Project Glaze

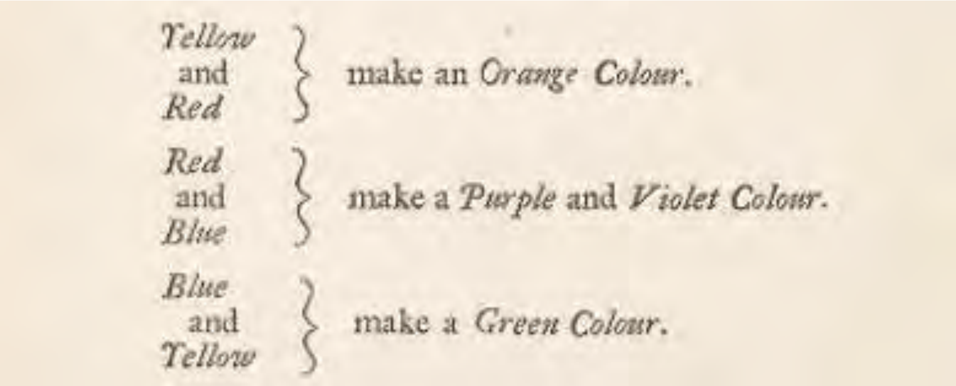
Does Color Theory Apply to Ceramics?

What Actually Is Color Theory?

- “Color theory is the art and science of using color. It explains how humans perceive color (both physically and psychologically) and how colors mix, match, and contrast with one another.”
- There are multiple different color wheels that are used today, including RGB (Red, Green, Blue), CMYK (Cyan, Magenta, Yellow, Black), and RYB (Red, Yellow, Blue).
  - RGB most often refers to visible light and wavelengths
  - CMYK most often deals with computerized color
  - RYB most often deals with physical materials like paint
    - RYB is known as the “traditional” color theory, and is the one which we will be looking at in this experiment.

History of RYB Color Theory

- In response the earlier groundbreaking color work of Isaac Newton and Johann Wolfgang von Goethe in the 1600s, German printmaker Jakob Christoph le Blon set forth the first outline of Color Theory in his book titled *Coloritto; Or the Harmony of Colouring in Painting.*
- He states that “Painting can represent all visible Objects with three Colours, Yellow, Red, and Blue; for all other Colours can be composed of these Three, which I call Primitive”



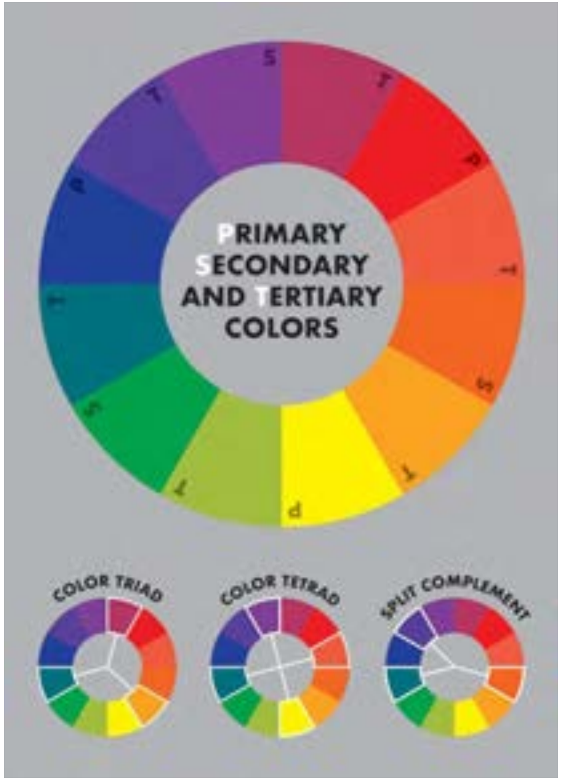
Yellow and *Red* } make an *Orange Colour*.

Red and *Blue* } make a *Purple* and *Violet Colour*.

