'PROGRESSIVE UNDERSTANDING' IN PRIMARY SCIENCE TEACHING AND LEARNING

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'Progressive Understanding' in Primary Science Teaching and Learning
by Eunice Tay

Abstract

'Progressive understanding' has been recognised worldwide (including Singapore) to be important, mainly because conceptual understanding and conceptual development in primary science learning are necessary for subsequent science learning in secondary school.

Three variables of pedagogy that promote 'progressive understanding' used in this study are 'active learning', 'level of response' and 'linkages that may extend understanding or depth of learning'.

In this paper, four key questions concerning 'progressive understanding' were posed, to see the extent of 'progressive understanding' encouraged by teachers in primary science teaching, and the extent of 'progressive understanding' achieved by primary students as a result of the teaching.

The findings in this study reveal the following:

1. Teachers in this study were teaching at the middle level of 'progressive understanding'.
2. Teachers in this study followed closely the broad teaching suggestions and activities provided by the Teacher’s Guides and the student’s text, but their style of teaching in terms of the three variables of pedagogy that lead to 'progressive understanding' remain their own.
3. Students in this study were not given opportunities to initiate their own science learning experiences. This could be due to the large class enrolment and also the possibility that excessive noise would be generated.
4. Students in this study were unable to explain adequately or accurately facts, or views about facts learnt. The 'ability to provide explanation' was subsumed under some student tasks, and students' achievement in this ability was found to be poor, although the 'ability to provide explanation' had been provided by most teachers in this study.

Keywords: Primary Science in Singapore, variables of pedagogy, teaching-learning interactions, student performance, 'progressive understanding'.
1. **Introduction**

This study covered in total two school years. Altogether, 18 teachers and 572 students from P3 through P6, from two government primary schools combined, participated in this study.

2. **Key Questions**

Four key questions concerning 'progressive understanding' were posed, to see the extent of 'progressive understanding' encouraged by teachers in primary science teaching, and the extent of 'progressive understanding' achieved by primary students as a result of the teaching.

i) To what extent were pedagogies that promote 'progressive understanding' in science present in the teaching of primary science?

ii) To what extent is 'progressive understanding' being achieved by students in primary science?

iii) In what ways do teachers provide opportunities for students to 'use some of their intellectual skills, namely observations, classification, the interpretation of observations, to make inferences and communicate their experiences in writing and verbally'?

iv) To what extent are 'intellectual skills, namely observations, classification, the interpretation of observations, to make inferences and communicate their experiences in writing and verbally' being achieved by students in primary science?

3. **Variables of Pedagogy**

Three variables of pedagogy that promote 'progressive understanding' used in this study are 'active learning', 'level of response' and 'linkages that may extend understanding or depth of learning'.

The theoretical basis for these three variables is derived from Carroll's model of school learning (Carroll, 1963, pp. 723-33), from Bloom's taxonomy (Bloom, 1956, with extensions to cover the observations and activities that are encouraged in the primary science lessons) and from Novak's learning process and effectiveness of teaching methods (Novak, 1976) respectively.

3.1. **'Active Learning' Encouraged by The Teacher**

'Active Learning' was categorised on a seven-point scale, 0 1 2 3 4 5 6, with:

0 = incidents where 'active learning' does not occur;
1 = teacher talk that requires students to listen only;
2 = teacher talk that induces lethargic responses from
the group or class;
3 = teacher requiring students to respond individually or in groups to direct factual questions;
4 = teacher requiring students to respond individually or in groups to probing questions that follow up the direct answers;
5 = teacher allowing students to ask questions that became the basis for their learning, individually or groups, of the topic; and
6 = teacher engaging students in a variety of related and purposeful learning activities for the learnings intended.

3.2. ‘Level of Response’ Encouraged by The Teacher

This was categorised under a four-point scale,

0 1 2 3

with:
0 = incidents where ‘level of response’ does not occur;
1 = teacher encourages responses at memory recall level including observations and instructions (lower order thinking);
2 = teacher encourages responses at comprehension, deduction and application level (middle order thinking); and
3 = teacher encourages responses at analysis, synthesis and evaluation level (higher order thinking).

