

**Homi Bhabha Centre for Science Education**  
Tata Institute of Fundamental Research  
V.N. Purav Marg, Mankhurd, Mumbai- 400088

*Sindhu Mathai - PhD project on*  
*“Visual and Verbal literacies in the context of human body systems”*  
*Questionnaires, coding schemes, analysis and results*

**Respiratory System Phase 2 Part 1: Questionnaire**

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*Summer camp on “Visualisation in Biology”*

*Please fill up the following details*

Your name:  
Class:  
School:  
Today’s date:

*To answer these questions you may use words or drawings as you wish.*

1. What do you understand by "respiration"?
2. Describe your respiratory system.
3. How do you think the inside of your nose looks like? Make a drawing of how it looks like when:
  - a) you breathe in air containing dust particles
  - b) you breathe out
4. What is the role of the nose in respiration? Does it have other functions also?
5. Describe the trachea. What is its role in respiration?
6. The trachea is quite strong and rigid compared to the oesophagus or food pipe. Why is it that way?
7. What would happen if the trachea was a smooth, flexible structure?
8. Describe your lungs.
9. How do your lungs help in respiration?

10. Describe the alveoli. Think of another shape for the alveoli. What is the difference between the two shapes?

11. What is the function of the alveoli?

12. Describe the diaphragm. What is the function of the diaphragm? Can you think of another shape for the diaphragm?

13. What do you understand by the word "breathing"?

14. What are the changes that take place to the respiratory organs when we breathe in and breathe out? Answer using the table given below.

| <b>Organ</b> | <b>Changes that happen while breathing in</b> | <b>Changes that happen while breathing out</b> |
|--------------|---|--|
| Lungs        |   |  |
| Diaphragm    |   |  |

15. Draw and explain the changes that take place to the lungs and diaphragm while:

- a) you breathe in
- b) you breathe out

16. Where does the Oxygen taken into the body go to?

17. Where does the Carbon dioxide we breathe out come from?

18. How do you think Oxygen is always taken in, and carbon dioxide sent out of the body? Do you think carbon-dioxide could be taken in and Oxygen sent out?

19. Do you think the air taken into the body could serve any other function besides its role in respiration?

20. What do you think is the difference between a sneeze and a cough?

21. What are the changes that you experience when you have a common cold? What are the reasons for these changes?

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**Respiratory system Phase 2 Part 1: Coding Scheme for Basic Knowledge and Visualisation**

**Basic Knowledge** was derived from performance on Questions 1, 2, 4, 5, 8, 9, 11, 13, 14, 16 and 17 of the Questionnaire above. The responses were coded based on the criteria of Segmentation, Order and Hierarchy. The scheme is summarized in the first four columns of the Table below, followed by the criteria for coding, which show the break-up of the scores.

**Table 1: Coding scheme for Phase 2 Part 1**

| Basic knowledge                      |  |                                     |  | Visualisation   |
|--------------------------------------|--|-------------------------------------|--|---|
| Text responses (T)                   |  | Drawn responses (D)                 |  | Generation and transformation of images (Text and Diagrams) |
| Structure (TS)                       | Function (TF)                                | Structure (DS)                      | Function (DF)                              |   |
| Names of Organs                      | -  | Segmentation (depiction of organs)  | -  |   |
| Order (described location of organs) | Order of action and Hierarchy (descriptions) | Order (depicted location of organs) | Order of action and Hierarchy (depictions) |   |

*Numbers in brackets refer to the total score for that criterion*

*Comprehension of structure*

I. Organs of the system (8)

1. Nostrils (Nose)
2. pharynx
3. trachea
4. bronchi
5. bronchioles
6. alveoli

7. lungs
8. diaphragm

## II. Order of functioning (similar criterion for both structure and function) (7)

1. nostrils-pharynx
2. pharynx-trachea
3. trachea-bronchi
4. bronchi-bronchioles
5. bronchioles-alveoli (in lungs)
6. alveoli-bloodstream
7. bloodstream- (cells) organs of the body

The total score for TS and DS was determined by adding the score for 'segmentation' and 'order' and normalising to a maximum score of 1. For example if 5 out of 8 organs were named (for TS) or depicted (for DS), the 'segmentation' score was  $5/8 = 0.63$ . If further 4 out of 7 order criteria were satisfied then the 'order' score was  $4/7 = 0.57$ . The TS (or DS) score would be then  $(0.63+0.57)/2 = 0.6$