Blue and *Yellow* } make a *Green Colour*.

Modern Understanding of Color Theory

- Most people learn at some point in their childhood that mixing yellow and red paint will result in orange paint, that blue and yellow makes green, and that red and blue makes purple.
- In other words, the mixing of the 3 primary colors results in the secondary colors.



How Does Color Theory Relate to Ceramics?

- Le Blon specified that he was “only speaking of Material Colours, or those used by ‘Painters; for a Mixture of all the primitive impalpable Colours, that cannot be felt, will not produce Black, but the very Contrary, White', as the Great Sir Isaac Newton has demonstrated in his Opticks.”
- In other words, le Blon was saying that his Color Theory *only* applied to physical materials like paints, and not to visible light, like that which Isaac Newton studied.
- However, ceramics fall into a unique category: glazes are physical materials, yet they must go through a change in energy (related to wavelength), in order for their “true” color to shine through.

The Big Question

Does Color Theory as we understand today, apply to ceramic glazes?

Hypothesis

- We hypothesize that color theory will NOT apply to ceramic glazes.
  - Ex: Red glaze mixed, layer, or glazed then layered, with Blue glaze will not result in a purple/violet color.
    - Why?
      - Color in ceramic glazes are determined by 3 different factors: the transition metal used, the ligand attached to the transition metal, and the environment in which it is fired.
  - Color theory doesn't seem to mention anything about energy gaps or calculations, which is the chemistry behind ceramic glazes. Although glazes themselves are physical materials, their color is reliant upon energy transitions, unlike a paint or a colored pencil.
    - In other words, because ceramic glazes do not involve pigmentation, the colors will not follow the rules of Color Theory.

Experimental Plan

1. Create 3 base glazes: Blue, Red, and Yellow
2. Attempt the following scenarios:
    a. Group 1: Pre-firing mix glazes
        i. A: Blue & Red Mix
        ii. B: Red & Yellow Mix
        iii. C: Yellow & Blue Mix
    b. Group 2: Pre-firing layer glazes
        i. A: Blue then Red
        ii. B: Red then Yellow
        iii. C: Yellow then Blue
    c. Group 3: Fire one glaze, layer other on top, fire again
        i. A: Blue then Red
        ii. B: Red then Yellow
        iii. C: Yellow then Blue
    d. Group 4: Switch which glaze is on bottom
        i. A: Red then Blue
        ii. B: Yellow then Red
        iii. C: Blue then Yellow
3. Observe the results

Step 1: Prepare the Glazes and Ceramic Pieces

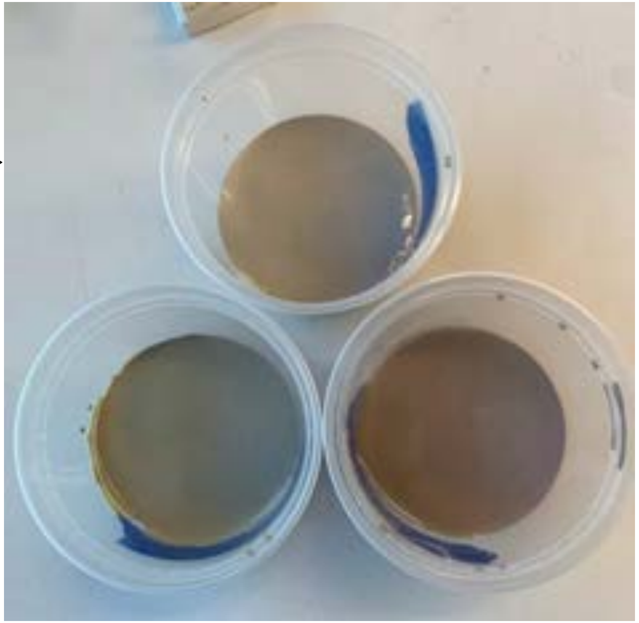
Create the Base Glazes

- In an effort to control for more confounding variables, we formulated our own glaze recipes, in order to keep the ingredients as similar as possible.
    - The base glaze recipe which we used was formulation B from Glaze Lab #1
        - 35g Silica
        - 30g EP Kaolin
        - 25g Potash Feldspar
        - 30g Whiting (Calcium Carbonate)
    - We chose this base recipe because we felt that it produced the best glaze in Lab #1

