Exploring the Effectiveness of an Online Genetics Laboratory on Narrow-Sense Heritability

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Background

What is Heritability?

Heritability is the proportion of the total phenotypic variance (V_P) that is attributable to genetic variations ($\mathbf{V_G}$).

Broad-Sense Heritability

Is the proportion phenotypic variance (V_P) that is attributable to <u>all</u> genetic variations ($\mathbf{V_G}$). (Example: Plant Disease-resistance)

$H^2 = \frac{V_G}{V_P}$ $\quad V_P = V_G \quad V_G = V_A + V_D + V_I$

Narrow-Sense Heritability

Is the proportion of phenotypic variance (V_P) that is attributable to <u>additive genetic variance</u> ($\mathbf{V_A}$). (Example: Height & Weight)

$h^2 = \frac{V_A}{V_P}$ $\quad V_P = V_A$

Heritability values ranges from 0-1:

0 = having low heritability

1 = having high heritability

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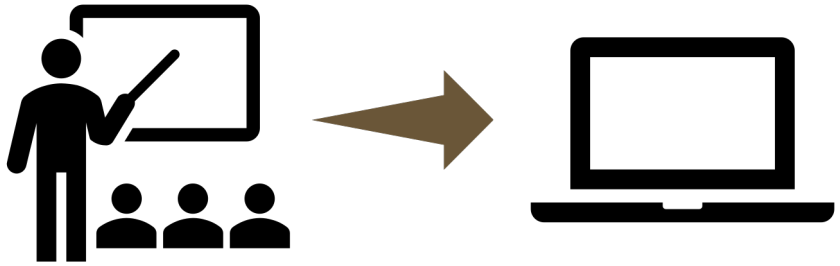
Introduction

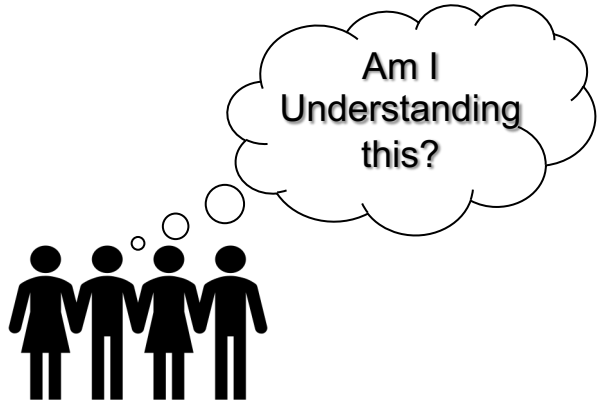
Problem:

- Transition of laboratories from in-person to online delivery.



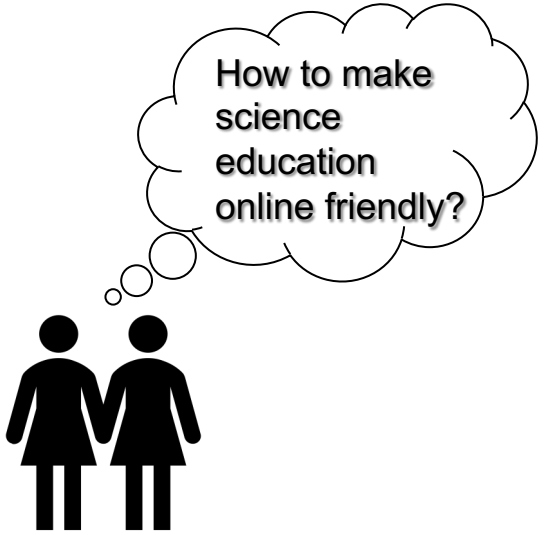
Why it matters?

- Difficulties in understanding narrow-sense heritability .



Potential Solutions

- Creating an online genetics laboratory that still gives students a hands-on lab experience with a physical specimen.



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Research Question

How effective is an online genetics laboratory activity that involves the calculation of narrow-sense heritability of physical specimens?

