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

Digestive 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 and drawings in any way that you wish.

1. Describe your digestive system.

2. Suppose you ask your friend to open wide his mouth. You then look inside it. What organs do you see inside the mouth? Describe their shape. How do these organs help in digestion of food?

3. Draw the inside of your friend's mouth as it might have appeared to you.

4. Describe the food-pipe. How does the food-pipe help in digestion?

5. Suppose the food-pipe was longer or shorter. What difference would it make? Would it affect digestion of food? If so, how?

6. Describe the stomach. How does the stomach help in digestion?

7. Suppose the stomach was in the shape of a pipe. What difference would it make? Would it affect digestion of food? If so, how?

8. Describe the small intestine. How does the small intestine help in digestion?

9. Suppose the small intestine was much shorter. What difference would it make? Would it affect digestion of food? If so, how?

10. Describe the large intestine. How does the large intestine help in digestion?

11. Think of another shape for the large intestine. Would that different shape have any effect on the working of the large intestine?

12. Imagine that you are eating a piece of bread toast. What changes does the toast go through in each digestive organ while it is being digested? Answer using the table given below. Use more paper if you wish.

Digestive Organ	**Changes that happen to the food while in this organ (use more paper to answer if you wish)**	**Condition of toast after it has passed through this organ (put a √ in the appropriate column)**		
		Liquid	**Semi-solid**	**Solid**
Mouth				
Oesophagus				
Stomach				
Small Intestine				
Large Intestine				

13. Try to show through a drawing what happens to the toast at each stage of the process of digestion.

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

Basic Knowledge was derived from performance on Questions 1, 4, 6, 8, 10 and 12 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.

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)	

Criteria for coding

Numbers within brackets refer to the total score for the criterion

Basic knowledge: Comprehension of structure

Variables: Structure expressed through Text (TS) and Structure expressed through Diagrams (DS)

I. Segmentation = Names (text) or Depiction (diagrams) of the organs of the system (12):

1. Mouth (comprising of 2. teeth, 3. tongue, 4. salivary glands), 5. oesophagus, 6. stomach, 7. duodenum, 8. liver, 9.pancreas, 10. small intestine, 11. large intestine, 12. anus

II. Order of passage of food to the various organs expressed through text or diagrams (the same criterion is used for understanding function too) (7):

1. mouth-oesophagus
2. oesophagus-stomach
3. stomach-duodenum
4. liver and pancreas connected to duodenum
5. duodenum-small intestine
6. small intestine-large intestine
7. large intestine-anus

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 8 out of 12 organs were named (for TS) or depicted (for DS), the `segmentation' score was 8/12 = 0.67. 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 (0.67+0.57)/2 = 0.62.

Basic knowledge: Comprehension of function

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

I. Order of function expressed through text or diagrams (same as that given for structure) (7)

II. Hierarchy (2)

1. alimentary canal
2. liver and pancreas

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 2, 3, 5, 7, 9, 11, 12 and 13.

*Four criteria for visualisation (holistically from both text and drawings), c*oded for each question requiring visualisation:

1. Generation of an image
2. Correctness / feasibility of the generated image
3. Ability to manipulate the generated image
4. Correct manipulation of generated image

These criteria were applied to the questions below. Assigning one point per criterion the maximum score was as given in brackets after each question. The question numbers are as per the numbering in the questionnaire:

2. Suppose you ask your friend to open wide his mouth. You then look inside it. What organs do you see inside the mouth? Describe their shape. How do these organs help in digestion of food? (4)

3. Draw the inside of your friend's mouth as it might have appeared to you. (4)

5. Suppose the food-pipe was longer or shorter. What difference would it make? Would it affect digestion of food? If so, how? (4)

7. Suppose the stomach was in the shape of a pipe. What difference would it make? Would it affect digestion of food? If so, how? (4)

9. Suppose the small intestine was much shorter. What difference would it make? Would it affect digestion of food? If so, how? (4)

11. Think of another shape for the large intestine. Would that different shape have any effect on the working of the large intestine? (4)

12. Imagine that you are eating a piece of bread toast. What changes does the toast go through in each digestive organ while it is being digested? Answer using the table given below. Use more paper if you wish.

