

Transformation 2013

PBL 5E

Planning Form

Guide

PBL Title: Mix it up: Precision and Accuracy in Manufacturing Processes

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School: Waxahachie Global High School

Subject: Science

Abstract: Students learn about controlling precision and accuracy in experimentation and the importance of these principles in quality control. Students design an automated paint blending process using LEGO Mindstorms NXT technology and Vernier probeware to complete the design challenge.

MEETING THE NEEDS
OF STEM EDUCATION
THROUGH PROBLEM
BASED LEARNING

Begin with the End in Mind

The theme or “big ideas” for this PBL:

Controlling precision and accuracy in experimentation. Automating chemical blending processes to reduce error.

TEKS/SEs that students will learn in the PBL:

- 2(b) collect data and make measurements with precision;
- 2(c) organize, analyze, evaluate make inferences, and predict trends from data.
- 3(c) evaluate the impact of research on scientific thought, society, and the environment.

Key performance indicators students will develop in this PBL:

Design	Data interpretation, reporting and presentation
Programming	Using data in design process.
Measurement	Time management
Project management	

21st century skills that students will practice in this PBL:

www.21stcenturyskills.org

1. Framing, analyzing and synthesizing information in order to solve problems and answer questions.
2. Acting on creative ideas to make a tangible and useful contribution to the domain in which the innovation occurs.

STEM career connections and real world applications of content learned in this PBL:

Model real world contexts for learning and work by extending topics of precision and process design to real world context of paint blending.

The Problem

You are a Quality Control Manager at Sherwin-Williams Paints. The CEO, Mr. Connor, has called a meeting to discuss problems in the paint department. Profits are sinking, dyes are more expensive, and errors in blending have resulted in large amounts of waste—paint that can't be sold. This cost is absorbed as a loss by the company. The company then defers that loss by reducing quarterly bonuses for managers.

Mr. Connor believes automation may increase the precision and accuracy of paint blending. Mr. Connor challenges his managerial team to design a process that blends paint which accurately matches the customers' desired paint color every time. He feels that your bonus should reflect the quality of your design, and that the best design should be patented and implemented in stores nationwide.

Map the PBL

Performance Indicators	Already Learned	Taught before the project	Taught during the project
1. Interpret and analyze graphs.	X		
2. How to program using NXT software.			X
3. Making measurements with precision and accuracy.	X		
4. Error analysis.			X
5. Presentation and design defense.			X
6. Teamwork and time management.			X
7. Experimental design and scientific process.			X

5E Lesson Plan

PBL Title: Mix it up: Precision and Accuracy in Manufacturing Mixtures

TEKS/TAKS objectives: 2ABC

Engage Activity

Show class a batch of “oops” paint that was purchased at discount. Start a discussion of what you do if you run out of paint before a job is through. Ask a volunteer to explain how paint is color matched and blended.

Class visits local paint store to observe the process of paint blending.

Before leaving, have each group define roles such as: **manager, challenger, energizer/summarizer, and recorder**. Explain what these roles mean (see link in resource section). Have the recorder write down everyone’s role in the portable notebook (small spiral).

At the store, ask questions which initiate discussion such as: “How does the computer match colors?” “What happens if you don’t get the right color?” Encourage group recorders to make notes in a small notebook.

When you return, direct the recorder to start up computer and open Microsoft Excel. Direct the group to discuss and transfer notes from the field trip. Demonstrate how to name the sheet **notebook**, and explain they are creating an electronic lab notebook. Add and name more sheets: **results, discussion, etc.**

Introduce the design challenge to the students:

You are a Quality Control Manager at Sherwin-Williams Paints. The CEO, Mr. Connor, has called a meeting to discuss problems in the paint department. Profits are sinking, dyes are more expensive, and errors in blending have resulted in large amounts of waste—paint that can’t be sold. This cost is absorbed as a loss by the company. The company then defers that loss by reducing quarterly bonuses for managers.

Mr. Connor believes automation many increase the precision and accuracy of paint blending. Mr. Conner challenges his managerial team to design a process that blends paint which accurately matches the customers’ desired paint color every time. He feels that your bonus should reflect the quality of your design, and that the best design should be patented and implemented in stores nationwide.