3.3. ‘Linkages that May Extend Understanding or Depth of Learning’ Encouraged by The Teacher

This was categorised on a three point-scale,

0 1 2

with:
0 = teacher makes no linkage between the lesson and the previous lesson or future lesson or prior knowledge or cited examples or applications outside school; (In the overall lesson score, this ‘0’ score is recorded if the overall lesson has less than ten per cent of the total of frequency score.)
1 = teacher makes some linkage between the lesson and the previous lesson or future lesson or prior knowledge or cited examples or applications outside school; (In the overall lesson score, this score of ‘1’ is recorded if the overall lesson has between ten per cent and 25 per cent of the total of frequency score.)
2 = teacher makes a number of clear links with previous lesson or future lesson or prior knowledge or cited examples and applications outside school. (In the overall lesson score, this score of ‘2’
is recorded if the overall lesson has 25 per cent or more of the total of frequency score.)

4 **Key Question i:**

To what extent were pedagogies that promote 'progressive understanding' in science present in the teaching of primary science?

Under 'active learning' 60 per cent of the total of 43 science lessons contained evidence of teachers asking probing questions, and 30 per cent contained evidence of teachers asking factual questions. Only 10 per cent of the lessons contained evidence of the teachers creating opportunities for students to ask questions that became the basis for their learning individually or in groups (see Table 1).

For 'level of response', 55 per cent of the lessons involved teachers asking questions at the lower order thinking level which required memory recall including observations and instructions, and 45 per cent of the lessons involved teachers asking questions at the middle order thinking level, which required comprehension, deduction and application of knowledge.

With respect to 'linkages', 60 per cent of the lessons contained evidence of teachers making a number of clear links between the particular lessons taught and the previous lessons or the prior knowledge of the students, 30 per cent of lessons contained evidence of teachers making some linkages, and ten per cent contained no evidence of teachers making linkages.

Findings in relation to Primary Science Teacher’s Guide, Science Syllabus and Science examination papers reveal the following:

- Teachers in this study follow closely the broad teaching suggestions and activities provided by the Teachers’ Guides and the students’ text, but their style of teaching in terms of the measures of the three variables of pedagogy that lead to 'progressive understanding' remain their own.

- Whatever the style, these teachers are constantly conscious of the nature of the examination their students will have to take. For example, Teachers 7 and 16 openly cautioned her students about the rigour of examination, and Teacher 1 the date of the examination.

- A scrutiny of some Science examination papers from P4 to P6 from both schools (see Figures 1 to 7 in the Appendix) found that these papers have a combination of questions that require factual recall, which is at level 1, or 'lower order thinking' level, and also the ability to comprehend, deduce and apply their understanding and knowledge, which is at level 2 or 'middle order thinking' level.

All these questions in the examination papers have virtually been done in class or in their workbook, and the students
are really only required to remember, recall and apply their knowledge in answering the questions. This type of response in the Bloom's taxonomy (Bloom et al., 1956), is a 'low order thinking', and at the most 'middle order thinking'.

### Table 1: Breakdown of the Science lessons in percentage under each category of variables of pedagogy

<table>
<thead>
<tr>
<th>DC Sch</th>
<th>'Active Learning' (0 - 6)</th>
<th>'Level of Response' (0 - 3)</th>
<th>'Linkages' (0 - 2)</th>
<th>Total No. of Lessons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>1 A</td>
<td>0</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>20</td>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td>2 A</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>35</td>
<td>30</td>
<td>65</td>
</tr>
<tr>
<td>1 B</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>65</td>
<td>35</td>
<td>65</td>
</tr>
<tr>
<td>2 B</td>
<td>5</td>
<td>13</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>70</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>1+2 A</td>
<td>5</td>
<td>9</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>50</td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td>1+2 B</td>
<td>7</td>
<td>17</td>
<td>13</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>70</td>
<td>55</td>
<td>45</td>
</tr>
<tr>
<td>1+2 A+B</td>
<td>12</td>
<td>26</td>
<td>5</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>60</td>
<td>10</td>
<td>55</td>
</tr>
</tbody>
</table>

**Note:**
1. Only the measures that have frequencies and percentages are recorded here.
2. The percentages are rounded to the nearest 5%.

