# Chapter 1
# Problem statement and Objective

## Problem statement

Have you ever played bubbles? Most of kids really like and enjoy blowing soap bubbles including us. We can make soap liquid to use it for blowing bubble. But soap bubbles that we blow always burst easily although it doesn't contact with other things. This problem makes kids cannot play it for a long time because they need to blow it frequently. There is some question, can we make a soap bubble blows longer? Some pepole tells that we need to add some admixture to make it blows longer such as lemon, sugar and glycerine. Another factor is temperature such as cool or hot. Therefore it becomes this design of experiment to find the best solution that can make soap bubbles blow longer.

## Objective

- The objective of this experiment is to compare time of bubble blowing among vary of factor level.
- To find the best solution that can make bubble blow longer.

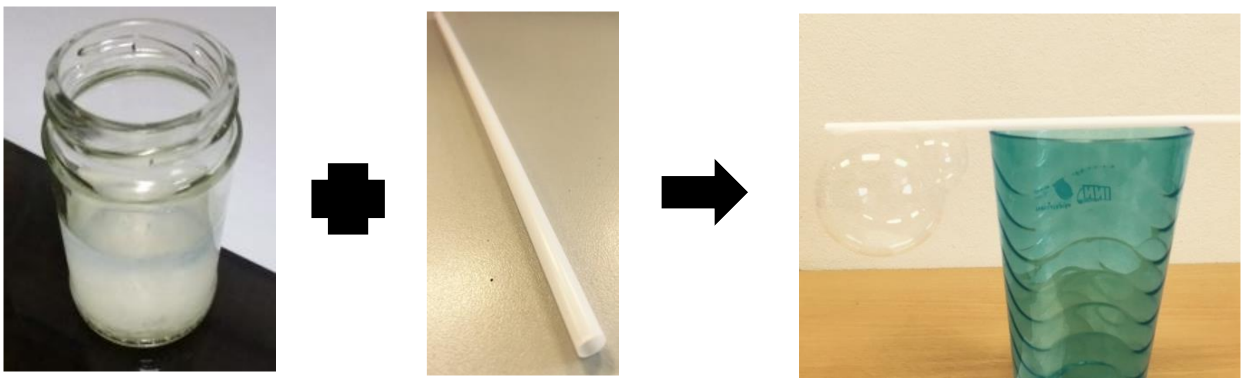
## Hypothesis

- Different admixture significantly affect the time of bubble blowing.
- The admixture of glycerin will affect the time of bubble more than lemon.
- More volume of admixture would make bubbles have more burst time.
- The lower diameter would be more efficient for blowing.
- The lower temperature would make more bursts time of bubble.

We will assess with statistical significance level (α) compare to 95%.

## Chapter 2
## Methodology

The burst time of soap bubble will be measured by using stopwatch to count time that bubbles blow. The time will be count since first bubble is blowing until it bursts (some case it will have more bubbles). The time will be count in second unit.



**Response Variable:**

A response variable of this experiment is bubble blows time in seconds unit.

**Measurement Precision / Accuracy:**

Measures by using stopwatch to count time that bubbles blow.

**Relationship to Objective:**

The greater value of seconds means that it use more time to stay until it bursts.

**Factors**

| Design Factor | Held-constant factors | Allowed-to-vary-factors | Uncontrollable factors |
|---|---|---|---|
| Admixture of solution | Place | Wind | Wind |
| Intensity of solution | People who play | | Strength of human blow |
| Diameter of blower | | | |
| Temperature | | | |

## Factor Levels

| Factor | Level | |
|---|---|---|
| | Low (-) | High (+) |
| Admixture of solution | Glycerine | Lemon |
| Volume of admixture | 1 ml | 2 ml |
| Diameter of blower | 0.5 cm | 1.4 cm |
| Temperature | Cool | Hot |

## Factor details

*Control variable*

| Control Variables | Measurement Precision / Accuracy | Predicted Effects |
|---|---|---|
| Admixture of solution | For glycerin, the quality is depended on product in the market.<br>For lemon, its depend where the lemon come from (Thailand, Other country) | The admixture of glycerin will affect the time of bubble more than lemon. |
| Volume of admixture | Use syringe to measure volume of admixture. The accuracy of the amount of volume depends on syringe. | More volume of admixture would make bubbles have more burst time. |
| Diameter of blower | Using tube as a blower, | The lower diameter would be more efficient for blowing. |
| Temperature | Cool /Hot (25,29 Celsius) | The lower temperature would make more bursts time of bubble. |

*Held Constant Factors*

| Held Constant Factors | Measurement Precision / Accuracy | Settings | Predicted Effects |
|---|---|---|---|
| Place | Place that we do the experiment is the same place and environment. | My bedroom | Negligible |
| People who play | The experiment will done with the same person all the time. | Krittaphat | Negligible |

*Nuisance Factors*

| Nuisance Factors | Measurement Precision / Accuracy | Settings | Predicted Effects |
|---|---|---|---|
| Wind | Wind power may make the bubble bursts at that time | n/a | Negligible |
| Strength of human blow | The strength of human blow will affect the size of bubbles. | n/a | Negligible |

# Chapter 3
# Experimental design

We study the effect of 4 factors that we think it affect the time that bubble use before it bursts. Each factor has two levels; high(+) and low(-). The experiment that appropriate for our experiment is $2^k$ factorial which k is equal to 4. The total number of run will be $2^4 = 16$ runs. However we have run our experiment with 2 replicates, so the total number of run will be 16x2 = 32 runs.

