Biological Evolution: A Tough Nut for Biology Teachers in Singapore?

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Why the Nut is Important

If there can be one basic theme which gives Biology a unifying coherence, it has to be the theory of evolution. Evolution provides a philosophical system that aids our understanding of the living world; by experiment and theory. The famous geneticist Dobzhansky put it well when he said that nothing made sense except in the light of evolution (Dobzhansky, 1973).

Contrary to expectation, research into teaching and learning about this major concept in biology has been sparse despite its centrality to science literacy (Cummins, Demastes and Hafner, 1994). Indeed, the little that has been conducted has largely been in exploring students' ideas (which usually are quite inadequate in understanding) or on teaching for conceptual change in the sub-areas of evolution, for example: natural selection, competition, and population dynamics (see Demastes, Settlage and Good, 1995).

The first author is a practicing high school biology teacher, and it has been his experience to encounter much difficulty in getting his message across to his students in this topic. One key factor, besides the prevalence of students' alternative conceptions, was his less than satisfactory appreciation of this complex topic. However, he was not alone, as the lack of knowledge in evolution among teachers has been widely reported in the literature by Cummins, Demastes and Hafner (1994).

We use the metaphor on the understanding of evolution as a tough nut to crack for teachers. We are suggesting that teachers themselves are often unsure of evolution and that this lack of competency might be a hindrance in student learning. The many elegant concepts associated with evolution are truly 'choice morsels' of knowledge and understanding, but remain poorly taught in classroom learning and teaching as they were often beyond the grasp of teachers. The nut has not yielded its substance for many teachers!

Therefore, we wanted to find the levels of knowledge in local high school teachers (senior and junior high) regarding biological evolution and its subconcept of ecology. If their levels of comprehension were low like other teachers around the world, it would be understandable that students would also find this topic to be difficult to learn. Finding this basic but important piece of information would have implications for teacher education and reeducation.

We Don't Need No Nut Crackers!

A mailed survey questionnaire to 70 teachers was developed. It consisted of 36 five-option multiple-choice questions (MCQ) on evolution and ecology, while other sections gathered some demographic data. The MCQ were based largely on assessment questions from the Cambridge General Certificate in Education (GCE) 'Ordinary' (at grade 10) and 'Advanced' (at grade 12) level biology examinations that had a wide area of content coverage over these different levels of cognition. Twelve items were on ecology, with 25 on evolution. Both types of questions were randomly mixed in the first part of the questionnaire. The MCQ section was unspeeded in order to discourage guessing behavior and was intended to be completed in one continuous session by the high school biology teacher.

As expected in the mailed survey questionnaire, the responses took a long time to be returned, in fact five months! Twelve senior high (SH) and 40 junior high (JH) teachers completed the forms. This was 75% of the intended sample of 70 biology teachers in the study. We used QUEST version 2.0 computer program (Adams and Khoo, 1996) to apply the Rasch model to our data. This obtained an objective representation of the ability levels of the two groups of teachers placed alongside the difficulty levels of the items on the same scale in logits.

Who Had Cracked the Nut?

Rasch analysis (see **Figure 1** on next page) of items (M=0.0 logits, SD=1.23 logits) showed that items had a wide spread in terms of difficulty from 3.05 to -3.10 logits. There were no items misfitting the Rasch model except for Question 1 which QUEST could not calculate, as it had obtained a perfect scoring.

1) ***How much did the teachers know about biological evolution?***

The average raw score for the entire sample over all 36 items was 25.0 (69.6%) with a standard deviation of 4.9 ; lowest raw score was 15 and the highest 34. Generally, the teachers had performed better than average. The average score for SH teachers was 79.4%, and JH teachers was 66.6%. The range of logits for SH teachers was from 3.53 to 0.33, and for JH teachers from 3.01 to -0.56. The variable map in Figure 1 shows that these teachers' ability levels were higher than the difficulty of many of the items.

VARIABLE MAP

	HIGHSCHOOL TEACHERS		ITEMS	
(logits)	Junior	Senior	Evolution	Ecology
4.0				
		X		
3.0	X	X	7 18	
		X		
	XXX	X		
2.0	XX	XXXX		
	XXX		6	
	XX		24	
	XX		16 30	
	XX	X		
1.0	XXXX		20 21 23	
	X			22
	XXXXXX			36
	X			
	XXX	XX	11	26
	XXXX			
0.0	X			8
	XX	X	5 10 15 25	33
	XX			
			14	
	X		13	27
				34 35
			4 31	32
-1.0			9 19 28 29	
			3	2
-2.0				17
-3.0				
			12	
-4.0				

Each X represents 1 Teacher

Figure 1. Item/Case map based on the responses by the junior and senior high biology teachers.