Mix the Base Glazes

- After researching other glaze recipes, we decided to try adding the following colorants to the base glaze recipe
- Blue
  - 3g of Cobalt Carbonate
- Red
  - 5g of Tin Oxide
  - 2g of Bentonite
  - 0.20g of Chrome Oxide
- Yellow
  - 8g of Titanium Dioxide
  - 6g of Light Rutile

Yellow →



Red →

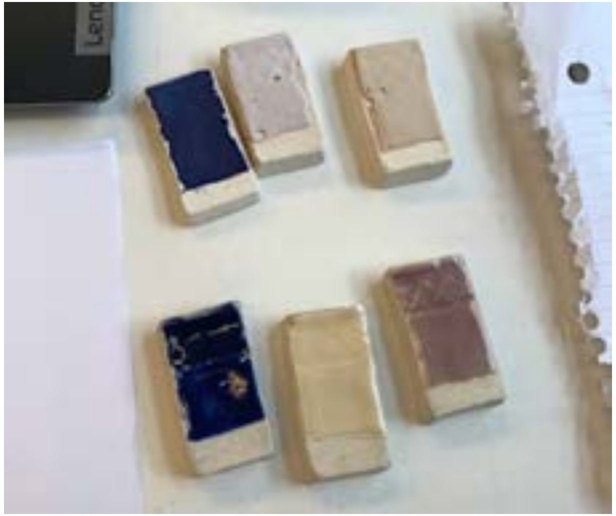
← Blue

Pre-Firing Base Tiles

Firing Temperature

- Since we created our own glaze recipes, we did not know at which temperature the glazes needed to be fired.
- We tested all three glazes on both the mid-range Iceman Clay at Δ5/6, and the high-fire Half and Half Clay at Δ10.

Δ5/6 →



← Δ10

- The Δ5/6 tiles were all underfired so we decided to go with Δ10 and the Half and Half clay
- We loved the blue glaze, but decided that we wanted to try to make the yellow and red more vibrant, so we researched and slightly reformulated the glazes.