## Design the experiment

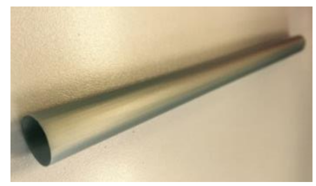
The factors tested in this experiment are as follows:

| Variable | Name | Low level (-) | High level (+) |
|---|---|---|---|
| A | Admixture of solution | Glycerine | Lemon |
| B | Volume of admixture | 1 ml | 2 ml |
| C | Diameter of blower | 0.5 cm | 1.4 cm |
| D | Temperature | Cool | Hot |

**The $2^4$ full fractional factorial design**

| Factor | Level | | | |
|---|---|---|---|---|
| | A | B | C | D |
| 1 | - | - | - | - |
| 2 | + | - | - | - |
| 3 | - | + | - | - |
| 4 | + | + | - | - |
| 5 | - | - | + | - |
| 6 | + | - | + | - |
| 7 | - | + | + | - |
| 8 | + | + | + | - |
| 9 | - | - | - | + |
| 10 | + | - | - | + |
| 11 | - | + | - | + |
| 12 | + | + | - | + |
| 13 | - | - | + | + |
| 14 | + | - | + | + |
| 15 | - | + | + | + |
| 16 | + | + | + | + |

## Materials

| Material | Quantity | Picture |
|---|---|---|
| 1. Glass bottle | 4 units |  |
| 2. Blower<br>2.1 Diameter 0.5 cm | <br>1 unit |  |
| 2.2 Diameter 1.4 cm | 1 unit |  |
| 3. Water | 1 unit | |
| 4. Spoon | 1 unit | |
| 5. Soap | 200 milliliter |  |
| 6. Lemon | 3 milliliter |  |
| 7. Glycerine | 3 milliliter |  |
| 8. Syringe | 1 unit |  |

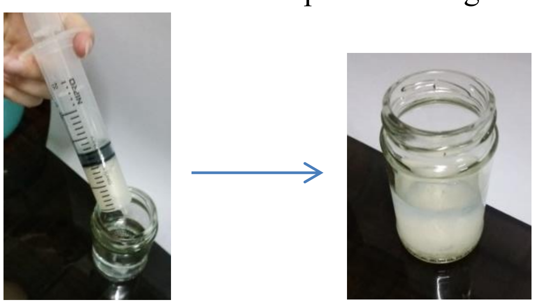
# Chapter 4
# Performing the experimental

## Procedure

1. Prepare all materials.
2. Add water 50 milliliter in 4 glass bottles.

3. Use syringe measure soap 10 milliliter.

4. Add 10 milliliter of soap to water 4 glass bottles and mix it.



5. Add 1 and 2 milliliter of glycerin to bottles 1 and 2 respectively. Then mix it.

6. Add 1 and 2 milliliter of lemon to bottles 3 and 4 respectively. Then mix it.

7. Use tube dip into solution to blow buble. (Do with 4 bottles.)
   7.1 Blow in two environments with 2 tubes.

   7.2 Use stopwatch to count time.


8. Collect result of each sample and record to experimental result.
9. Analyze the result and draw a conclusion of this experiment.

## Experiment result

| Factor | Level | | | | Bursting Time | |
|---|---|---|---|---|---|---|
| | A | B | C | D | Time1 | Time2 |
| 1 | - | - | - | - | 0.37.00 | 0.34.10 |
| 2 | + | - | - | - | 0.24.79 | 0.27.08 |
| 3 | - | + | - | - | 0.46.30 | 0.40.72 |
| 4 | + | + | - | - | 0.13.59 | 0.15.47 |
| 5 | - | - | + | - | 1.11.1 | 1.12.62 |
| 6 | + | - | + | - | 0.15.80 | 0.14.00 |
| 7 | - | + | + | - | 0.32.43 | 0.28.24 |
| 8 | + | + | + | - | 0.21.71 | 0.18.54 |
| 9 | - | - | - | + | 1.10.55 | 0.58.5 |
| 10 | + | - | - | + | 0.50.55 | 0.55.16 |
| 11 | - | + | - | + | 2.22.31 | 2.28 |
| 12 | + | + | - | + | 0.44.22 | 0.43.17 |
| 13 | - | - | + | + | 0.55.47 | 1.04.38 |
| 14 | + | - | + | + | 0.31.73 | 0.25.49 |
| 15 | - | + | + | + | 1.19.55 | 1.26.45 |
| 16 | + | + | + | + | 0.35.56 | 0.44.60 |

# Chapter 5
# Statistical analysis

After we get the experiment result of the bursting time of bubbles. We use the software called Minitab to analyze the result. At first we have to check the model adequacy by using the normal probability plot of residuals, plot of residuals versus fitted values and Residuals versus order plot. If it satisfies the model adequecy, we can use ANOVA to acquire the experimental results.