### ***Basic knowledge: Comprehension of function***

#### ***Variables: Function expressed through Text (TF) and Function expressed through Diagrams (DF)***

## I. Order of action (similar criterion as for structure) (7)

### II. Hierarchy (2)

1. movement of air from the nose to the alveoli and gas exchange; mechanics of respiration (external respiration)
2. internal / cellular respiration

The total score for TF and DF was determined by combining the criteria for 'order' and 'hierarchy', as follows. If 4 out of 7 'order' criteria were satisfied and 1 out of 2 'hierarchy' criteria were satisfied then the TF (or DF) score would be  $(4+1)/(7+2) = 0.56$ . The maximum score was 1.

The procedure differed from that used in obtaining structure scores because the parameter 'hierarchy' has a maximum point of 2 so possible scores were only 0.0, 0.5 and 1.0. We found this procedure was loading and biasing the function scores. Thus we opted to add the 'hierarchy' and 'order' criteria to directly give a TF or DF score. The net result is to reduce the weightage given to 'hierarchy' as compared with 'segmentation' and 'order', which makes educational sense to us.

**Visualisation** was derived from performance on Questions 3, 6, 7, 10, 12, 15, 18 and 19, 20.

*Criteria for **visualisation** (holistically from both text and drawings)  
Coded separately for both structure and function questions*

1. Generation of an image (1)
2. Correctness / feasibility of the generated image (1)
3. Manipulation of generated image (1)
4. Correct manipulation of generated image (1)

These criteria will be employed for the following questions alone. This is in addition to analysis using the criteria mentioned earlier.

3. How do you think the inside of your nose looks like? Make a drawing of how it looks like when:

- a) you breathe in air containing dust particles (4)
- b) you breathe out (4)

6. The trachea is quite strong and rigid compared to the oesophagus or food pipe. Why is it that way? (4)

7. What would happen if the trachea was a smooth, flexible structure? (4)

10. Describe the alveoli. Think of another shape for the alveoli. What is the difference between the two shapes? (4)

12. Describe the diaphragm. What is the function of the diaphragm? Can you think of another shape for the diaphragm? (4)

15. Draw and explain the changes that take place to the lungs and diaphragm while:  
a) you breathe in (4)  
b) you breathe out (4)

18. How do you think Oxygen is always taken in, and carbon dioxide sent out of the body? Do you think carbon-dioxide could be taken in and Oxygen sent out? (4)

19. Do you think the air taken into the body could serve any other function besides its role in respiration? (4)

20. What do you think is the difference between a sneeze and a cough? (4+4)

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Scores on Textbook knowledge (not used in Mathai and Ramadas (2009))

Comparison with standard propositions from the Std. 6 Science textbook was used as a separate criterion to compare propositions in students' responses with standard propositions in the textbook.

### *Structure propositions*

1. Hair and mucus is present inside the nose.
2. Lungs lie in the chest cavity bound by the ribs and the diaphragm.
3. The chest and diaphragm is made up of muscles.
4. The diaphragm is a powerful muscle situated inside the chest cavity below the lungs.

### *Function propositions*

1. Respiration involves exchange of gases: intake of Oxygen and release of carbon dioxide. This process is called breathing.
2. Energy released by the breakdown of digested foodstuff is called respiration.
3. Air enters the respiratory system through the nostrils during breathing.
4. The hair and mucus present inside the nose prevent dirt, dust and germs from entering the respiratory system.
5. Air that is rich in Oxygen is inhaled during breathing.
6. Oxygen containing air reaches the lungs, and then Oxygen enters the blood.
7. Blood transports Oxygen to different parts of the body.
8. Blood collects carbon dioxide from the different parts of the body with the help of the pigment haemoglobin present in it.
9. Carbon dioxide is formed as a waste product during respiration.
10. Water vapour and carbon dioxide are released from the blood into the lungs.
11. When we breathe out, water vapour and carbon dioxide are removed from the lungs.
12. Muscles of the chest and diaphragm help in breathing in and breathing out.
13. During inhalation, the diaphragm is pulled down (it appears flattened).
14. The lungs and chest cavity expand during inhalation of air.
15. During exhalation, the diaphragm moves up to its normal, curved position.
16. During exhalation, the lungs deflate or relax by pushing air out.