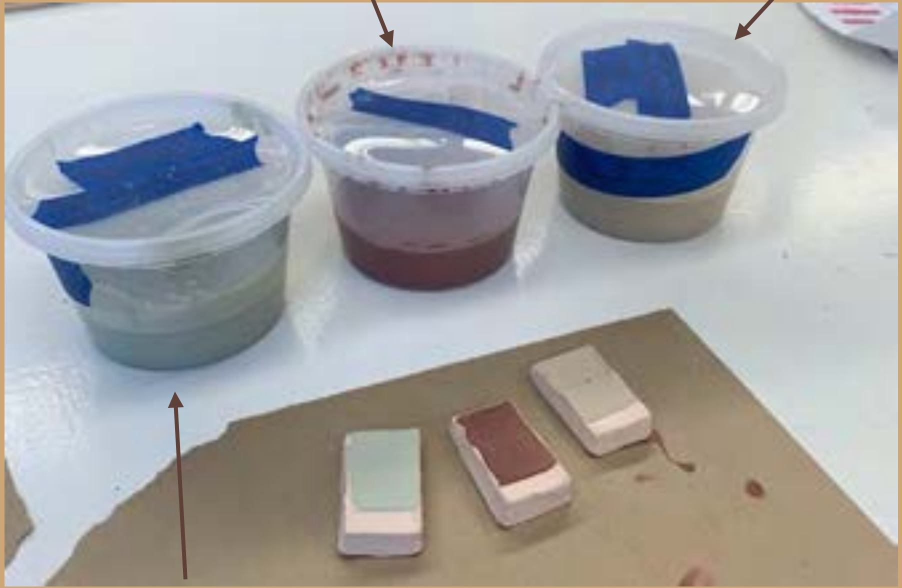
Reformulate Base Glaze Recipes

- Yellow
  - We liked the color, but wanted it to be more vibrant, so we upped the amount of Light Rutile used in the recipe from 6g →15g.
- Red
  - We attempted 2 different glaze recipes
    - The first was to just add more of the same ingredients to the same recipe: Tin oxide went from 5g → 10g, Chrome Oxide went from 0.20g → 0.40g
    - The second was an entirely new glaze recipe, with different ingredients used as the colorant (but the same base recipe): 11g of Red Iron Oxide

Reformulate Base Glaze Recipes

New Red

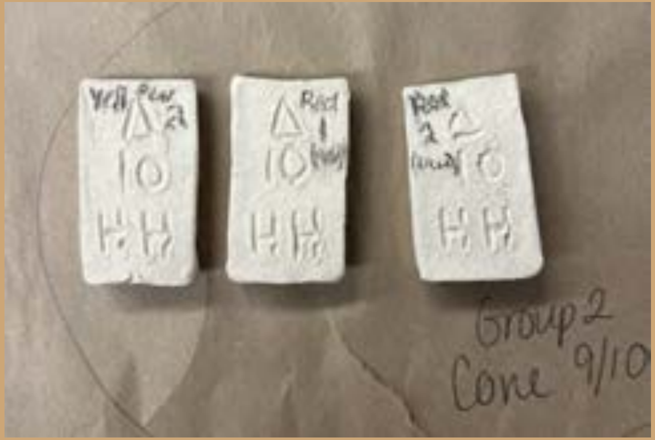
Original Yellow w/ Additions



Original Red w/ Additions

Results of 2nd Batch of Base Glaze Firing

- We achieved a much more vibrant yellow color with the updated glaze, as well as a slightly more vibrant red with the updated glaze.
- The new red glaze using red iron oxide however, turned out black, and very much so not red.



Finalize Base Glaze Recipes

- Blue
  - 35g Silica
  - 30g EP Kaolin
  - 25g Potash Feldspar
  - 30g Whiting (Calcium Carbonate)
  - 3g of Cobalt Carbonate
- Red
  - 35g Silica
  - 30g EP Kaolin
  - 25g Potash Feldspar
  - 30g Whiting (Calcium Carbonate)
  - 10g of Tin Oxide
  - 2g of Bentonite
  - 0.40g of Chrome Oxide
- Yellow
  - 35g Silica
  - 30g EP Kaolin
  - 25g Potash Feldspar
  - 30g Whiting (Calcium Carbonate)
  - 8g of Titanium Dioxide
  - 15g of Light Rutile