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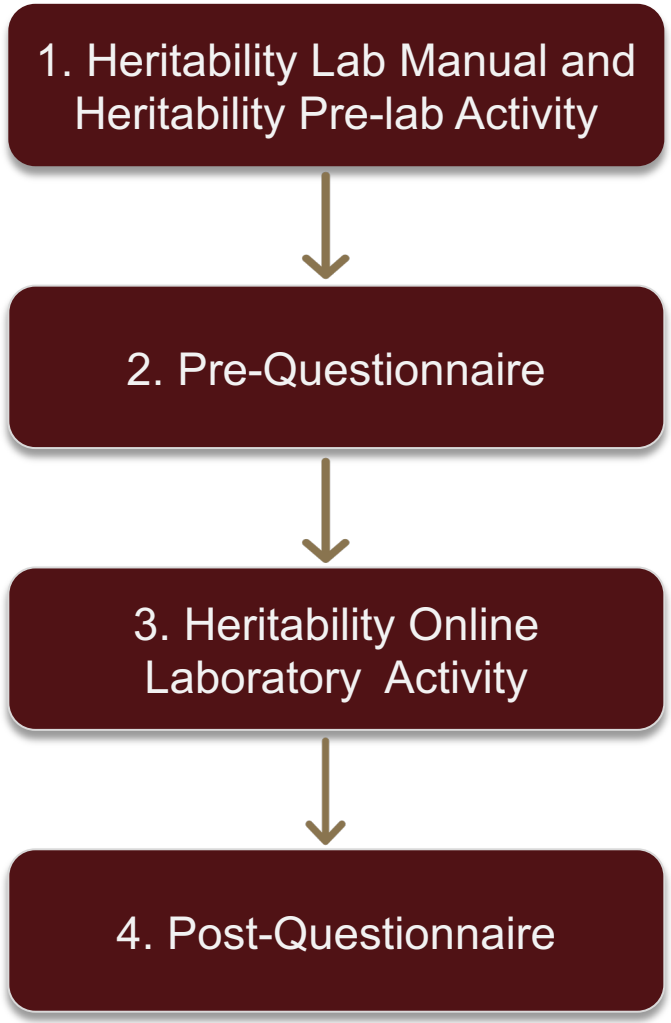
Experimental Design

- **Measurement of students' understanding of heritability**

- **Sample Population: Science Majors in an Online Summer 2021 Genetics Course (n=56)**



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Research Question- How effective is an online genetics laboratory activity that involves the calculation of narrow-sense heritability of physical specimens?

- **Null Hypothesis:**

There is not a significant difference between the genetics students' pre/post-questionnaire scores

- **Alternative hypothesis:**

There is a significant difference between the genetics students' pre/post-questionnaire scores

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Questionnaire presented to students (Part 1)

Heritability Lab Pre-Questionnaire

Student Name:_____

Highlight the statement that applies to you
__I will use a **physical** Heritability Lab Kit
__I will use a **photo version** of the Heritability Lab Kit

1. The number of spots on the wings of 5 ladybugs (Labeled A-E) and 25 offspring ladybugs was measured. Each parent ladybug had 5 offspring (Labeled 1-5) for the F1 generation. Using the data table shown below, the given covariance (COV_{XY}) and parental phenotypic variance (s_X^2), as well as the equation sheet provided on page 4, calculate the parent mean, overall offspring mean, parent-offspring regression coefficient, and the narrow-sense heritability.
   a. Parent mean ($\bar{X}$)= _____
      (*NOTE: Round to the nearest whole number*)
   b. Overall offspring mean ($\bar{Y}$) = _____
      (*NOTE: Round to the nearest whole number*)
   c. Parent-Offspring Regression Coefficient (***b***)= _____
      (*NOTE:* $COV_{XY} = 42.3$ & $s_X^2 = 92.5$)
      (*NOTE: Round to the nearest hundredth*)
   d. Narrow-Sense Heritability (h^2) = _____
      (*NOTE: Round to the nearest hundredth*)