## Normal Probability Plot of Residuals

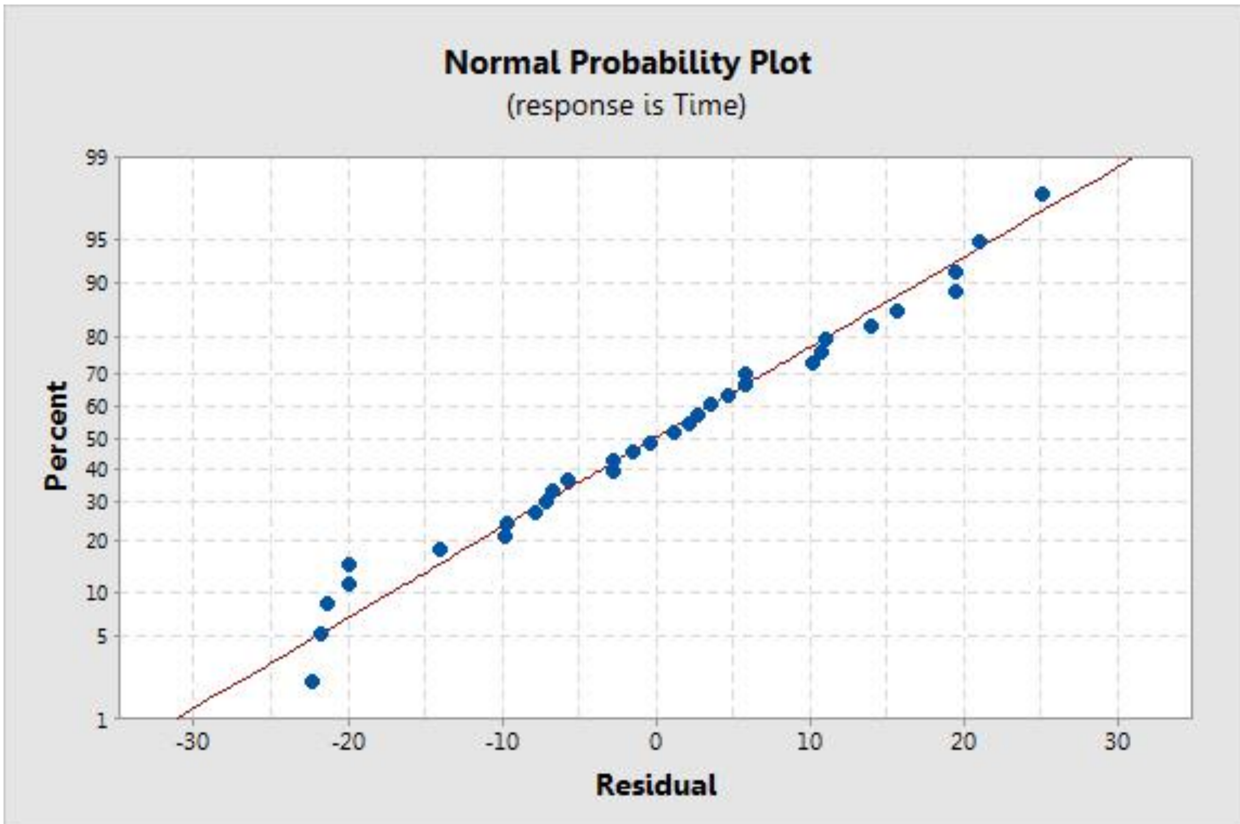



**Figure 1** Normal Probability Plot

Figure1 shows the normal probability plot of response (Time) of the experiment. You can see in the graph that most of the response is follow the straight line. So we can conclude that the normal distribution is the appropriate model for these data and the normality assumption is satisfied.