Engage Activity Products and Artifacts

Electronic Notebook (Excel)

Engage Activity Materials/Equipment

small spiral notebook, oops paint, MS Excel, laptop, copies of design challenge for students

Engage Activity Resources

Group roles defined: <http://groups.physics.umn.edu/physed/Research/CGPS/roles.html>

Paint making process: <http://www.madehow.com/Volume-1/Paint.html>

Explore Activity I

Rainbow Lab:

Enter some of the equipment from the materials list on a new sheet in the lab notebook titled: **materials**. Demonstrate the sort ascending function of Excel. Direct the recorder to copy the list into Excel Sheet, and sort ascending.

Direct students to add a sheet titled **procedures**. Direct them to copy and paste the lab procedure to their notebook. Have them read over the procedure, identify, and add at least three safety precautions they must show the instructor before being cleared to begin the lab.

As the instructor verifies that lab procedures are complete, students will add a sheet titled **references**, and copy the link for the Rainbow Lab into the sheet.

Distribute beakers of primary colors when the work space is organized. Students conduct the Rainbow Lab following the procedure. Direct students copy response questions into a new sheet titled **Discussion**. After responses are recorded, direct the recorder to enter the results under the tab “results” and challenge recorder, and the group energizer to create a graph that illustrates the results using Excel (encourage them to look at the icons and use help).

The group leader and challenger bring test tubes to the demonstration table and record a digital image of the results, which is transferred to the digital notebook (flash disk).

Use the following IVCDV chart to help students understand the experimental design:

Designing an experiment

1. Define the problem.
2. Complete the IVCDV chart to generate a hypothesis.
3. List the materials you will test. Be sure to include all of them and to list exact quantities.
4. Write the steps of your procedure. Be sure to **number** them and list them in **sequence**. Use diagrams where appropriate.
5. Perform the experiment and document results.
6. Write a conclusion for the experiment.

Independent Variable (IV)		Constants	Dependent Variable (DV)

Complete the V chart:

Independent Variable

Dependent Variable

+

+

If (IV) + verb,

then (DV) + verb.

Hypothesis:

Explore Activity Products and Artifacts

Rainbow Lab Response Sheet
Journal entries

Explore Activity Materials/Equipment

For each pair of students you will need:

- 6 30 mL test tubes
- test tube rack
- 1 or 2 pipettes
- 50 or 100 mL beaker (or larger) with Red liquid
- 50 or 100 mL beaker (or larger) with Blue liquid
- 50 or 100 mL beaker (or larger) with Yellow liquid
- 1 beaker of clean water (if not working near a sink)
- 1 empty beaker
- 2 - 25 mL graduated cylinders
- 2 - 10 mL graduated cylinders
- 1 wax pencil
- goggles
- apron

Explore Activity Resources

Rainbow Lab activity: <http://www.middleschoolscience.com/rainbowlab.html>

Explain Activity

Review lab discussion questions to target vocabulary based on responses. At the start of discussion, have reporters add a section on the notebook sheet for **vocabulary**. Write target words on the board as they come up in discussion. Invite each group to share graphs and photos limiting them to 2 minutes each.

Target Vocabulary:

accuracy, precision, error, hypothesis, independent variable (IV), dependent variable (DV)

Hypothesis: Communicates what you think is going to happen in the experiment.

Always acceptable: **If** (the independent variable) **is** (verb: increased, decreased, changed), **then** (the dependent variable) **will** (verb: increase, decrease, change.)

Example: **If** the sunlight **is** increased, **then** the height of the plants **will** increase.

Independent Variable: (IV) (also called the **Manipulated Variable**) -- the variable you purposely change or manipulate. Will be the CAUSE of the changes you measure.

Example: The sunlight

Dependent Variable: (DV) (also called the **Responding Variable**) -- the variable you will measure after the experiment is set up. Will be the EFFECT of the action you took.