Parent Label:	**A**	**B**	**C**	**D**	**E**
Number of Spots for Parent:	0	5	10	25	15
Parent Mean ($\bar{X}$)					
F1 Offspring Label:	Number of spots for offspring of **Parent A**	Number of spots for offspring of **Parent B**	Number of spots for offspring of **Parent C**	Number of spots for offspring **Parent D**	Number of spots for offspring of **Parent E**
1	5	10	5	15	10
2	4	5	6	17	10
3	6	3	3	14	21
4	7	11	10	21	18
5	9	10	4	15	17
Individual Offspring Means ($\bar{Y}_i$):	**6**	**8**	**5**	**16**	**17**
Overall Offspring Mean ($\bar{Y}$):					

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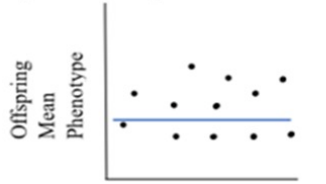
Questionnaire presented to students (Part 2)

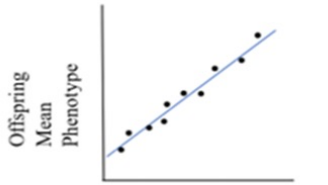
2. In few sentences, please describe the meaning of your narrow-sense heritability (h^2) calculated in problem 1d.

3. Given the parent-offspring regression graph, state the expected narrow-sense heritability (h^2) and regression coefficient (b) values for the graph. Also, in a few sentences, what conclusions can be drawn about the degree of heritability present in the population? (HINT: Is there high, medium, or low heritability; is the heritability due to environmental or additive genetic factors).



a.

YOUR ANSWER HERE:



b.

YOUR ANSWER HERE:

Questionnaire presented to students (Part 3)

4. Below you have been given terms and definitions. Match the definitions given to their corresponding terms.

   i. Covariance (COV_{XY})_____
   ii. Narrow-sense heritability (h^2)_____
   iii. Regression Coefficient (b)_____
   iv. Phenotypic Variance (s^2) ___

   a. Is a measure of the spread of distribution around the phenotype mean; it interprets how much variation exists within the sample.
   b. Estimates the proportion of phenotypic variation that is due to additive genetic variation
   c. Describes the slope of regression line of offspring mean phenotype v. parent's phenotype graph.
   d. Describes the degree to which parents and offspring vary together and is calculated as the average product of the deviation.

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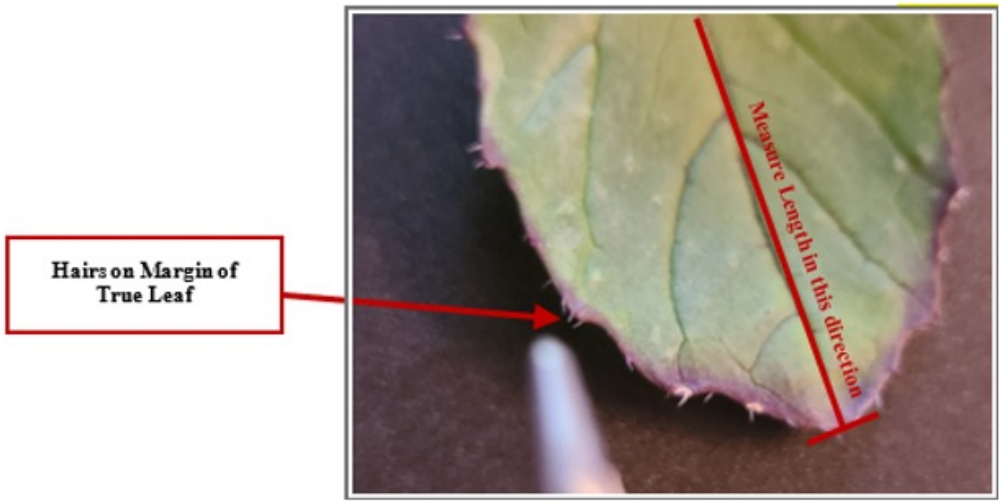
Heritability Lab Activity

I



Hairs on the leaf margin

Model Organism - *Brassica rapa* (Wisconsin Fast Plants)

- Trait variability -the distribution of hair counts on the leaf margin of *Brassica rapa* plants is clearly not a trait that fits into distinct categories, (like hairs and no hairs) and thus can serve as a model for a heritability study

Inexpensive and can be conducted at home

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Heritability Lab Activity

- Students established growing stations at home.