### Residuals Versus Fitted Values Plot

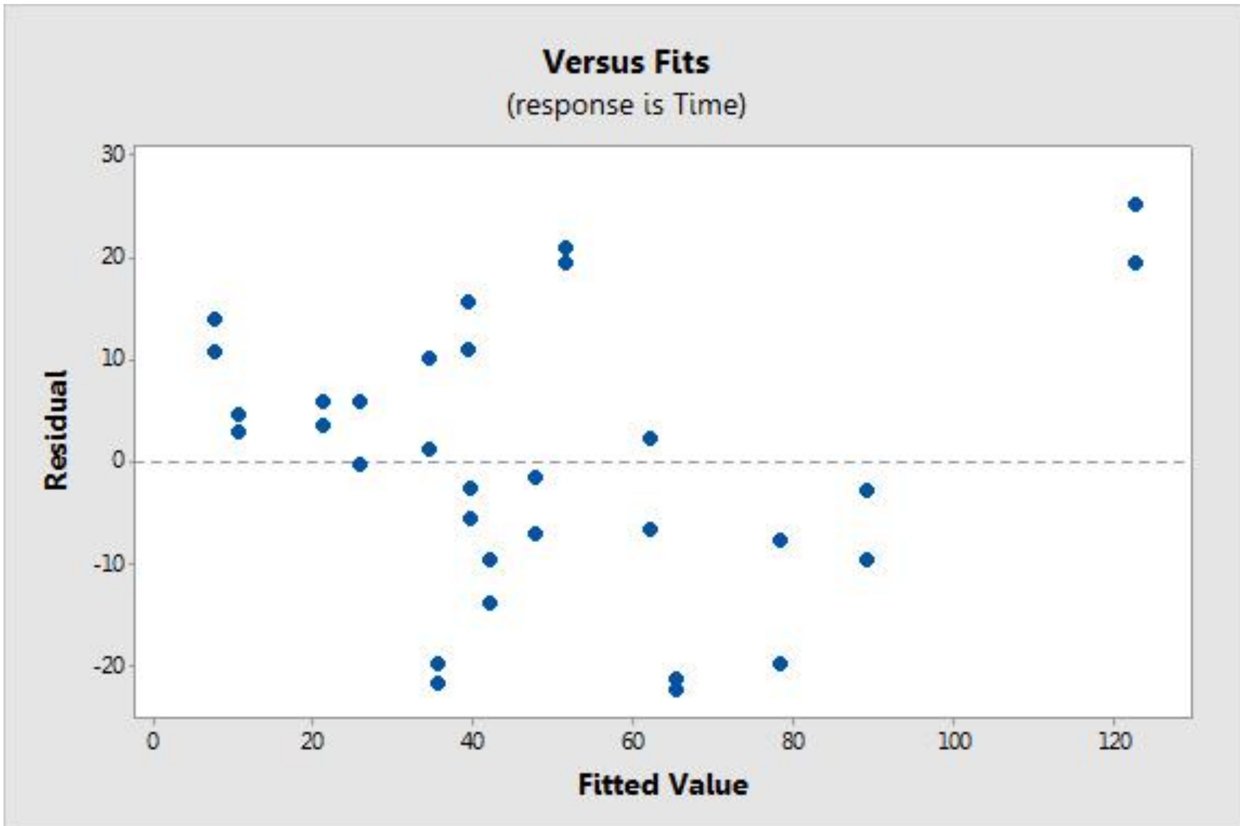



**Figure 2** Residuals Versus Fitted Values Plot

From figure 2, you can see that the data seem to be random. It doesn't have the pattern, so the data are unrelated to each other variables. With the equal variance assumption, the variance of the observation in each treatment should be equal. From the plot, we can conclude that the constant variance assumption is satisfied.

## Residuals Versus Order Plot

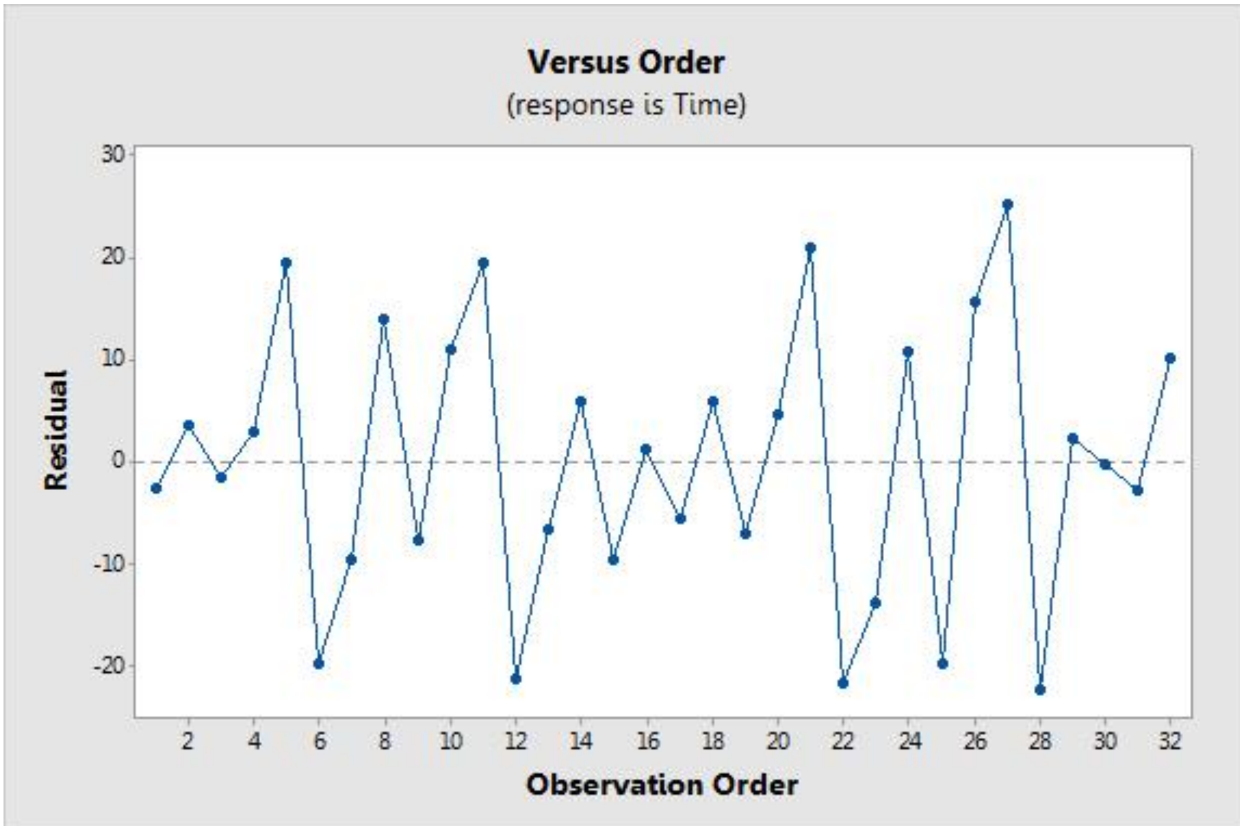



**Figure 3** Residuals Versus Order Plot

From figure 3, the plot doesn't show any pattern, it seem to be random. From the independence assumption the observation should be randomly selected and should not be effect by time. With this graph, we can conclude that the independence assumption is satisfied.