Example: The height of the plants

Constants: All the other variables that **remain the same** for all the trials – otherwise they could affect the results (they could ALSO change the dependent variable) and distort the connection between your *one* IV and the DV.

Example: 4" pots, 100 g potting soil, 25 mL water daily

Control: The group that does NOT contain the independent variable -- -the no treatment group or normal treatment group. Helps establish a baseline result that you can compare with your experimental groups.

Example: the plants that receive 12 hours sun/12 hours dark (which best simulates real life) – this will allow you to compare the results for the experimental plants growing in 24 hours darkness and 24 hours sunlight

Trials: The number of times the experiment is repeated. The more times you can repeat the experiment and get the same results, the more valid your conclusions are.

*****Homework:** Rewrite the lab procedure to eliminate sources of error so that more accurate results can be achieved.

Explain Activity Products and Artifacts

Excel Spreadsheet
Homework assignment

Explain Activity Materials/Equipment

Student laptop, Microsoft Excel

Explain Activity Resources

Experimental Design presentation:

http://www.dentonisd.org/522206183847630/lib/522206183847630/Science_as_a_process.pdf

Experimental Design reference:

www2.fultonschools.org/teacher/mauldina/experimental_design.doc

Explore Activity 2

Have groups review rewrites, and consolidate individual efforts into one lab procedure that will be given to another group. **Encourage students to look for ways that team members modified the lab to reduce error.** Save individual efforts, and final draft to network folder.

Each student must make an initial electronic entry on the notebook tab for Day 2 based on the group collaboration. Ask students to record their observations from group discussion about error. Students need to date entries.

Groups exchange their Rewritten Rainbow Labs, read over the exchanged labs, and prepare for a second trial. Have recorders copy into **procedures**, and site under **sources**. Introduce the term **hypothesis**. Write the statement: **“If IV then DV.”** on the board. Prompt students to recall what IV (independent variable)/ DV (dependent variable) stands for, then prompt them to identify IV/DV for this experiment. Review terms and identify IV/DV for this experiment. Give students time to enter their hypothesis in the **notebook** section.

Review pictures of TRIAL 1 results. Discuss visible light spectrum and target vocabulary: **precision, quantitative, qualitative, sensors, pigment (added to notebook)**

Teacher demonstration of the use of a light sensor and/or spectrometer to quantify experimental results.

Attention: Inform students that they are looking for the most accurate lab procedure, and that the group with the most accurate procedure will make a demonstration video for the

rest of the class (**this will encourage students to measure carefully**). **How will we know which results are most accurate? Do any groups have precise results that are not accurate?**

Have students conduct the rainbow lab following rewritten instructions, and add a quantitative component using Vernier probeware (light sensor and/or spectrometer) and record results of TRIAL 2. Answer response questions on the **discussion tab**.

Have students exchange procedures another time and record values for TRIAL 3 (the second exchange) in **results**. Students should compare the qualitative and quantitative results from trials two and three.

Explore Activity 2 Products and Artifacts

Rainbow Lab Response Sheet
Journal entries

Explore Activity 2 Materials/Equipment

For each pair of students you will need:

- 6 30 mL test tubes
- test tube rack
- 1 or 2 pipettes
- 50 or 100 mL beaker (or larger) with Red liquid
- 50 or 100 mL beaker (or larger) with Blue liquid
- 50 or 100 mL beaker (or larger) with Yellow liquid
- 1 beaker of clean water (if not working near a sink)
- 1 empty beaker
- 2 - 25 mL graduated cylinders
- 2 - 10 mL graduated cylinders
- 1 wax pencil
- goggles
- apron
- Light sensor and/or spectrometer

Explore Activity 2 Resources

Rainbow Lab activity: <http://www.middleschoolscience.com/rainbowlab.html>

Research Paper – “Multispectral Imaging of Paintings in the Infrared to Detect and Map Blue Pigments”: http://www.nap.edu/openbook.php?record_id=11413&page=120

Explain Activity 2

Facilitate a discussion of each groups' experimental results, focusing on what makes the results “good”. Introduce error calculations to the students and have them calculate % error (in their case, % difference) between the two trials two and three. Teach students how to make the calculation in their spreadsheets as well.