Figure 1: First day set up of *Brassica rapa*

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Heritability Lab Activity

- When the first true leaves are 2 cm long, the hairs along the leaf margin are counted.

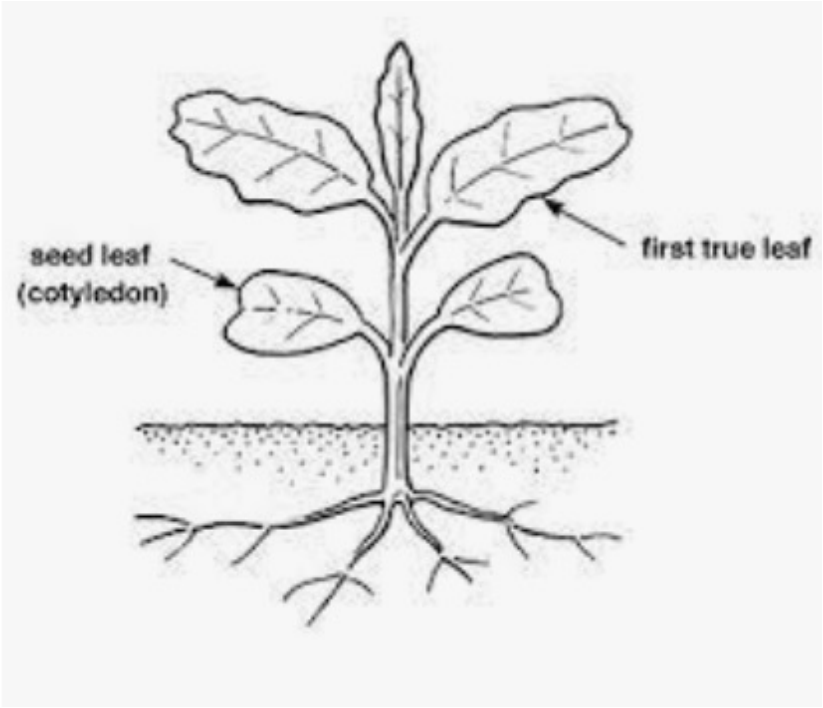

Figure 2: First leaves

The leaves need to be at least 2 cm long, about the size of the smallest leaf shown at a minimum. The difference between first leaves seen at the bottom right and the first true leaves is distinct.

Heritability Lab Activity (Video showing hair counting)

- When the first true leaves are 2 cm long, the hairs along the leaf margin are counted.