Create the Ceramic Objects

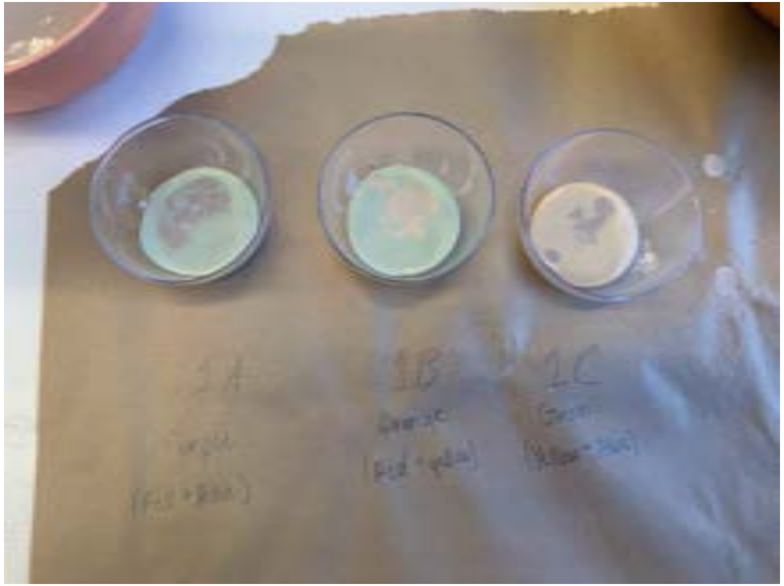
Bisque Fire the Ceramic Pieces

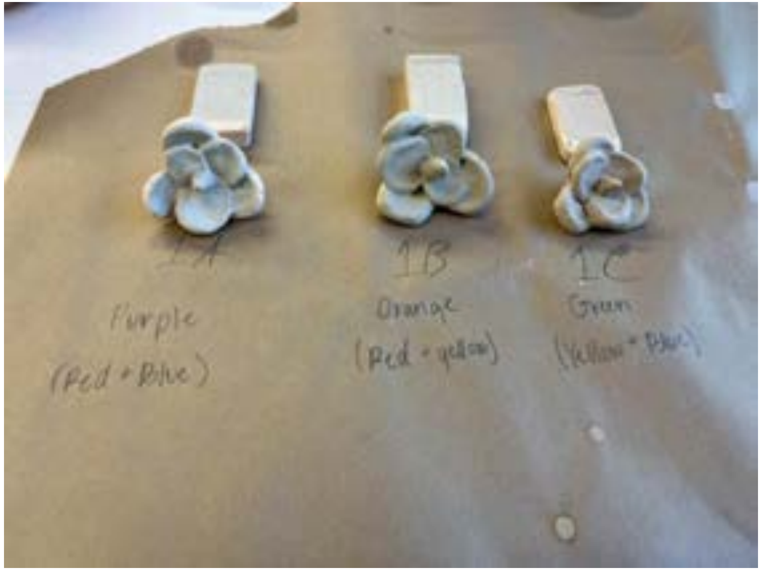
Waxing and Labeling

Step 2: Experimentation

Group 1: Pre-Mixed Glazes

- While we did not measure a specific amount of each glaze to create the mixture, we made sure to do about equal parts, using 1 standard kitchen spoonful of each
- We dipped each tile/flower twice, to make sure that this group would match all the other groups in having two layers of glaze applied to the surface.





Group 2: Pre-Firing Layered Glazes

- We chose not to do the two different options with this group (switching which color was on the bottom), because we did not feel that it would result in a different color since both colors would be fired at the same time as opposed to groups 3 and 4.

Groups 3 & 4: Fire One Glaze, Layer the Second on Top, Fire Again

- At this stage, we can only layer the first glaze, let it dry, and then fire it. Later we will layer the second glaze and fire it.
- The star above the color indicates which color was layered first.

First Pre-Firing Photo

Post First Firing for Groups 3&4

Second Glaze for Groups 3&4

Mystery Tile

- We had a few extra tiles and decided to see what would happen if we mixed all three glazes together. Color Theory states that mixing all three primary colors for pigments will result in a black color. Color Theory for wavelengths says that all three primary colors will result in white when mixed.
- We hypothesize that all three glazes will NOT result in black or white.