Ask the students, how does what you have learned relate to the mixing of paints for consumers? What is it important to measure accurately AND precisely?

Which results are more important, qualitative or quantitative? Why?

How might a paint manufacturer use these measurement tools in the paint mixing process?

Homework: bring a small item that can be used to color match for the design challenge.

Explain Activity 2 Products and Artifacts

Excel Spreadsheet

Explain Activity 2 Materials/Equipment

Student laptop, Microsoft Excel

Explain Activity 2 Resources

Percent Error calculation: <http://www.ric.edu/faculty/bgilbert/s3pcerr.htm>

Elaborate Activity

Students will research the paint blending process and design an automated system to model/monitor the process using LEGO Mindstorms technology, common materials, what they’ve learned through the exploratory labs, and their creativity and knowledge gained from research.

Re-visit the open-ended design challenge with the students:

“You are a Quality Control Manager at Sherwin-Williams Paints. The CEO, Mr. Connor, has called a meeting to discuss problems in the paint department. Profits are sinking, dyes are more expensive, and errors in blending have resulted in large amounts of waste—paint that can’t be sold. This cost is absorbed as a loss by the company. The company then defers that loss by reducing quarterly bonuses for managers.

Mr. Connor believes automation many increase the precision and accuracy of paint

blending. Mr. Conner challenges his managerial team to design a process that blends paint which accurately matches the customers' desired paint color every time. He feels that your bonus should reflect the quality of your design, and that the best design should be patented and implemented in stores nationwide.

You will conduct a number of trials using food color and water to model the paint blending process and identify sources of error. Based on your research, create an automated color blending process using food coloring and water. This process needs to accurately produce the targeted color with precision (5 trials). You will produce a visually appealing report of your findings and defend your design.”

Elaborate Activity Products and Artifacts

Automaton process that executes blending of color five times.
Map the Project chart that outlines the process.

Elaborate Activity Materials/Equipment

Lego Mindstorms, Electronic Lab Notebook, internet accessibility, materials as needed based on student designs, Vernier: light sensor, spectrometer, NXT adaptor

Elaborate Activity Resources

Research Paper – “Multispectral Imaging of Paintings in the Infrared to Detect and Map Blue Pigments”: http://www.nap.edu/openbook.php?record_id=11413&page=120

Paint making process: <http://www.madehow.com/Volume-1/Paint.html>

NXT builds/programs: www.nxtprograms.com

Engineering projects using LEGO Mindstorms NXT:

<http://engineering.vernier.com/general/projects/>

Evaluate Activity

Students present Lab brief:

Visual poster presentation which includes an Abstract, Results, Discussion, Conclusions, Graphs, and pictures and model of their color blending process.

Evaluate Activity Products and Artifacts

1. Visual Design brief. Title, Abstract, Results, Conclusion, Graphs and Photos mounted on 36”X48” foam core poster.
2. Two minute presentation that describes the design process from beginning to end, and includes video of automated blending device.

Evaluate Activity Materials/Equipment

Students to provide based on their team needs.

Evaluate Activity Resources

none

Plan the Assessment

Engage Artifact(s)/Product(s): Notebook section of the Electronic Lab Notebook which will include role assignments, notes about field trip, and Project Milestones.
Explore Artifact(s)/Product(s): Electronic Lab Notebook : An EXCEL workbook with sheets titled: Introduction (includes daily milestones), Materials, Procedure, Results, Discussion, Conclusions, Sources.
Explain Artifact(s)/Product(s): Rainbow Lab procedures written to eliminate error. Notes on error, control variables, and results that evaluate percent error. Conclusions
Explore Artifact(s)/Product(s): Rainbow Lab procedures written to incorporate new measurement devices. Notes on various measurement technologies and results that evaluate which measurement device results in the least percentage error.
Explain Artifact(s)/Product(s): Rainbow Lab procedures written to blend color of students choice.
Explore Artifact(s)/Product(s): Map the project for color blending automate the process
Explain Artifact(s)/Product(s): Automaton that blends colors using the most accurate measurement technology consistently for five trials.
Elaborate Artifact(s)/Product(s): Automaton that executes blending of color five times. Map the Project chart that outlines the process.
Evaluate Artifact(s)/Product(s): Visual Design brief. Title, Abstract, Results, Conclusion, Graphs and Photos mounted on 36"X48" foam core poster. Two minute presentation that describes the design process from beginning to end, and includes video of automated blending device.