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Heritability Lab Activity

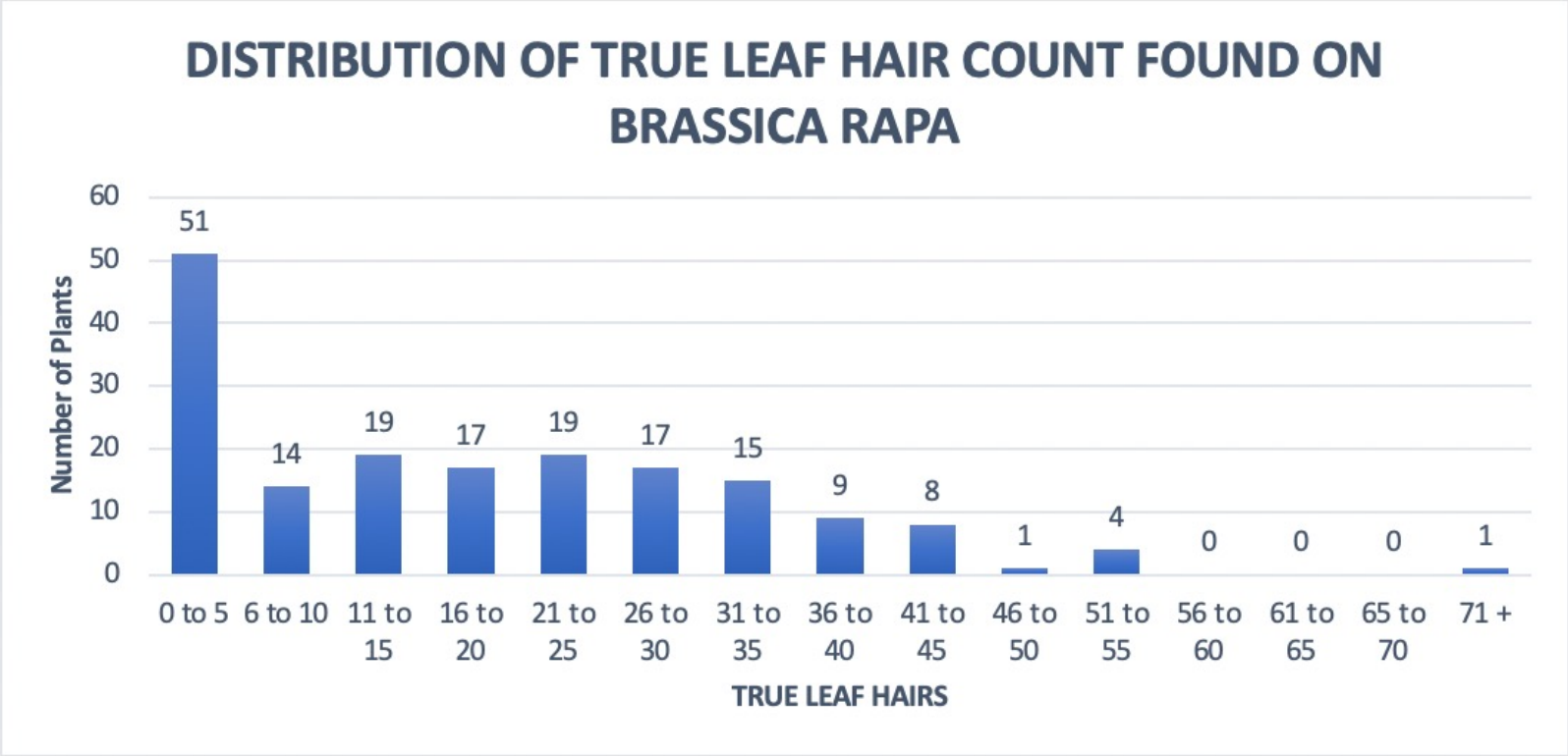

Figure 4: Hair Count Distribution of the First True Leaves

The ranges of hairs are placed along the X axis, while the number of plants is seen along the Y axis. A large proportion of the plants are in the 0-5 category, and the rest are evenly distributed into the ranges set between 6-45 leaf hairs, with a few outliers.

Heritability Lab Activity

Table 1: Calculations of Narrow sense Heritability

The narrow sense heritability was calculated by dividing the covariance by the variance. The result was a narrow sense heritability value of 0.206.

Sample	Parent	Offspring Average		
J-J	18	8		Variance =249.36
J-L	28	21		Covariance = 51.31
J-N	20	23		b= 0.206
J-R	0	7		Narrow SenseHeritibility= 0.206
J-A	15	31		
J-C	20	15		
J-E	18	43		
J-K	0	22		
J-L	20	11		
J-R2	28	29		
S-S	30	18		
S-A	28	13.33		
S-R	30	27.66		
C-C	30	35		
C-E	0	0		
C-H	20	1		
C-A	68	21		
C-K	0	18		
H-H	0	4		
H-G	28	0		
H-K	30	17.33		
H-E	0			

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Results: Response Rate

- **Response Rate for Students that Completed Both Pre- and Post- Questionnaires**
  - 41 out of 56 students completed **both** Pre- and Post-Questionnaires: **73% Response Rate**

