# MODULE 10 EXAMPLES

TAs: Nihal Reddy
Email: nireddy@ucsd.edu
OH: Thursdays 6-7pm

Slide Credits: Kira Fleischer

# PROBLEM #: KEY TOPICS FROM PROBLEM

Problem setup and description.

**Question**

Key notes from readings/lectures needed to answer the question

**Solution:** written with as much detail as we expect you to give on your homework sets

# PROBLEM 1: ANOVA TESTING

A professor at UCSD has taught the same class in three different forms: hybrid, in person, and remote. She is interested in whether the mean final scores are the same for the three types. She summarized the final scores of her students in each of the c

| Statistics | Remote | Hybrid | In-person |
|---|---|---|---|
| | 80 | 94 | 78 |
| | 84 | 85 | 83 |
| | 90 | 87 | 93 |
| | 84 | 90 | 81 |
| | 89 | | 76 |
| | | | 89 |
| | | | |

**(a) Write down the null and alternative hypotheses.**

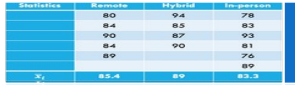
**Solution:** Let $\mu_R, \mu_H, \mu_{IP}$ be the mean final scores of the students who are in remote, hybrid, and in-person classes, respectively.

Then we test $H_0: \mu_R = \mu_H = \mu_{IP}$ vs

$H_A$: at least one mean is different

# PROBLEM 1: ANOVA TESTING

A professor at UCSD has taught the same class in three different forms: hybrid, in person, and remote. She is interested in whether the mean final scores are the same for the three types. She summarized the final scores of her students in each of the c

| Statistics | Remote | Hybrid | In-person |
|---|---|---|---|
| | 80 | 94 | 78 |
| | 84 | 85 | 83 |
| | 90 | 87 | 93 |
| | 84 | 90 | 81 |
| | 89 | | 76 |
| | | | 89 |
|  | **85.4** | **89** | **83.3** |

**(b) How many degrees of freedom does the Mean Squared Error (MSE) have? What about the degrees of freedom of the Mean Squared between Groups (MSG)? Fill in the table for the unknown values.**

**Solution:** $df_{MSG} = k - 1 = 3 - 1 = 2$

$df_{MSE} = n - k = 15 - 3 = 12$

# PROBLEM 1: ANOVA TESTING

A professor at UCSD has taught the same class in three different forms: hybrid, in person, and remote. She is interested in whether the mean final scores are the same for the three types. She summarized the final scores of her students in each of the classes in the following table:

| Statistics | Remote | Hybrid | In-person |
|---|---|---|---|
| | 80 | 94 | 78 |
| | 84 | 85 | 83 |
| | 90 | 87 | 93 |
| | 84 | 90 | 81 |
| | 89 | | 76 |
| | | | 89 |
| $\bar{x}_i$ | **85.4** | **89** | **83.3** |

**(c) Suppose we know that all the conditions are met, compute the F-ratio.**

$$F = \frac{MSG}{MSE};\ MSG = \frac{1}{k-1}\sum_{i=1}^{k} n_i(\bar{x}_i - \bar{x})^2;$$

$$MSE = \frac{1}{n-k}\left(\sum_{i=1}^{n}(x_i - \bar{x})^2 - \sum_{i=1}^{k} n_i(\bar{x}_i - \bar{x})^2\right)$$

# PROBLEM 1: ANOVA TESTING

| Statistics | Remote | Hybrid | In-person |
|---|---|---|---|
| | 80 | 94 | 78 |
| | 84 | 85 | 83 |
| | 90 | 87 | 93 |
| | 84 | 90 | 81 |
| | 89 | | 76 |
| | | | 89 |
| | **85.4** | **89** | **83.3** |

**(c) Suppose we know that all the conditions are met, compute the F-ratio.**

$F = \frac{MSG}{MSE}$; $MSG = \frac{1}{k-1}\sum_{i=1}^{k} n_i(\bar{x}_i - \bar{x})^2$;

$MSE = \frac{1}{n-k}(\sum_{i=1}^{n}(x_i - \bar{x})^2 - \sum_{i=1}^{k} n_i(\bar{x}_i - \bar{x})^2)$

**Solution:** Compute overall average $\bar{x} = \frac{(85.4*5)+(89*4)+(83.3*6)}{15} = 85.52$

$$MSG = \frac{1}{3-1}[5(85.4 - 85.52)^2 + 4(89 - 85.52)^2 + 6(83.3 - 85.52)^2] = 39.042$$

$$MSE = \frac{1}{15-3}[((80 - 85.52)^2 + (84 - 85.52)^2 + (90 - 85.52)^2 + \cdots) - (2 * 39.042)]$$

$$= \frac{1}{12}[403.736 - 78.084] = 27.14. \text{ Thus } F = \frac{MSG}{MSE} = \frac{39.042}{27.14} = 1.439$$

# PROBLEM 1: ANOVA TESTING

A professor at UCSD has taught the same class in three different forms: hybrid, in person, and remote. She is interested in whether the mean final scores are the same for the three types.

**(d) What is the p-value? What would you conclude at the significance level α = 0.05?**

**Solution:** p-value: $P(F \geq 1.439) = 0.275$ (using R code: pf(1.439, 2, 12, lower.tail = FALSE))

Since p-value $= 0.275 >$ α = 0.05, we fail to reject the null hypothesis. We do not have convincing evidence that the mean final scores are different for the three class types.