### **Summary of the parameters and scores assigned to Part 1 variables**

**Part I:** Part 1 was scored overall for students' responses and not for each question individually except for the questions on visualisation

#### **1. Text-Structure**

Organs: 8

Order of location of organs: 7

Standard propositions: 4

Total: 19

#### **2. Text-Function**

Hierarchy: 2

Standard propositions: 16  
 Total: 18

### 3. Diagrams-Structure

Segmentation: 8  
 Order of location: 7  
 Total: 15

### 4. Diagrams-Function

Order of function: 7  
 Hierarchy: 2  
 Total: 9

### 5. Visualisation

Question nos: 3a (4), 3b (4), 6 (4), 7 (4), 10 (4), 12 (4), 15a (4), 15b (4), 18 (4), 19 (4), 20 (8) Total: 48

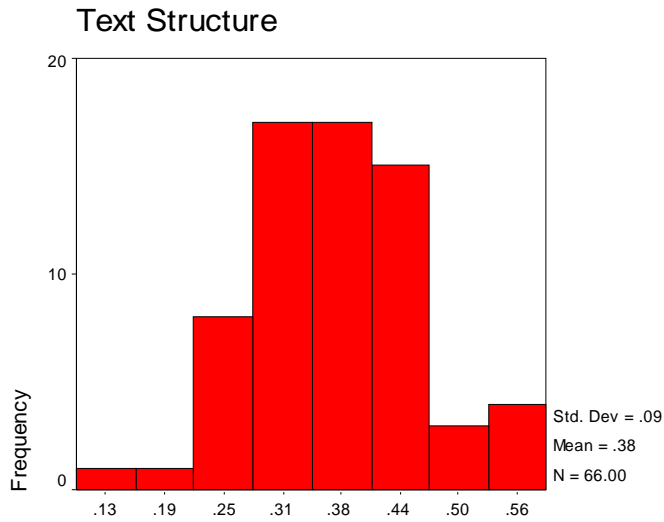
### Comparison of mean scores for the respiratory system and the inequalities between variables

|                                 | No. of students | Respiratory system                                   |
|---------------------------------|-----------------|--|
| All students                    | 66              | TS > TF > DS > V > DF<br>.38 > .29 > .23 > .22 > .17 |
| Only students who drew diagrams | 45              | TS > DF, DS > V > DF<br>.41 > .33, .33 > .26 > .25   |
| Students who drew no diagrams   | 21              | TS > TF > V<br>.32 > .19 > .14                       |

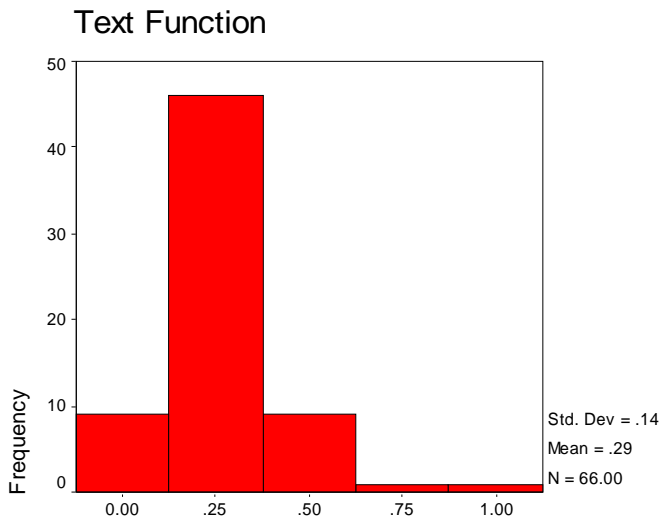
### Mean scores for respiratory system Part 1 variables

| Variable | Mean score | Standard deviation |
|----------|------------|--------------------|
| TS       | 0.38       | 0.1                |
| TF       | 0.29       | 0.14               |
| DS       | 0.23       | 0.21               |
| DF       | 0.17       | 0.17               |
| PS       | 0.37       | 0.22               |
| PF       | 0.63       | 0.18               |
| V        | 0.22       | 0.2                |

| System      | Variable                    | Mean score | Std. deviation |
|-------------|-----------------------------|------------|----------------|
| Respiratory | Propositions structure (PS) | 0.37       | 0.22           |
|             | Propositions function (PF)  | 0.63       | 0.18           |