Rubrics

Modeling a Process : Automated Color Blending

Team Name: _____

CATEGORY	4	3	2	1
Plan	Plan is neat with clear measurements and labeling for all components.	Plan is neat with clear measurements and labeling for most components.	Plan provides clear measurements and labeling for most components.	Plan does not show measurements clearly or is otherwise inadequately labeled.
Modification/Testing	Clear evidence of troubleshooting, testing, and refinements based on data or scientific principles.	Clear evidence of troubleshooting, testing and refinements.	Some evidence of troubleshooting, testing and refinements.	Little evidence of troubleshooting, testing or refinement.
Scientific Knowledge	Explanations by all group members indicate a clear and accurate understanding of scientific principles underlying the construction and modifications.	Explanations by all group members indicate a relatively accurate understanding of scientific principles underlying the construction and modifications.	Explanations by most group members indicate relatively accurate understanding of scientific principles underlying the construction and modifications.	Explanations by several members of the group do not illustrate much understanding of scientific principles underlying the construction and modifications.
Function	Structure functions extraordinarily well, holding up under atypical stresses.	Structure functions well, holding up under typical stresses.	Structure functions pretty well, but deteriorates under typical stresses.	Fatal flaws in function with complete failure under typical stresses.
Notebook - Content	Journal provides a complete record of planning, construction, testing, modifications, reasons for modifications, and some reflection about the strategies used and the results.	Journal provides a complete record of planning, construction, testing, modifications, and reasons for modifications.	Journal provides quite a bit of detail about planning, construction, testing, modifications, and reasons for modifications.	Journal provides very little detail about several aspects of the planning, construction, and testing process.

Making A Poster : Project Poster Brief

Team Name: _____

CATEGORY	4	3	2	1
Graphics -Clarity	Graphics are all in focus and the content easily viewed and identified from 6 ft. away.	Most graphics are in focus and the content easily viewed and identified from 6 ft. away.	Most graphics are in focus and the content is easily viewed and identified from 4 ft. away.	Many graphics are not clear or are too small.
Required Elements	The poster includes all required elements as well as additional information.	All required elements are included on the poster.	All but 1 of the required elements are included on the poster.	Several required elements were missing.
Attractiveness	The poster is exceptionally attractive in terms of design, layout, and neatness.	The poster is attractive in terms of design, layout and neatness.	The poster is acceptably attractive though it may be a bit messy.	The poster is distractingly messy or very poorly designed. It is not attractive.
Content - Accuracy	At least 7 accurate facts are displayed on the poster.	5-6 accurate facts are displayed on the poster.	3-4 accurate facts are displayed on the poster.	Less than 3 accurate facts are displayed on the poster.
Grammar	There are no grammatical mistakes on the poster.	There is 1 grammatical mistake on the poster.	There are 2 grammatical mistakes on the poster.	There are more than 2 grammatical mistakes on the poster.
Content - Accuracy	At least 7 accurate facts are displayed on the poster.	5-6 accurate facts are displayed on the poster.	3-4 accurate facts are displayed on the poster.	Less than 3 accurate facts are displayed on the poster.
Grammar	There are no grammatical mistakes on the poster.	There is 1 grammatical mistake on the poster.	There are 2 grammatical mistakes on the poster.	There are more than 2 grammatical mistakes on the poster.
Mechanics	Capitalization and punctuation are correct throughout the poster.	There is 1 error in capitalization or punctuation.	There are 2 errors in capitalization or punctuation.	There are more than 2 errors in capitalization or punctuation.
Labels	All items of importance on the poster are clearly labeled with labels that can be read from at least 3 ft. away.	Almost all items of importance on the poster are clearly labeled with labels that can be read from at least 3 ft. away.	Several items of importance on the poster are clearly labeled with labels that can be read from at least 3 ft. away.	Labels are too small to view OR no important items were labeled.