5. **Key Question ii:**

To what extent is 'progressive understanding' being achieved by students in primary science?
'Progressive understanding' as observed in this study involved to a great extent the understanding and accumulation of facts. This was contrary to the intentions of the development of 'progressive understanding' that were held by the curriculum designers. 'Progressive understanding' to the curriculum designers, means that children are able to explain facts and have views about facts. It is a matter of getting them to explain what they know, and getting them to explore or expand what they already know.

Students in this study were unable to explain adequately or accurately facts, or views about facts learnt. Because the probing questions the teachers asked seemed to direct the students' attention to the importance of remembering and recalling facts, students often waited for further questions to be asked in which an explanation was required of them, rather than providing an explanation in detail. Quite often the responses offered in their explanations were short, and hence inadequate. In this way the students gave the impression that they were not well informed, and were not able to give a coherent explanation which indicated full understanding.

Teachers also tended to ask direct factual questions, which again deprived students of the opportunity to expand their thinking skills.

To illustrate, some vignettes of the teaching and learning situations are presented below.

a) Teacher 13: Can you see the water level? (referring to the water levels in the hose).
   Children: Yes.
   Teacher 13: Can you see that it is horizontal?
   Children: Yes.

b) Teacher 15: What do you call the process of growing plants from the vegetative parts?
   Terence: Can't remember.
   Teacher 15: Can't remember already. At the Science Centre you saw those specimens and I told you the other day... Josiah.
   Josiah: Vegetative propagation.
   Teacher 15: Yes, vegetative propagation.

The way in which these teachers presented the scientific facts, and how they probed their students to ensure that they fully understood such facts, as well as how they were disappointed when students could not remember the facts learnt, showed that these teachers were of the view that science is a body of facts which they, as teachers had to 'pour' into their students' minds (which is consistent with a banking or 'tabula rasa' view of education). Hence, this is a very limited view of what 'progressive understanding' is about.

6. **Key Question iii:**

   In what ways do teachers provide opportunities for students
to 'use some of their intellectual skills, namely observations, classification, the interpretation of observations, to make inferences and communicate their experiences in writing and verbally'?

The kinds of observation, classification, interpretation of observation, and inference employed in the observed lessons were very much teacher-directed, for example, when students were asked to tell the colour of a rain tree flower, the texture of the bark of a tree (whether rough or smooth), and the height of a tree (Is the tree tall or short?). Hence the observation skill was directed to what the teachers wanted them to observe, mainly because the text-books, the Teacher's Guide and the Workbooks required the students to be able to answer the questions based on their observations. In this way, the scope for observation, classification, interpretation of observations, making inferences and communicating their experiences in writing and verbally was very narrow.

The communication of the students' experiences in writing was only confined to their deskwork, which involved written exercises from their workbooks.

7. **Key Question iv**

To what extent are 'intellectual skills, namely observations, classification, the interpretation of observations, to make inferences and communicate their experiences in writing and verbally' being achieved by students in primary science?

The extent the 'intellectual skills' mentioned above are being achieved by students in primary schools can be observed through the student response in the student tasks (ST1). ST1 (Figures 8 to 13) can be found in the Appendix.

Subsumed under the student tasks are:

- the ability to measure,
- the ability to design an experiment,
- the ability to apply a concept in interpreting information,
- the ability to express a concept in diagrammatic form,
- the ability to use results to answer the problem,
- the ability to control variables in order to make a fair test, and
- the ability to provide explanation.