Digestive Organ	**Changes that happen to the food while in this organ (use more paper to answer if you wish)**	**Condition of toast after it has passed through this organ (put a √ in the appropriate column)**		
		Liquid	**Semi-solid**	**Solid**
Mouth				

Oesophagus				
Stomach				
Small Intestine				
Large Intestine				

13. Try to show through a drawing what happens to the toast at each stage of the process of digestion. (20 points for both 12 and 13 taken together)

Summary of scores assigned to Part 1 variables for the digestive system
(S: Structure, F: Function, S-F: Structure-Function relationship)

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: 12
- Order: 7
Total score: 19

- Propositions: 6

2. Text-function

-Order of action: 7
- Hierarchy: 2
Total score: 9

- Propositions: 18

3. Diagrams-structure

- Segmentation: 12
- Order: 7
Total score: 19

4. Diagrams-function

- Order: 7
- Hierarchy: 2
Total score: 9

5. Visualisation

Question nos. with score for each question within brackets: 2 (4), 3 (4), 5 (4), 7 (4), 9 (4), 11 (4), 12/13 (20)
Total score: 44

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

In addition, 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. The tongue is a muscular organ.
2. There are four types of teeth in our mouth: incisors, canines, pre-molars and molars.
3. The oesophagus is also called food pipe.
4. The foodpipe is a passage.
5. The stomach is a bag-like structure.
6. The small intestine is a long tubular structure arranged in the form of a coil.

Function propositions

1. Different regions of the tongue carry different taste sensations.
2. Teeth are used to chew food during the process of mastication.
3. The incisors are used for biting.
4. The canines are used for biting and tearing.
5. The pre-molars and molars are used for grinding.
6. Food particles are mixed with saliva.
7. Saliva is secreted by the salivary glands.
8. Tongue helps in mixing saliva with the food.
9. Tongue helps in swallowing.
10. The foodpipe takes food from the mouth to the stomach.
11. The stomach contains an acidic juice.
12. Acids help in the digestion of proteins.
13. Food goes to the duodenum (first part of the small intestine) from the stomach.
14. Absorption of digested food takes place in the small intestine.
15. Digestion of food is completed in the duodenum and small intestine.
16. The waste material left after absorption of food moves to the large intestine.
17. The large intestine absorbs water.
18. The large intestine removes undigested food through the anus.

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Digestive system Phase 2 Part 1: Tables of results for Basic Knowledge and Visualisation

Mean scores and standard deviations for Part 1 variables

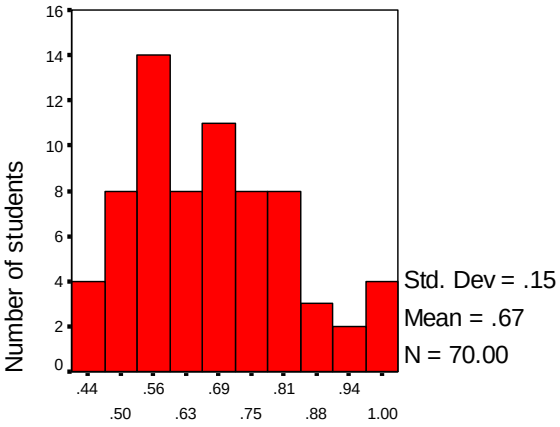
Variable	Mean score	Std. deviation
Text Structure (TS)	0.67	0.15
Text Function (TF)	0.63	0.21
Visualisation (V)	0.57	0.20
Diagram Function (DF)	0.39	0.37
Diagram Structure (DS)	0.32	0.34

Comparison of mean scores on all variables for the digestive system

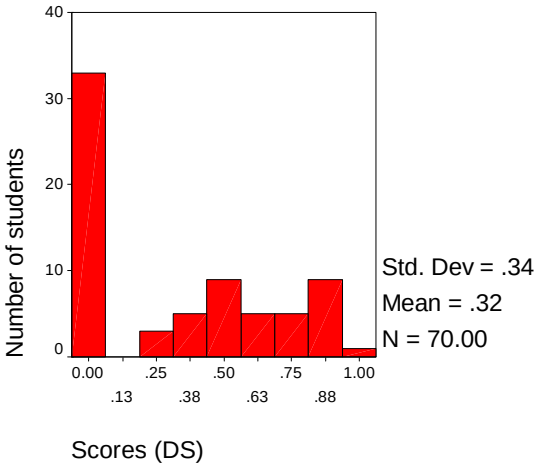
Category of students	No. of students	Digestive system
All students	70	TS > TF > V > DF > DS .67 > .63 > .57 > .39 > .32
Only students who drew diagrams	41	TS > TF > DF > V > DS .72 > .70 > .65 > .61 > .54
Students who drew no diagrams	29	TS > TF > V .61 > .53 > .50

Figures 3 (a-d): Anomalous distributions of scores on the digestive system indicating
(i) a low incidence of diagrams drawn and
(ii) relatively large sub-populations of students with "medium" scores, who turned out to hold common alternative conceptions