Lab Report : Electronic Notebook

Team Name: _____

CATEGORY	4	3	2	1
Notebook/Introduction	Clear, accurate, dated notes are taken regularly.	Dated, clear, accurate notes are taken occasionally.	Dated, notes are taken occasionally, but accuracy of notes might be questionable.	Notes rarely taken or of little use.
Experimental Hypothesis	Hypothesized relationship between the variables and the predicted results is clear and reasonable based on what has been studied.	Hypothesized relationship between the variables and the predicted results is reasonable based on general knowledge and observations.	Hypothesized relationship between the variables and the predicted results has been stated, but appears to be based on flawed logic.	No hypothesis has been stated.
Procedures	Procedures are listed in clear steps. Each step is numbered and is a complete sentence.	Procedures are listed in a logical order, but steps are not numbered and/or are not in complete sentences.	Procedures are listed but are not in a logical order or are difficult to follow.	Procedures do not accurately list the steps of the experiment.
Materials	All materials and setup used in the experiment are clearly and accurately described.	Almost all materials and the setup used in the experiment are clearly and accurately described.	Most of the materials and the setup used in the experiment are accurately described.	Many materials are described inaccurately OR are not described at all.
Discussion	The relationship between the variables is discussed and trends/patterns logically analyzed. Predictions are made about what might happen if part of the lab were changed or how the experimental design could be changed.	The relationship between the variables is discussed and trends/patterns logically analyzed.	The relationship between the variables is discussed but no patterns, trends or predictions are made based on the data.	The relationship between the variables is not discussed.

Results	Professional looking and accurate representation of the data in tables and/or graphs. Graphs and tables are labeled and titled.	Accurate representation of the data in tables and/or graphs. Graphs and tables are labeled and titled.	Accurate representation of the data in written form, but no graphs or tables are presented.	Data are not shown OR are inaccurate.
Conclusion	Conclusion includes whether the findings supported the hypothesis, possible sources of error, and what was learned from the experiment.	Conclusion includes whether the findings supported the hypothesis and what was learned from the experiment.	Conclusion includes what was learned from the experiment.	No conclusion was included in the report OR shows little effort and reflection.
Sources	Several reputable background sources were used and cited correctly. Material is translated into student's own words.	A few reputable background sources are used and cited correctly. Material is translated into student's own words.	A few background sources are used and cited correctly, but some are not reputable sources. Material is translated into student's own words.	Material is directly copied rather than put into students own words and/or background sources are cited incorrectly.

Multimedia Project : Two Minute Presentation

Team Name: _____

CATEGORY	4	3	2	1
Presentation	Well-rehearsed with smooth delivery that holds audience attention.	Rehearsed with fairly smooth delivery that holds audience attention most of the time.	Delivery not smooth, but able to maintain interest of the audience most of the time.	Delivery not smooth and audience attention often lost.
Content	Covers topic in-depth with details and examples. Subject knowledge is excellent.	Includes essential knowledge about the topic. Subject knowledge appears to be good.	Includes essential information about the topic but there are 1-2 factual errors.	Content is minimal OR there are several factual errors.
Organization	Content is well organized using headings or bulleted lists to group related material.	Uses headings or bulleted lists to organize, but the overall organization of topics appears flawed.	Content is logically organized for the most part.	There was no clear or logical organizational structure, just lots of facts.
Originality	Product shows a large amount of original thought. Ideas are creative and inventive.	Product shows some original thought. Work shows new ideas and insights.	Uses other people's ideas (giving them credit), but there is little evidence of original thinking.	Uses other people's ideas, but does not give them credit.
Workload	The workload is divided and shared equally by all team members.	The workload is divided and shared fairly by all team members, though workloads may vary from person to person.	The workload was divided, but one person in the group is viewed as not doing his/her fair share of the work.	The workload was not divided OR several people in the group are viewed as not doing their fair share of the work.