From the curriculum document, the emphasis in each of the seven abilities was progressively increased from P3 through P6 (see Table 2). While the emphasis in six out of seven abilities in the curriculum document were the same as the corresponding abilities in the observed Science lessons, the emphasis on the 'ability to use results to answer a problem' was less in the curriculum document than in the observed Science lessons.
### Table 2  
**Ranking of the 'Abilities' provided in the Science lessons and in the primary science curriculum**

<table>
<thead>
<tr>
<th>Rank</th>
<th>Observed Science</th>
<th>Primary Science Document</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>to provide explanation</td>
<td>to provide explanation</td>
</tr>
<tr>
<td>2.</td>
<td>to express a concept in diagrammatic form</td>
<td>to express a concept in diagrammatic form</td>
</tr>
<tr>
<td>3.</td>
<td>to apply a concept in interpreting information</td>
<td>to apply a concept in interpreting information</td>
</tr>
<tr>
<td>4.</td>
<td>to use results to answer a problem</td>
<td>to design an experiment</td>
</tr>
<tr>
<td>5.</td>
<td>to design an experiment</td>
<td>to control variables in order to make a fair test</td>
</tr>
<tr>
<td>6.</td>
<td>to control variables in order to make a fair test</td>
<td>to use results to answer a problem</td>
</tr>
<tr>
<td>7.</td>
<td>to measure</td>
<td>to measure</td>
</tr>
</tbody>
</table>

### Table 3  
**Ranking of the 'Abilities' provided in the Science lessons and in CS students' performance in ST1**

<table>
<thead>
<tr>
<th>Rank</th>
<th>Observed Science</th>
<th>CS Students' performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>to provide explanation</td>
<td>to measure (ST1.1)</td>
</tr>
<tr>
<td>2.</td>
<td>to express a concept in diagrammatic form</td>
<td>to design an experiment (ST1.2)</td>
</tr>
<tr>
<td>3.</td>
<td>to apply a concept in interpreting information</td>
<td>to express a concept in diagrammatic form (ST1.4)</td>
</tr>
<tr>
<td>4.</td>
<td>to use results to answer a problem</td>
<td>to control variables in order to make a fair test (ST1.6)</td>
</tr>
<tr>
<td>5.</td>
<td>to design an experiment</td>
<td>to apply a concept in interpreting information (ST1.3)</td>
</tr>
<tr>
<td>6.</td>
<td>to control variables in order to make a fair test</td>
<td>to use results to answer a problem (ST1.5)</td>
</tr>
<tr>
<td>7.</td>
<td>to measure</td>
<td>to provide explanation</td>
</tr>
</tbody>
</table>
By presenting the two sets of ‘ranked abilities’ in Table 3, it can be seen that although there were lots of opportunities supplied by the teachers for students to provide explanation in their Science lessons, many students still failed to provide explanation in the tasks.

It is interesting to note that although the ‘ability to measure’ was the least provided for in the observed lessons, yet these students found the measuring task in ST1.1 easiest. While the ‘ability to use results to answer a problem’ was less emphasised in the curriculum document, it was ranked fourth among the other abilities emphasised in the observed Science lessons. Except for this, all the emphases on the other abilities in the observed Science lessons match closely with the curriculum intentions.

No examples were found of abilities which were encouraged in the observations that were not found in the curriculum. This suggests that the curriculum is really being followed very closely by the teachers.

Students in the upper grades did better in ST1 tasks than the students in the lower grades. This is understandable as the emphasis on each of the seven abilities was progressively increased. Also, for example, in P3, these students had only started Science, while the other students would have at least a year of Science.

From ST1 in DC1 to repeated ST1 in DC2, the ‘ability to design an experiment’ shows the greatest improvement. Yet it was not taught very much as seen in Table 3. The ‘ability to design an experiment’ was found in ST1.2 (Heat Travels), and it is this task that many students tried out at home, which acted as a powerful reinforcement from outside.