Text Structure



Text Function



Diagram Structure

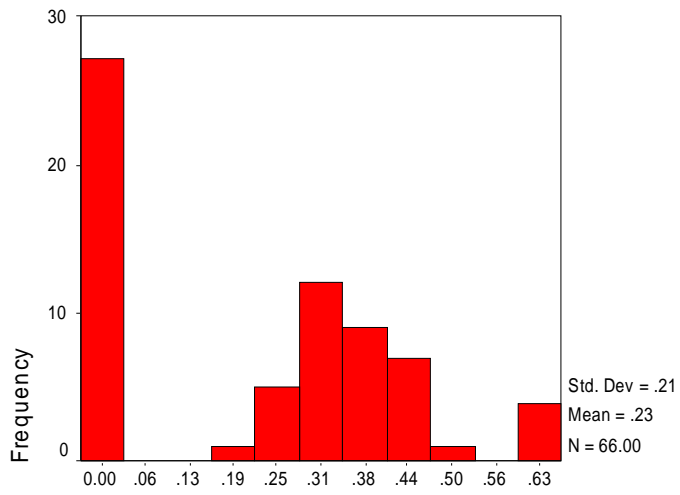


Diagram Structure

Diagram Function

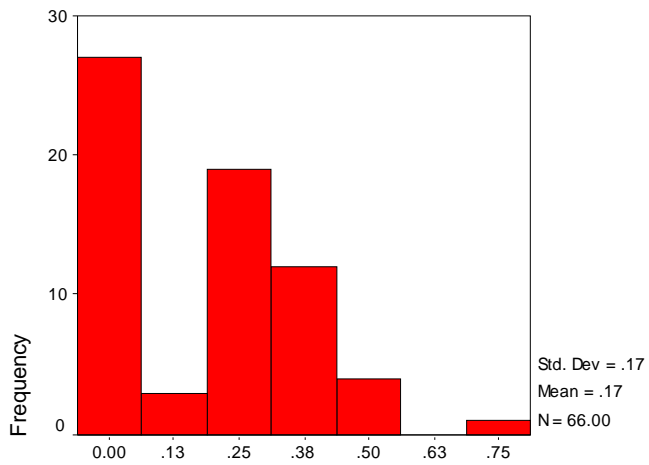
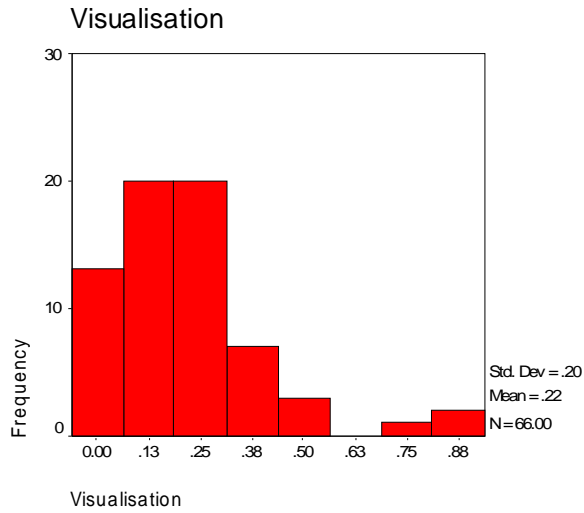


Diagram Function



**Spearman's Rho for the entire sample of students (66)**

|    |                         | TS    | TF    | DS    | DF    | V     |
|----|-------------------------|-------|-------|-------|-------|-------|
| TS | Correlation Coefficient | 1.0   | 0.9** | 0.6** | 0.5** | 0.4** |
| TF | Correlation Coefficient | 0.9** | 1.0   | 0.6** | 0.6** | 0.4** |
| DS | Correlation Coefficient | 0.6** | 0.6** | 1.0   | 0.9** | 0.5** |
| DF | Correlation Coefficient | 0.5** | 0.6** | 0.9** | 1.0   | 0.5** |
| V  | Correlation Coefficient | 0.4** | 0.4** | 0.5** | 0.5** | 1.0   |