After we have checked the model adequacy, we use the ANOVA to analyze the experimental result by using the software Minitab. The result of ANOVA is shown below.

## ANOVA Table

### Factorial Regression: Time versus A(Admixture , B(Intensity , C(Diameter o, D(Temperatur

Analysis of Variance

| Source | DF | Adj SS | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|
| Model | 10 | 26922.3 | 2692.2 | 10.22 | 0.000 |
| Linear | 4 | 20550.9 | 5137.7 | 19.51 | 0.000 |
| A(Admixture of solution) | 1 | 10740.6 | 10740.6 | 40.79 | 0.000 |
| B(Intensity of solution) | 1 | 549.0 | 549.0 | 2.08 | 0.164 |
| C(Diameter of blower) | 1 | 739.6 | 739.6 | 2.81 | 0.109 |
| D(Temperature) | 1 | 8521.7 | 8521.7 | 32.36 | 0.000 |
| 2-Way Interactions | 6 | 6371.4 | 1061.9 | 4.03 | 0.008 |
| A(Admixture of solution)*B(Intensity of solution) | 1 | 684.7 | 684.7 | 2.60 | 0.122 |
| A(Admixture of solution)*C(Diameter of blower) | 1 | 13.3 | 13.3 | 0.05 | 0.824 |
| A(Admixture of solution)*D(Temperature) | 1 | 832.3 | 832.3 | 3.16 | 0.090 |
| B(Intensity of solution)*C(Diameter of blower) | 1 | 608.7 | 608.7 | 2.31 | 0.143 |
| B(Intensity of solution)*D(Temperature) | 1 | 2655.7 | 2655.7 | 10.09 | 0.005 |
| C(Diameter of blower)*D(Temperature) | 1 | 1576.7 | 1576.7 | 5.99 | 0.023 |
| Error | 21 | 5529.7 | 263.3 | | |
| Lack-of-Fit | 5 | 5265.2 | 1053.0 | 63.69 | 0.000 |
| Pure Error | 16 | 264.5 | 16.5 | | |
| Total | 31 | 32452.0 | | | |

Model Summary

| S | R-sq | R-sq(adj) | R-sq(pred) |
|---|---|---|---|
| 16.2271 | 82.96% | 74.85% | 60.43% |