8. Implications for Policy and Practice

i) Over-reliance on the curriculum materials, such as the students’ textbooks and the Teacher’s Guides resulted in some teachers not being innovative enough to make the lessons stimulating and interesting.

ii) It is only through questioning and probing that teachers are able to assess the extent to which students have understood the lessons. However, the kind of questions asked should be carefully planned, if teachers wish to develop in students the ability to think and expand their thinking skills.

iii) Learning would become more meaningful if teachers could lead students to discover concepts and relationships for themselves through direct hands-on experiences and discussions. The quality of the discussions should also be considered.

9. Implications for Theory

Within the science concepts lies a problem which has caused some concern to some educationists, and that is the misconceptions some children hold.
Some of the theoretical questions raised are:

i. How do these misconceptions arise?

ii. Are they the result of the children developing directly from their observations a misunderstanding of things they see in the world around them?

iii. Do they arise from the disconnected way in which teachers present ideas? and

iv. What are the signs of the existence of these misconceptions?

In this study it is found that when teaching is fragmented and disconnected children begin to form their own ideas, for example:

Minah: Mr T said for mammals the eggs are developed inside the mother’s stomach. If it is like that, then all the food the mother eats, and all the water the mother drinks will go inside the stomach. How? The baby will be buried under the food. Can the baby die?

Sheena: I think, for mammals, inside the mother’s stomach, got one side for keeping the baby, and one side where the food goes.

This resulted from this incident:

Teacher 4: The baby is developed (paused) the egg is developed inside the body, inside the mother’s stomach, until the time is up and then the mother will give (paused) they don’t lay eggs, they give...

10. Implications for Further Research

i). There has been a great deal of theorizing work done on examination of concept development by children, but little theorizing has been done on how children learn intellectual skills, such as observing, classifying, interpreting and inferring. Unlike the practical skills which can be acquired through demonstration and imitation, intellectual skills involve much more.

The lack of theoretical understanding of intellectual skills could have caused the observed inadequacies in the teaching performance.

ii). One incidental but important finding from this study was that students who had had rich out-of-school experiences were the ones who performed better on the science tasks compared to others who had only limited out-of-school experiences.

Another further research could be planned to investigate how children learn from out-of-school experiences to science learning, and to find out how effective learning of science can be ascribed to out-of-school experiences.
11. Conclusion

This study examined the teaching strategies some teachers in Singapore adopted in the teaching of primary science. It also examined the teaching-learning interactions that lead to 'progressive understanding'. 'Progressive understanding' is one of the goals in the Singapore science curriculum.

Generally, children love learning science. In this study, there was only a minor misbehaviour in the science lessons observed, and very frequently the students were observed to participate enthusiastically in their science lessons.

All the teachers in this study showed positive attitudes towards the teaching of science, and they expressed enjoyment in teaching science. This positive attitude from students and teachers could be attributed to the Science Education policies in Singapore.

However, one concern is that the performance of the Singaporean students as compared to that of students in the 18 other countries in the Second IEA Science Study in 1983–1984 (Keeves, 1992, pp. 7 and 13), was relatively low. Perhaps the remedy is to commence the teaching and learning of science at Primary 1 level, as it has been found in the IEA Study that countries which have children commencing science at Primary 1 are the countries that performed well in Science at all subsequent stages.

References


Appendix

Figure 1

When the empty bottle is placed into the water, the balloon shrinks. This shows that the water is _____.

Figure 2

If the following animals are kept in the cage as in the diagram below, which animal will remain strong and healthy after 2 days. Give a reason for your answer.

Figure 3

Zhenxing wants to find out which of the three water wheels A, B and C, he made would turn best.

To make it a fair test, which of the following variables must be kept the same?

A: The size of the blades.
B: The flow of the water.
C: The height of falling water on the water wheels.
D: The time taken to test each water wheel.
E: The number of blades in each water wheel.