**Spearman's Rho for the sample of students who drew diagrams (45)**

|    |                         | TS    | TF    | DS    | DF    | V     |
|----|-------------------------|-------|-------|-------|-------|-------|
| TS | Correlation Coefficient | 1.0   | 0.8** | 0.5** | 0.4** | 0.5** |
| TF | Correlation Coefficient | 0.8** | 1.0   | 0.4** | 0.4** | 0.5** |
| DS | Correlation Coefficient | 0.5** | 0.4** | 1.0   | 0.7** | 0.5** |
| DF | Correlation Coefficient | 0.4** | 0.4** | 0.7** | 1.0   | 0.5** |
| V  | Correlation Coefficient | 0.5** | 0.5** | 0.5** | 0.5** | 1.0   |

**Spearman's Rho for the sample of students who did not draw diagrams (21)**

|    |                         | TS    | TF    | V    |
|----|-------------------------|-------|-------|------|
| TS | Correlation Coefficient | 1.0   | 0.8** | -0.1 |
| TF | Correlation Coefficient | 0.8** | 1.0   | 0.1  |
| V  | Correlation Coefficient | -0.1  | 0.1   | 1.0  |

**Cross tabulation of TS and TF scores for the Respiratory system**

|      | TS-L | TS-M | TS-H |
|------|------|------|------|
| TF-L | 24   | 28   | 0    |
| TF-M | 0    | 9    | 0    |
| TF-H | 0    | 2    | 0    |

**Cross tabulation of DS and DF scores for the Respiratory system**

|      | DS-L | DS-M | DS-H |
|------|------|------|------|
| DF-L | 44   | 17   | 0    |
| DF-M | 1    | 3    | 0    |
| DF-H | 0    | 1    | 0    |

**Cross tabulation between text, diagram and visualisation scores for Part 1 variables of the Respiratory system**

|            | <b>T-l</b> | <b>T-m</b> | <b>T-h</b> |
|------------|------------|------------|------------|
| <b>V-l</b> | 30         | 20         | 0          |
| <b>V-m</b> | 2          | 7          | 0          |
| <b>V-h</b> | 0          | 2          | 1          |

|            | <b>D-l</b> | <b>D-m</b> | <b>D-h</b> |
|------------|------------|------------|------------|
| <b>V-l</b> | 43         | 8          | 0          |
| <b>V-m</b> | 6          | 3          | 0          |
| <b>V-h</b> | 0          | 2          | 1          |

|            | <b>T-l</b> | <b>T-m</b> | <b>T-h</b> |
|------------|------------|------------|------------|
| <b>D-l</b> | 29         | 16         | 0          |
| <b>D-m</b> | 2          | 11         | 0          |
| <b>D-h</b> | 0          | 0          | 1          |

*Average scores for the respiratory system for Part 1 analysis criteria*

|                                 |      |
|---------------------------------|------|
| Diagrams- Order of function (F) | 0.14 |
| Diagrams- Order of location (S) | 0.15 |
| Text- Order of action (F)       | 0.22 |
| Text-Order of location (S)      | 0.22 |
| Diagrams-Segmentation (S)       | 0.3  |
| Diagrams-Hierarchy (F)          | 0.31 |
| Text-Hierarchy (F)              | 0.53 |
| Text-Names of organs (S)        | 0.54 |

**Inter-rater correlations**

| <b>Variable</b> | <b>Respiratory system</b> |
|-----------------|---------------------------|
| TS              | 0.41*                     |
| TF              | 0.88**                    |
| DS              | 0.88**                    |
| DF              | 0.79**                    |
| V               | 0.75*                     |
| PS              | 0.6*                      |
| PF              | 0.68**                    |