Coded Coefficients

| Term | Effect | Coef | SE Coef | T-Value | P-Value |
|---|---|---|---|---|---|
| Constant | | 48.41 | 2.87 | 16.88 | 0.000 |
| A(Admixture of solution) | -36.64 | -18.32 | 2.87 | -6.39 | 0.000 |
| B(Intensity of solution) | 8.28 | 4.14 | 2.87 | 1.44 | 0.164 |
| C(Diameter of blower) | -9.62 | -4.81 | 2.87 | -1.68 | 0.109 |
| D(Temperature) | 32.64 | 16.32 | 2.87 | 5.69 | 0.000 |
| A(Admixture of solution)*B(Intensity of solution) | -9.25 | -4.63 | 2.87 | -1.61 | 0.122 |
| A(Admixture of solution)*C(Diameter of blower) | 1.29 | 0.65 | 2.87 | 0.22 | 0.824 |
| A(Admixture of solution)*D(Temperature) | -10.20 | -5.10 | 2.87 | -1.78 | 0.090 |
| B(Intensity of solution)*C(Diameter of blower) | -8.72 | -4.36 | 2.87 | -1.52 | 0.143 |
| B(Intensity of solution)*D(Temperature) | 18.22 | 9.11 | 2.87 | 3.18 | 0.005 |
| C(Diameter of blower)*D(Temperature) | -14.04 | -7.02 | 2.87 | -2.45 | 0.023 |

```
Regression Equation in Uncoded Units

Time = 48.41 - 18.32 A(Admixture of solution) + 4.14 B(Intensity of solution)
       - 4.81 C(Diameter of blower) + 16.32 D(Temperature) - 4.63 A(Admixture of solution)
       *B(Intensity of solution) + 0.65 A(Admixture of solution)*C(Diameter of blower)
       - 5.10 A(Admixture of solution)*D(Temperature) - 4.36 B(Intensity of solution)
       *C(Diameter of blower) + 9.11 B(Intensity of solution)*D(Temperature)
       - 7.02 C(Diameter of blower)*D(Temperature)


Alias Structure

Factor  Name

A       A(Admixture of solution)
B       B(Intensity of solution)
C       C(Diameter of blower)
D       D(Temperature)
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After finish the alnalysis, we also acquire 2 graphs of the result following:

- **The normal plot of the standardized effects**

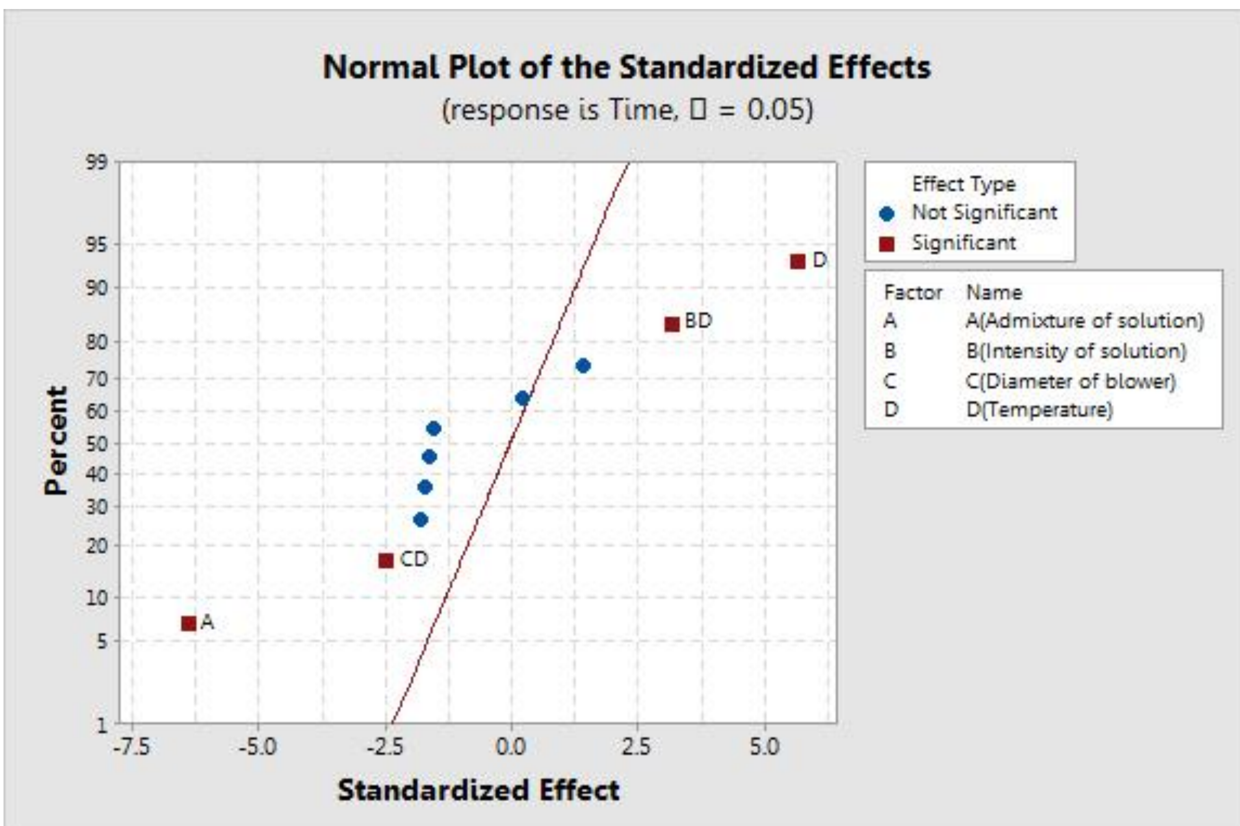


**Figure 4** Normal Plot of the Standardized Effects

- **The pareto chart of the standardized effects**

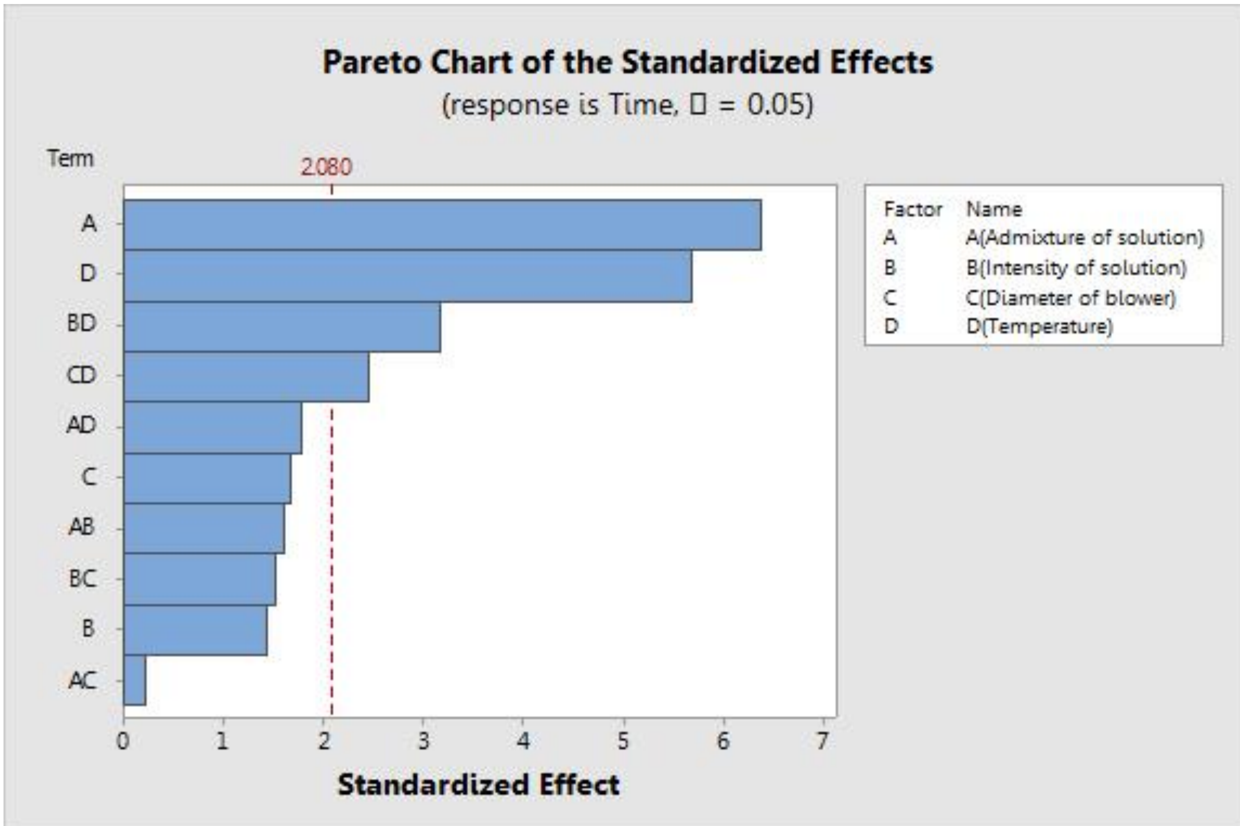


**Figure 5** Pareto Chart of the Standardized Effects

From the ANOVA result it has 2 main effects and 2 two-order interactions that are significant at the significant level of 0.05. The factors that effect the response are

