to when you will complete each step.
2. Study the Puzzle Cube Design Brief located below.
3. Brainstorm and sketch on isometric grid paper possible puzzle part cube combinations for your cube using Activity 4.1a Puzzle Cube Combinations.
4. Create two different Puzzle Cube designs from your possible parts using Activity 4.1b Engineering Graphics. Note that the design brief that follows requires that each puzzle part contain at least four and no more than six hardwood cubes. For each design, neatly sketch and color code an isometric view of each of the five component parts and show how they fit together in the isometric view of the cube on isometric grid paper. See your teacher for an example. You will need a total of two solutions with ten unique parts.
5. Choose your best option from the two solutions.
6. Hand sketch a multi-view drawing for each of the five puzzle parts of your solution using Activity 4.1b Engineering Graphics. Exchange your sketches with a classmate, virtually build your partner's parts according to the activity, and provide feedback.
7. Select one of your partner's six cube puzzle parts. Neatly fabricate the part from the multi-view sketch. Give appropriate feedback using Activity 4.1b Engineering Graphics.
8. Complete Activity 4.1d or Activity 4.1e Software Modeling Introduction.
9. Create the five parts to your cube using 3-D modeling software. Color the parts within the CAD environment using the same color combination used in the sketching phase of your project.
10. Assemble your cube using 3-D modeling software.
11. Fabricate your five puzzle parts. Color your parts using markers (colored pencils or paint) to match the colors of your CAD model and assemble your cube.
12. Test the solution time of your puzzle cube. Identify at least ten test subjects. Be sure to choose your test subjects so that the data you gather can provide evidence of meeting (or not meeting the design criteria). Each test subject will solve your puzzle three times. You will measure and record the time to solve the puzzle each time. Also, collect demographic information that might be important to determine how well you have addressed the needs of your target market (and to help you answer the conclusion questions).
13. Find statistics related to your test data (using technology as appropriate) to include the following:
    - Mean, median, mode, range, and standard deviation of the solution time for the first attempt for all test subjects.
    - The mean of the solution times for the second attempt for all test subjects.
    - The mean of the solution times for the third attempt for all test subjects.

14. View the **Assembly Constraints** presentation. Using 3D solid modeling software, create an assembly model of your puzzle.
15. View the **Creating Drawings in CAD** presentation. Create a drawing using 3-D modeling software to display a fully dimensioned multi-view for each of the five parts and two different isometric views of the assembled puzzle. The isometric views should provide enough information so that another classmate can solve the puzzle using only those two views.
16. Exchange your drawing with a classmate and provide feedback on errors, omissions, and recommendations to improve your classmate's drawing.
17. Using Excel, create a scatterplot and find a trend line for the relationship between *number of attempts* (independent variable) and the *average solution time* (dependent variable). You will have three data points: (1- average solution time for first attempt), (2 - average solution time for second attempt), and (3 - average solution time for third attempt). Properly label the axes of the scatterplot and include units. Write the relationship between the two variables in function notation and define your variables. (You should complete Activity 4.1c Mathematical Modeling prior to completing this requirement.) Express your model using function notation.
18. Using your trend line, address the following:
    - Interpret the slope and the y-intercept of the trend line and explain their meaning in words.
    - Estimate the average solution time on the fifth attempt. Indicate the solution both graphically (by showing how to use the input of 5 to find the time output on the graph) and numerically (using the equation of the trend line).
    - Estimate the number of attempts a person has made at solution if they solve the puzzle in 23 seconds. Indicate the solution both graphically and numerically.
19. Consider changes to your puzzle cube that might improve your design.

PLTW | Engineering

Puzzle Design Challenge Brief

Client **Fine Office Furniture, Inc.**

Target Consumer **Ages: High school aged**

Designer _____

Problem Statement

A local office furniture manufacturing company throws away tens of thousands of scrap ¾" hardwood cubes that result from its furniture construction processes. The material is expensive, and the scrap represents a sizeable loss of profit.

Design Statement

Fine Office Furniture, Inc. would like to return value to its waste product by using it as the raw material for desktop novelty items that will be sold on the showroom floor. Design, build, test, document, and present a three-dimensional puzzle system that is made from the scrap hardwood cubes. The puzzle system must provide an appropriate degree of challenge to high school students.

Criteria

1. The puzzle must be fabricated from 27 – ¾″ hardwood cubes.
2. The puzzle system must contain exactly five puzzle parts.
3. Each individual puzzle part must consist of at least four, but no more than six hardwood cubes that are permanently attached to each other.
4. No two puzzle parts can be the same.
5. The five puzzle parts must assemble to form a 2 ¼″ cube.
6. Some puzzle parts should interlock.
7. The puzzle should require high school students an average of _____ minutes/seconds to solve. (Fill in your target solution time.)

Submittal

View the **Portfolio** presentation. Create a project portfolio to include the following:

- Design Process Description. Summarize your work during each step of the design process. Include documentation (written work, sketches, CAD drawings, images, etc.) to support your discussion. Your documentation must include the following information located in the appropriate Design Process step:
  - Title page
  - Brief autobiography and your picture

- Puzzle Design Challenge Brief
- Brainstorming Possible Part Combinations (Activity 4.1a Puzzle Part Combinations)
- Isometric sketches of two possible complete Puzzle Cube designs
- Justification of your chosen Puzzle Cube design solution
- Multi-view sketch, fully dimensioned of each of the five puzzle parts in your chosen design (Activity 4.1b Engineering Graphics)
- CAD drawing(s) displaying a fully dimensioned multi-view of each puzzle part and two different isometric views of the assembled puzzle.
- Drawing review comments from a classmate.
- Image(s) of your building process and puzzle prototype.
- Physical model of your puzzle.
- Statistics related to the solution time of your puzzle as required above.
- A written summary of your puzzle test results and a discussion of the validity of your design. Does your design meet the design criteria? Does your design "provide an appropriate degree of challenge to high school students" (as stated in the design statement)?
- A discussion of possible changes to your puzzle cube that would improve the design.

Conclusion

1. Why is it important to model an idea before making a final prototype?

2. Which assembly constraint(s) did you use to constrain the parts of the puzzle to the assembly such that it did not move? Describe each of the constraint types used and explain the degrees of freedom that are removed when each is applied between two parts. You may wish to create a sketch to help explain your description.

3. Based on your experiences during the completion of the Puzzle Design Challenge, what is meant when someone says, "I used a design process to solve the problem at hand"? Explain your answer using the work that you completed for this project.

4. How does the age of the puzzle solver affect solution time?
    a. Make a specific statement related to the rate of increase or decrease of solution time with respect to age. Provide evidence that supports your statement.

    b. Write an equation using function notation that represents **puzzle solution time** in terms of **age**. Be sure to define your variables and identify units.

    c. Predict the solution time on the first attempt of a child who is 3 years of age. Show your work.

    d. Predict the solution time on the first attempt of a person who is 95 years of age. Show your work.

    e. Do these predictions make sense? Why or why not?

    f. What is a realistic domain for the function?

    g. Collect additional data to verify your mathematical model.