\* Significant at 0.05 level

\*\* Significant at 0.01 level

### T tests for Part 1 variables: overall sample

#### Paired Samples Test

|        |  | Paired Differences |                |                 |   |        | t      | df | Sig. (2-tailed) |
|--------|--|--------------------|----------------|-----------------|---|--------|--------|----|-----------------|
|        |  | Mean               | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference |        |        |    |                 |
|        |  |                    |                |                 | Lower                                     | Upper  |        |    |                 |
| Pair 1 | Text Structure - Text Function                 | .0923              | .09519         | .01172          | .0689                                     | .1157  | 7.882  | 65 | .000            |
| Pair 2 | Diagram Structure - Diagram Function           | .0564              | .10089         | .01242          | .0316                                     | .0812  | 4.539  | 65 | .000            |
| Pair 3 | Text Structure - Diagram Structure             | .1545              | .17025         | .02096          | .1126                                     | .1963  | 7.371  | 65 | .000            |
| Pair 4 | Text Function - Diagram Function               | .1185              | .13637         | .01679          | .0850                                     | .1520  | 7.058  | 65 | .000            |
| Pair 5 | Structure Propositions - Function Propositions | -.2598             | .22037         | .02713          | -.3140                                    | -.2057 | -9.580 | 65 | .000            |
| Pair 6 | Text Structure - Visualisation                 | .1629              | .17574         | .02163          | .1197                                     | .2061  | 7.530  | 65 | .000            |
| Pair 7 | Text Function - Visualisation                  | .0705              | .16897         | .02080          | .0290                                     | .1121  | 3.391  | 65 | .001            |
| Pair 8 | Diagram Structure - Visualisation              | .0084              | .19666         | .02421          | -.0399                                    | .0568  | .347   | 65 | .729            |
| Pair 9 | Diagram Function - Visualisation               | -.0480             | .17699         | .02179          | -.0915                                    | -.0044 | -2.201 | 65 | .031            |

### T tests for Part 1 variables: for the sample of students who did not draw diagrams

#### Paired Samples Test

|        |  | Paired Differences |                |                 |   |        | t      | df | Sig. (2-tailed) |
|--------|--|--------------------|----------------|-----------------|---|--------|--------|----|-----------------|
|        |  | Mean               | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference |        |        |    |                 |
|        |  |                    |                |                 | Lower                                     | Upper  |        |    |                 |
| Pair 1 | Text Structure - Text Function                 | .1279              | .08077         | .01763          | .0911                                     | .1646  | 7.254  | 20 | .000            |
| Pair 2 | Structure Propositions - Function Propositions | -.2576             | .27113         | .05916          | -.3810                                    | -.1342 | -4.354 | 20 | .000            |
| Pair 3 | Text Structure - Visualisation                 | .1774              | .14011         | .03058          | .1136                                     | .2412  | 5.801  | 20 | .000            |
| Pair 4 | Text Function - Visualisation                  | .0495              | .13858         | .03024          | -.0136                                    | .1126  | 1.638  | 20 | .117            |

## T tests for Part 1 variables: sample of students who drew diagrams

### Paired Samples Test

|        |  | Paired Differences |                |                 |   |        | t      | df | Sig. (2-tailed) |
|--------|--|--------------------|----------------|-----------------|---|--------|--------|----|-----------------|
|        |  | Mean               | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference |        |        |    |                 |
|        |  |                    |                |                 | Lower                                     | Upper  |        |    |                 |
| Pair 1 | Text Structure - Text Function                 | .0758              | .09766         | .01456          | .0464                                     | .1051  | 5.205  | 44 | .000            |
| Pair 2 | Diagram Structure - Diagram Function           | .0827              | .11319         | .01687          | .0487                                     | .1167  | 4.899  | 44 | .000            |
| Pair 3 | Text Structure - Diagram Structure             | .0764              | .14183         | .02114          | .0338                                     | .1191  | 3.616  | 44 | .001            |
| Pair 4 | Text Function - Diagram Function               | .0833              | .13640         | .02033          | .0424                                     | .1243  | 4.098  | 44 | .000            |
| Pair 5 | Structure propositions - Function propositions | -.2609             | .19576         | .02918          | -.3197                                    | -.2021 | -8.940 | 44 | .000            |
| Pair 6 | Text Structure - Visualisation                 | .1527              | .19496         | .02906          | .0941                                     | .2112  | 5.253  | 44 | .000            |
| Pair 7 | Text Function - Visualisation                  | .0769              | .18300         | .02728          | .0219                                     | .1319  | 2.818  | 44 | .007            |
| Pair 8 | Diagram Structure - Visualisation              | .0762              | .19025         | .02836          | .0191                                     | .1334  | 2.688  | 44 | .010            |
| Pair 9 | Diagram Function - Visualisation               | -.0064             | .18516         | .02760          | -.0621                                    | .0492  | -.233  | 44 | .816            |