Step 3: Results & Discussion

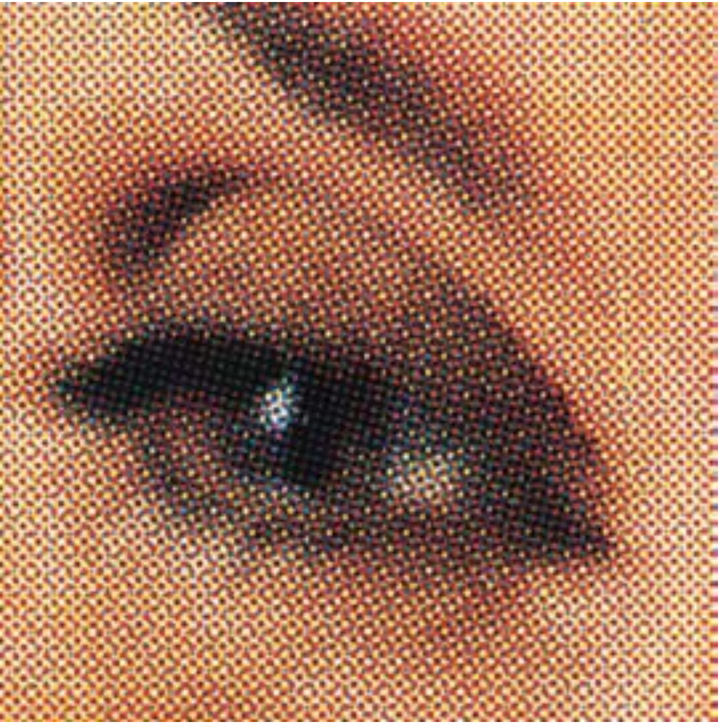
Group 1

Group 2


2A
Purple
(Blue then Red)
2B
Orange
(Red then Yellow)
2C
Green
(Yellow then Blue)

Optical blending

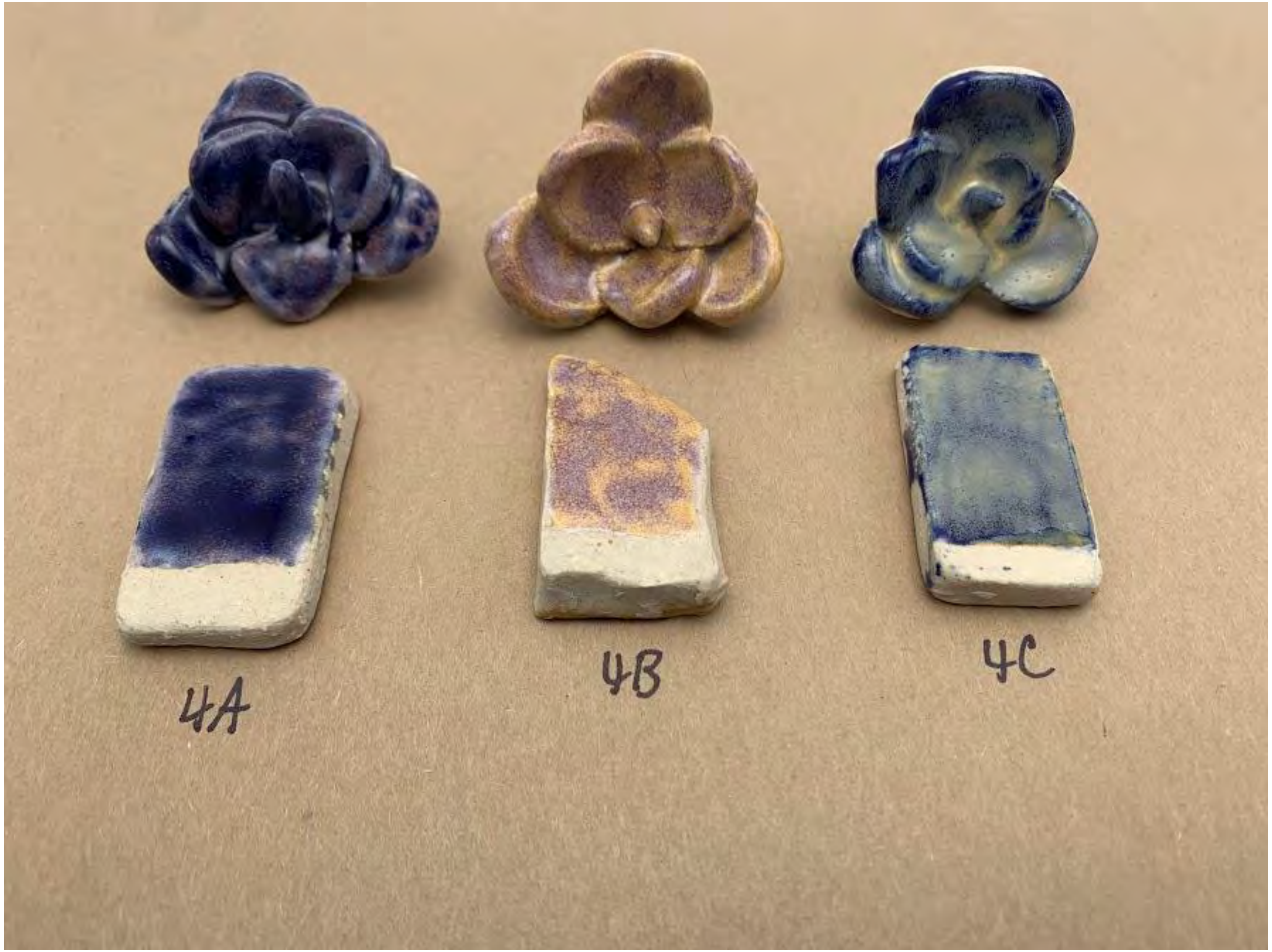
Georges Pierre-Seurat, “A Sunday Afternoon on the Island of La Grande Jatte”