- Main effect A : Admixture of the solutions
- Main effect D : Temperature
- Interaction effect BD : Intensity of solution x Temperature
- Interaction effect CD : Diameter of blower x Temperature

From the pareto chart of standardized effects in figure 4, we can conclude that the most factor that effect the response time is A (Admixture of solution) follow by D (Temperature), BD and CD.

And from the normal plot of standardize effect in figure 5, we can interpret the plot as follow

- If the factor falls in left-hand side of the normal line like A and CD. When the factor is low, the response will be high. If the factor is high, the response will be low.

- If the factor falls in right-hand side of the normal line like D and BD. When the factor is high, the response will be low. If the factor is low, the response will be high.

We can also know that the amount distance propotional to the effect to the response. It means that if the amount of distance propotional is high, the response will be strongly affects. For example, A and D that are very far from the normal line.

Form the ANOVA result we also can get the regression model of the response time of bubble.

$$Time = 48.18 - 18.32A + 4.14B - 4.81C + 16.32D - 4.63AB + 0.65AC - 5.10AD - 4.36BC + 9.11BD - 7.02CD$$

There are another way to analyze which factor affects the response by using main effect plot and interaction plot against the response. The graph is shown below.

## Main Effect Plot

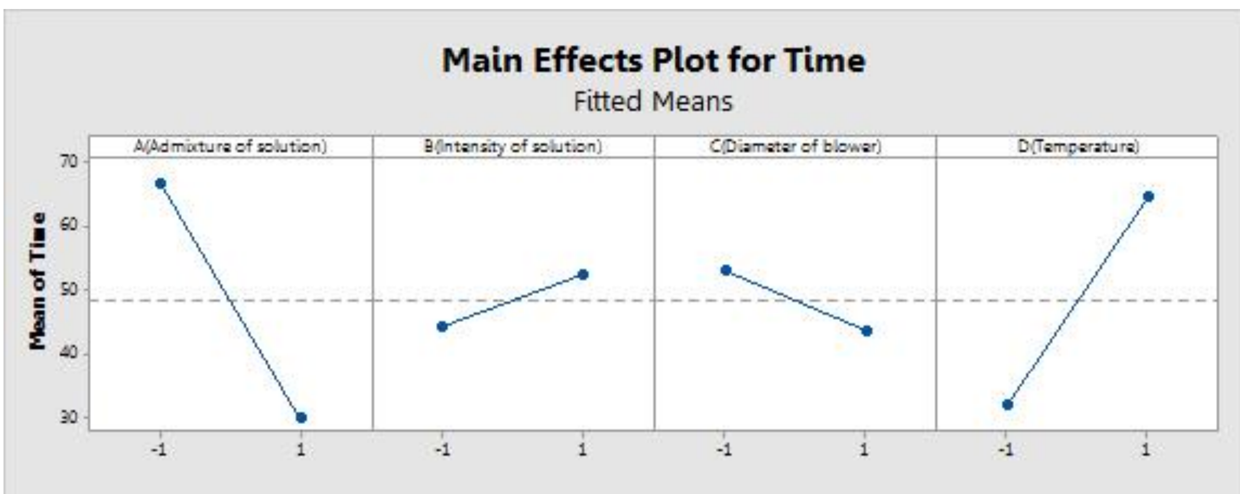


**Figure 6** Main Effect Plot

From figure 6, we can see the A and D have high slope of graph which mean that it is strongly affects the response. Since the slope of graph is propotional to the effect to the response.

**Interaction Effect Plot**

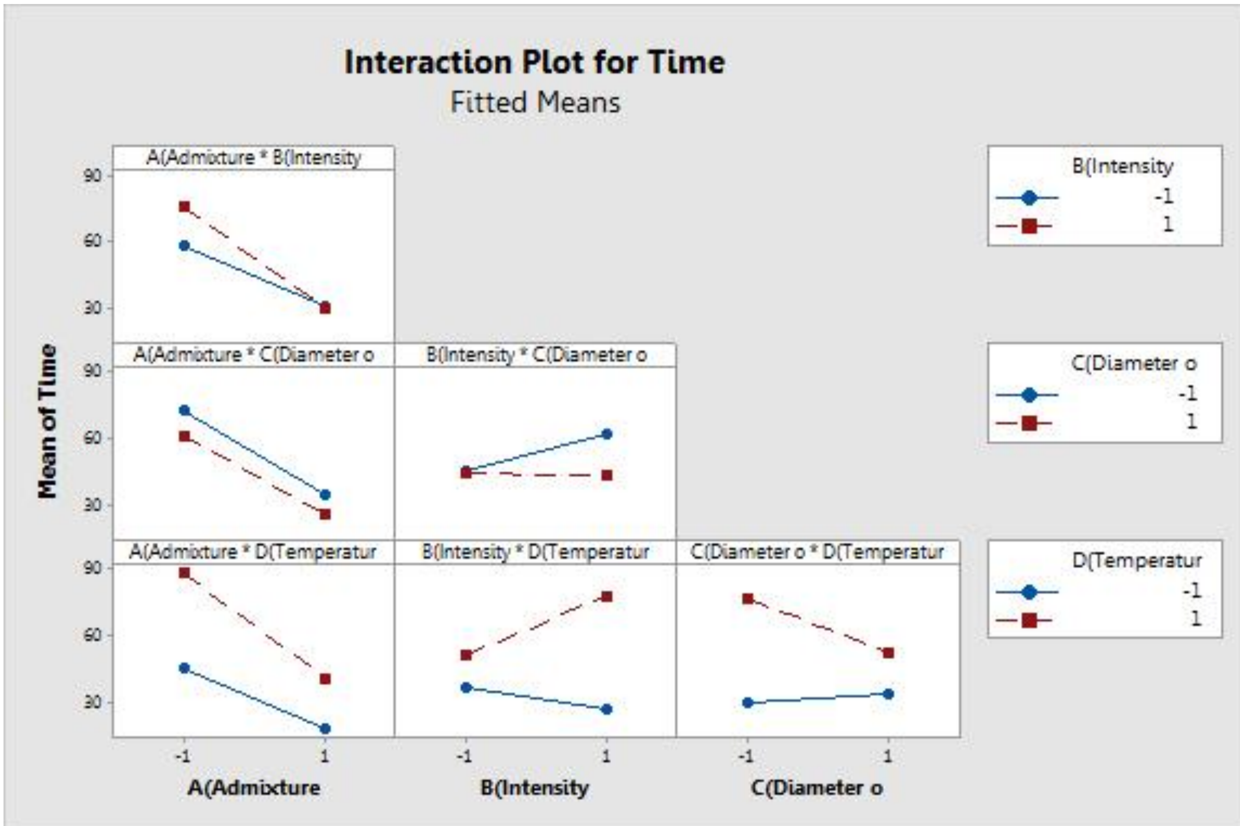


**Figure 7** Interaction Effect Plot

From figure 7, if the slope of both line are going in the same way, it means that the interaction effect doesn't affect the response. But if the slope are different, it means that the interaction effect is affect to the response and it is signigicat. In this experiment, BD and CD affect the response.