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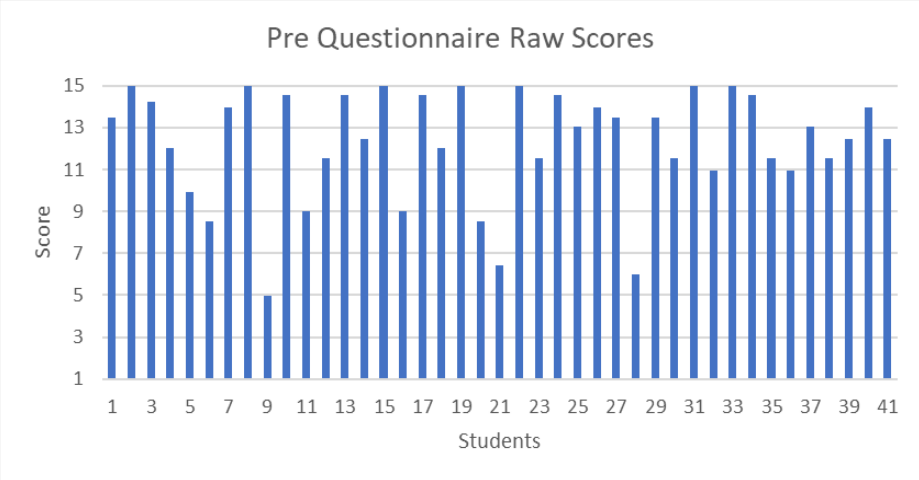
Results: Pre-Questionnaire and Post-Questionnaire

Table 1.

Raw Scores for Pre- Questionnaires and Post-Questionnaires



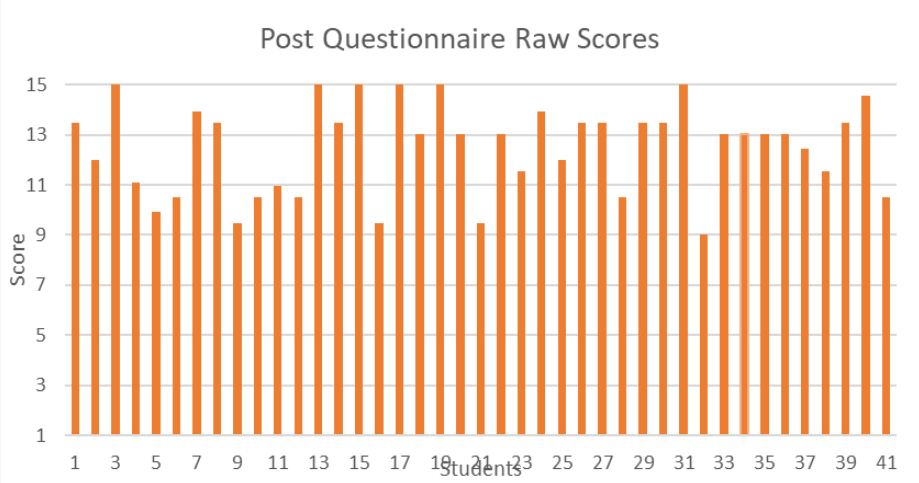


Table 2.

t-test for the Paired Pre-Questionnaire and Post-Questionnaire Sample Means

	Pre-Questionnaire Score Mean	Post-Questionnaire Score Mean
Mean	9.01	9.18
Variance	3.82	1.74
Observations (n)	41	41
P(T<=t) one-tail	0.22	
P(T<=t) two-tail	0.44	

Maximum Score for Questionnaires is 15 points

Note: p-value greater than 0.05, there is no significant difference between the students' pre- and post-questionnaire scores.

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Conclusions

- Research Question: How effective is an online genetics laboratory activity that involves the calculation of narrow-sense heritability using physical specimens?

- **Quantitative analysis:** Pre- and Post-Questionnaire Analysis
  - Failed to reject **null hypothesis:** There was no significant difference between the genetics students' pre/post-questionnaire scores.
  - **Online** lab activity using physical specimens may not be be effective in helping students understand concepts of narrow-sense heritability**.**

Qualitative research: Qualitative analysis of student comments from open-response questions will be conducted to determine the hurdles student have in understanding the concepts of narrow-sense heritability.

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- **QUESTIONS?**

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References

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