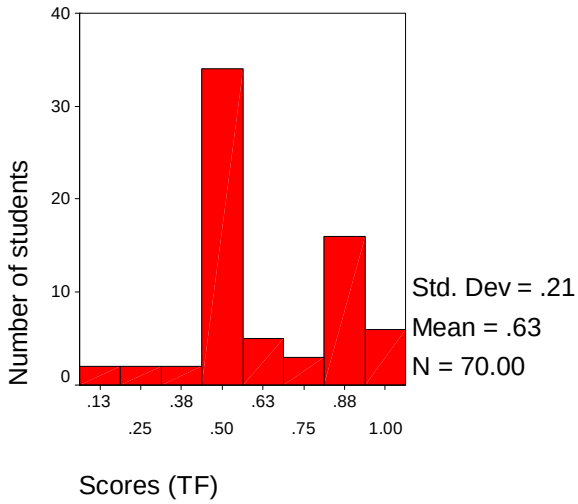
a. Structure expressed through text (TS)



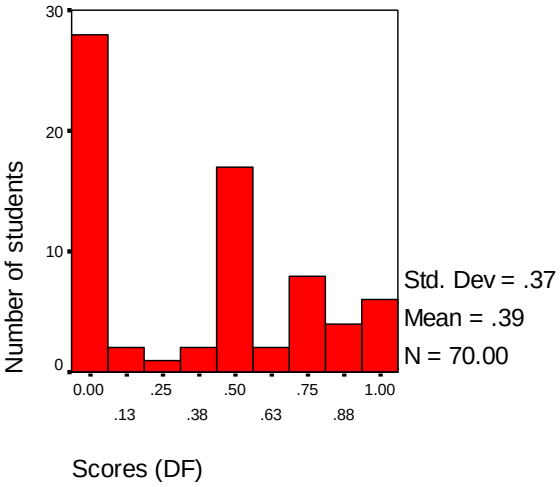
c. Structure expressed through diagrams (DS)



b. Function expressed through text (TF)



d. Function expressed through diagrams (DF)



Correlation matrices

Spearman's Rho for the overall sample (70)

		TS	TF	DS	DF	V
TS	Correlation Coefficient	1.0	0.9**	0.4**	0.6**	0.5**
TF	Correlation Coefficient	0.9**	1.0	0.4**	0.6**	0.6**
DS	Correlation Coefficient	0.4**	0.4**	1.0	0.8**	0.3*
DF	Correlation Coefficient	0.6**	0.6**	0.8**	1.0	0.4**
V	Correlation Coefficient	0.5**	0.6**	0.3*	0.4**	1.0

** . Correlation is significant at .01 level (2 - tailed).

* . Correlation is significant at the .05 level (2 - tailed).

Spearman's Rho for the sample of students who drew diagrams (41)

		TS	TF	DS	DF	V
TS	Correlation Coefficient	1.0	0.9**	0.4**	0.7**	0.5**
TF	Correlation Coefficient	0.9**	1.0	0.3	0.6**	0.6**
DS	Correlation Coefficient	0.4**	0.3	1.0	0.7**	0.3**
DF	Correlation Coefficient	0.7**	0.6**	0.7**	1.0	0.4**
V	Correlation Coefficient	0.5**	0.6**	0.3*	0.4**	1.0

**. Correlation is significant at .01 level (2 - tailed).

* . Correlation is significant at the .05 level (2 - tailed).

Spearman's Rho for the sample of students who did not draw diagrams (29)

		TS	TF	V
TS	Correlation Coefficient	1.0	0.8**	0.3
TF	Correlation Coefficient	0.8**	1.0	0.4**
V	Correlation Coefficient	0.3	0.4**	1.0

**. Correlation is significant at .01 level (2 - tailed).
* . Correlation is significant at the .05 level (2 - tailed).

Re-coded scores:

l = Low (0-0.33), m = Medium (0.34-0.66) and h = High (0.67-1.00)

Cross tabulation of TS and TF scores for the Digestive system

	TS-l	**TS-m**	**TS-h**
TF-l	0	4	0
TF-m	0	31	6
TF-h	0	2	25

Cross tabulation of DS and DF scores for the Digestive system

	DS-l	**DS-m**	**DS-h**
DF-l	31	2	0
DF-m	3	13	1
DF-h	2	4	14

Cross tabulation between text, diagram and visualisation scores for the digestive system