Chuck Close, 'Alex II' with close-up detail (1989)

Group 3

Group 4



Mystery Tile

General Limitations

- The base red color that we were able to achieve was not the "reddest" red possible, mostly because the best red glaze colors are achieved in a reduction environment.
  - For our experiment, we wanted to keep all possible variables the same, to control for differences. Thus, we did not want to fire the yellow and blue pieces in an oxidation environment, while the red was in a reduction environment. This may have led to confounding variables that could have skewed the results.
  - There was also a time constraint issue. During the amount of time allotted to work on this project, only 1 reduction firing was going to be occurring. This would have meant that we could not have tested the base glazes before diving into the experiment, nor could be have tested what happens when a glaze is fired, and then another layer is added on top and the piece is re-fired.
  - In a future experiment, we would hopefully be able to use the reduction environment to see if that changes the results of this experiment.

General Limitations

- We also noticed that our blue glaze was incredibly saturated, which may have been why some of the glazes were so blue heavy, even though we added the same amount of each glaze. If we had had more time and more experience with glazes, we may have been able to formulate an even better blue color that was saturated enough, but not overpowering.

Conclusion

- In conclusion, we believe our hypothesis was correct.
    - Across the board, there were no consistent patterns of primary colors mixing to create the expected secondary colors.
    - There were instances of success in a few cases, for example:
        - 1C did result in green
        - 2A looked purple from a less focused glance
- The way/order that the glazes are applied matters for the color outcome.
    - But isn't consistent across the board: some work better being mixed, some work better being layered.
- We did notice that the test tiles/flowers that did not use the red pigment were the most successful, compared to the tiles/flowers that used red.
    - This might indicate that our inability to achieve a "true red" color did in fact affect the results of the experiment.

References

- https://library.si.edu/exhibition/color-in-a-new-light/science
- https://library.si.edu/digital-library/book/colorittoharmon00lebl
- https://ceramicartsnetwork.org/daily/article/Rare-Earth-Metals-at-Cone-6
- https://www.britishmuseum.org/collection/term/BIOG35081
- https://www.colorsexplained.com/color-theory/
- https://ceramicartsnetwork.org/ceramics-monthly/ceramics-monthly-article/Contextualizing-Ceramic-Color#
- https://www.interaction-design.org/literature/topics/color-theory
- https://ceramicartsnetwork.org/ceramic-recipes/recipe/Cobalt#
- https://ceramicartsnetwork.org/daily/article/Technofile-Demystifying-Chrome-Oxide-for-Fantastic-Ceramic-Glaze-Color

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