(1) A and E only  (2) B and C only  (3) A, B, C and D only  (4) A, B, C and E only

Figure 4

Ali has been asked to make a terrarium which is to be sealed from the air outside. Below is a picture of his terrarium.

His teacher says that he has forgotten to include something very important.
What could it be? Why was it important?
Fruits are different in many ways. From the diagram below we can tell that a banana has a fleshy part and is yellow when ripe.

Fruits with one seed

Fruits with a fleshy part


d = banana

Fruits that become yellow when ripe

which one of the following is the fruit marked 'X'?

(1) lemon
(2) mango
(3) rambutan
(4) parasya

In an experiment, Salim uses different amounts of a preservative P to preserve food F. The results are recorded in the table below.

<table>
<thead>
<tr>
<th>Amt. of P used in 100 g of F</th>
<th>1 g</th>
<th>2 g</th>
<th>3 g</th>
<th>4 g</th>
<th>5 g</th>
<th>6 g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of days before F starts to decay</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td>20</td>
<td>No decay</td>
<td>No decay</td>
</tr>
</tbody>
</table>

(a) If the amount of P used is 1.5 g, F will decay after _________ days.

(b) If you want to preserve 300 g of F indefinitely, you should use a minimum of _________ of P.

The graph above shows the guppy population. A predator of the guppies was put into the aquarium during the period of experiment.

(a) The predator of the guppies was put in during the _________ week.

(b) What could the predator be?
Jane sets up a ramp by using a wooden plank and a pile of books. She lets a toy car go down the ramp and measures the distance travelled by the car along the floor.

What is the distance travelled by the car along the floor if Jane uses:

5 books? (Answer = _______ cm.)
6 books? (Answer = _______ cm.)
7 books? (Answer = _______ cm.)
8 books? (Answer = _______ cm.)

(observe how the child measures i.e., to which part of the car, and ask)

Tell me why you measure like that?

(Referring to their answers above, i.e., involving the number of books used, ask)

Can you explain your results?

Does this remind you of something you have done in school?

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**Figure 8**
The Ramp

(distance travelled)

**Figure 9**
Heat Travels

1. When a metal spoon is put into a mug of hot water for some time, the handle of the metal spoon feels hot.

2. Would the handles of a plastic spoon, a wooden spoon and a china spoon also become hot? Why?

3. How would you tell which spoon heats up faster?

4. Does this remind you of something you have done in school?
Figure 10

Sensation

Blindfolded, Gag on mouth, Ear-muffs, Peg on nose

a) Which of these things could all of these people still tell? Tick in any box which is true.

□ Is the drink coffee or tea?
□ Is the rose orange or red?
□ Is the pie hot or cold?
□ Is the watch ticking or not?
□ Is the soap sweet-smelling or not?

b) Why do you think this?
Because

Does this remind you of something you have done in school?

Figure 11

"Watering can"

The dotted line shows where the surface of the water is in this watering can.

a) Draw a line to show where the surface is in the spout.

b) The watering can is tipped so that the water just begins to drip through the spout.

Draw a line to show where the water surface is now.

c) Does this remind you of something you have done in school?
On a visit to a river some children said it looked as if the water was more muddy near the banks than in the middle. To find out if this was true they collected a small bucketful of water from each place.

This is what they did next:

1. Sieved out the mud by pouring it through two pieces of cloth the same as each other.
2. Waited for the dripping to stop.
3. Weighed each cloth with the mud on it separately.

How do you think they used these results to decide whether the water was more muddy at A or B?

Does this remind you of something you have done in school?

Tom cut an orange into pieces.

He ate some of the pieces and was going to keep the rest for later.

His mother said: "Cover them with some glad wrap so they don't dry up".

Tom decided to see if covering them really did make any difference.

He decided to cover some of the pieces of orange and to leave others uncovered. He would see which ones dried up most by weighing them.

To make this a proper test he should make some things the same in case they make a difference to the result.

Write down three things that should be the same.

1. 
2. 
3. 

Does this remind you of something you have done in school?