	T-l	**T-m**	**T-h**
V-l	1	6	1
V-m	1	27	8
V-h	0	7	18

	D-l	D-m	D-h
V-l	6	2	0
V-m	19	10	7
V-h	8	8	9

	T-l	T-m	T-h
D-l	4	24	7
D-m	0	14	6
D-h	0	2	13

Cross tabulations for Part 2 and 3 variables of the digestive system

	P1 (2a) - l	P1 (2a) - m	P1 (2a) – h
V-l	2	2	1
V-m	0	6	10
V-h	0	6	8

	P2 (2a) - l	P2 (2a) - m	P2 (2a) – h
V-l	4	0	1
V-m	1	6	9
V-h	2	2	6

	P1 (2b) - l	P1 (2b) - m	P1 (2b) – h
V-l	0	2	1
V-m	1	6	9
V-h	2	2	6

	P2 (2b) - l	P2 (2b) - m	P2 (2b) – h
V-l	1	0	0
V-m	5	4	3
V-h	0	8	2

	t1 (3a) - l	t1 (3a) - m	t1 (3a) – h
V-l	3	2	1
V-m	5	13	7
V-h	4	11	7

	t2 (3a) - l	t2 (3a) - m	t2 (3a) – h

V-l	4	1	1
V-m	11	11	8
V-h	7	8	9

Inter-rater correlations for Part 1 variables

Variable	Digestive system
TS	0.84**
TF	0.80**
DS	0.83**
DF	0.71**
V	0.65**
PS	0.90**
PF	0.85**

** Significant at 0.05 level*
*** Significant at 0.01 level*

Average scores for the digestive system for Part 1 analysis criteria

	Parameter	**Average score**
Parameters within diagram analysis	Order of location (S)	0.31
	Segmentation (S)	0.34
	Order of function (F)	0.38
	Hierarchy (F)	0.44
Parameters within text analysis	Order of action (F)	0.61
	Order of location (S)	0.62
	Hierarchy (F)	0.66
	Names of organs (S)	0.73
	Propositions (S)	0.74
	Propositions (F)	0.52

Parameter	**Mean score**	**Std. deviation**
Propositions structure (PS)	0.74	0.12
Propositions function (PF)	0.52	0.22

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	.0396	.11297	.01350	.0127	.0666	2.936	69	.005
Pair 2	Diagram Structure - Diagram Function	-.0654	.19542	.02336	-.1120	-.0188	-2.801	69	.007
Pair 3	Propositions Structure - Propositions Function	.2190	.20354	.02433	.1705	.2675	9.002	69	.000
Pair 4	Text Structure - Diagram Structure	.3480	.30791	.03680	.2746	.4214	9.456	69	.000
Pair 5	Text Function - Diagram Function	.2429	.29502	.03526	.1726	.3133	6.889	69	.000
Pair 6	Text Structure - Visualisation	.1070	.18030	.02155	.0640	.1500	4.965	69	.000
Pair 7	Text Function - Visualisation	.0674	.19688	.02353	.0204	.1143	2.862	69	.006
Pair 8	Diagram Structure - Visualisation	-.2410	.34274	.04097	-.3227	-.1593	-5.883	69	.000
Pair 9	Diagram Function - Visualisation	-.1756	.34394	.04111	-.2576	-.0936	-4.271	69	.000

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	.0760	.11348	.02107	.0329	.1192	3.608	28	.001
Pair 2	Propositions Structure - Propositions Function	.2603	.20306	.03771	.1831	.3376	6.904	28	.000
Pair 3	Text Structure - Visualisation	.1038	.19071	.03541	.0313	.1763	2.931	28	.007
Pair 4	Text Function - Visualisation	.0278	.20950	.03890	-.0519	.1074	.714	28	.481

t tests for Part 1 variables: for the 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	.0206	.08266	.01291	-.0055	.0467	1.596	40	.118
Pair 2	Diagram structure - Diagram function	-.1091	.21373	.03338	-.1766	-.0417	-3.270	40	.002
Pair 3	Structure propositions - Function propositions	.1898	.20120	.03142	.1262	.2533	6.039	40	.000
Pair 4	Text Structure - Diagram structure	.1785	.27703	.04327	.0911	.2660	4.127	40	.000
Pair 5	Text Function - Diagram function	.0488	.21303	.03327	-.0185	.1160	1.466	40	.150
Pair 6	Text Structure - Visualisation	.1094	.17469	.02728	.0543	.1645	4.010	40	.000
Pair 7	Text Function - Visualisation	.0888	.17529	.02738	.0335	.1441	3.243	40	.002
Pair 8	Diagram structure - Visualisation	-.0691	.30466	.04758	-.1653	.0270	-1.453	40	.154
Pair 9	Diagram function - Visualisation	.0400	.25254	.03944	-.0397	.1197	1.014	40	.317