In both graph (figure 6,7), it gives the same result that A, D, BD and CD are significant.

After we have analyzed the result, then we compare with the hypothesis. The table shows the comparison between predicted effects and actual effect form the experiment.

| **Control Variables** | **Predicted Effects** | **Predicted Effects** |
|---|---|---|
| Admixture of solution | The admixture of glycerin will affect the time of bubble more than lemon. | The admixture of glycerin will affect the time of bubble more than lemon. |
| Volume of admixture | More volume of admixture would make bubbles have more burst time. | There is no effect to the response. (insignificant) |
| Diameter of blower | The lower diameter would be more efficient for blowing. | There is no effect to the response. (insignificant) |
| Temperature | The lower temperature would make more bursts time of bubble. | The high temperature would make more bursts time of bubble. |

# Chapter 6
# Conclusion

Most of kids really like and enjoy blowing soap bubble, but when they blow, it bursts easily. This problem makes kids may be bored to play the soap bubble because they need to blow it frequently. Even, you buy the soap bubble form the toy store, it may blow up easily too and somehow it is expensive. So with this problem, does it is better that you can make your own soap that cheaper than you buy and get more time before it bursts. We perform the experiment to test and find which factor or which way that can make the soap bubble use the most time until it burst.

From the experimental result, the most factor that effect the time of soap bubble is the admixture of the solution which is Glycerin. The other factor that effect the response time are temperature, which high temperature is better than low temperature and use high intensity of the solution. For the last factor is Diameter of blower, use small diameter of blower is better.

In conclusion, we know that glycerine affect to bubble blowing. Therefore, we don't need to buy soap bubble anymore. We can do by our self at home and enjoy have fun.