2) ***Do senior high or junior high teachers have better understanding?***

A t-test to compare the mean performances for SH (M=79.4% or measure 1.86 logits, SD=1.0) and JH teachers (M=66.6% or measure 0.89 logits, SD=0.9) was significant at $p<0.005$ level in favor of SH teachers. Figure 1 shows the item/case map of the two subpopulations of teachers, together with the items on evolution and ecology on the logit scale. Similarly, SH teacher raw scores over the sub-section of evolution **(Table 1)** were also significantly higher ($p<0.001$) but not with regard to ecology. The evidence suggests that SH biology teachers have a better understanding than JH teachers with regard to evolution, as was to be expected.

There were eight misfitting cases in the Rasch model (teacher nos. 6, 19, 20, 38, 42, 44, 50, and 51) according to **Figure 2** INFIT MNSQ (Adams and Khoo, 1996). However, none of the case values were more than 0.42 beyond the expected INFIT MNSQ value of 1.0, and only three exceeded 1.3.

QUEST produces KIDMAPs of cases. These are graphical representations of response patterns of the respondent together with the ability levels and the item difficulties on the same scale. These maps can help detect guessing behavior in the respondents.

A teacher who showed possible guessing behavior was case 42. According to **Figure 2**, the response behavior of this teacher was rather different from the rest of the teachers because they had a higher than expected INFIT MNSQ.

Examination of case 42's KIDMAP in **Figure 3** reveals many items in both Harder Not Achieved and Easier Not Achieved categories. This might indicate guessing behavior. Notice that while lucky guessing may have gained three right answers, unlucky guessing lost five improbable wrong answers. These features make KIDMAPs a valuable feedback mechanism for respondents in any test.

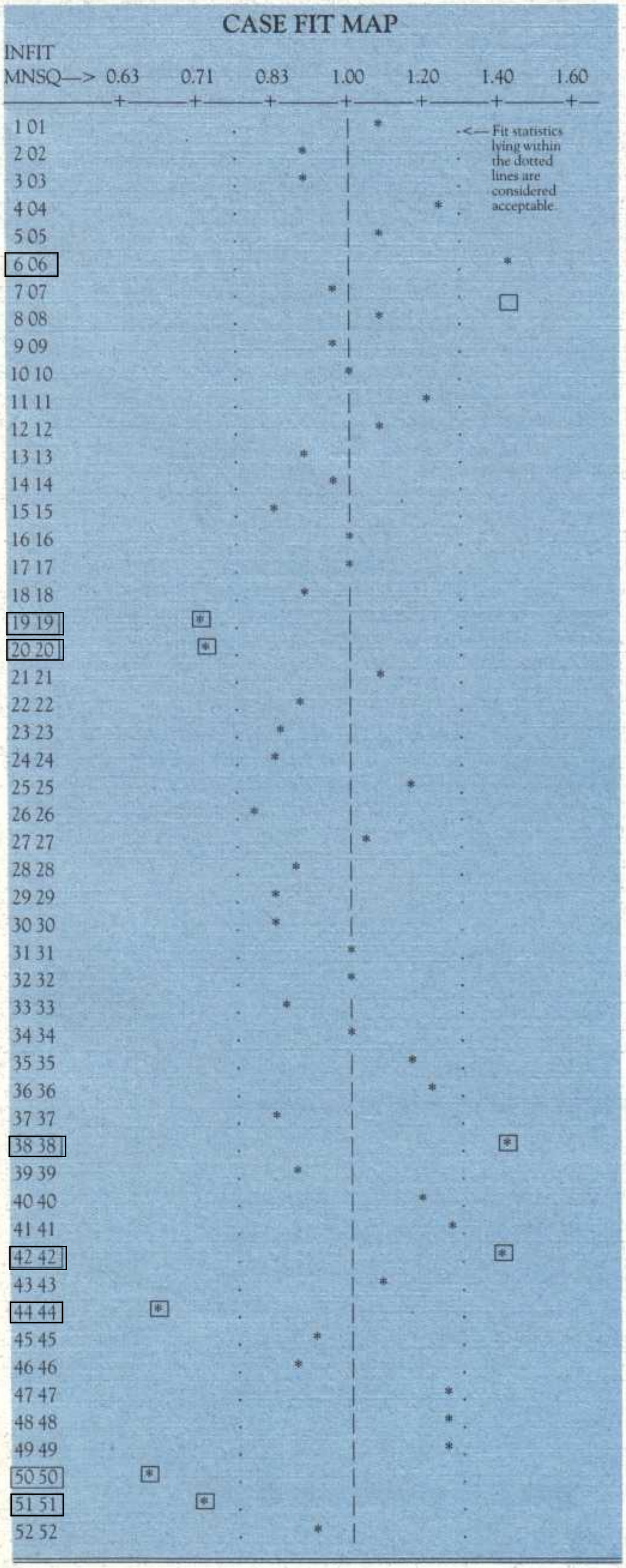

Figure 2. QUEST data output of the Case Fit Map.

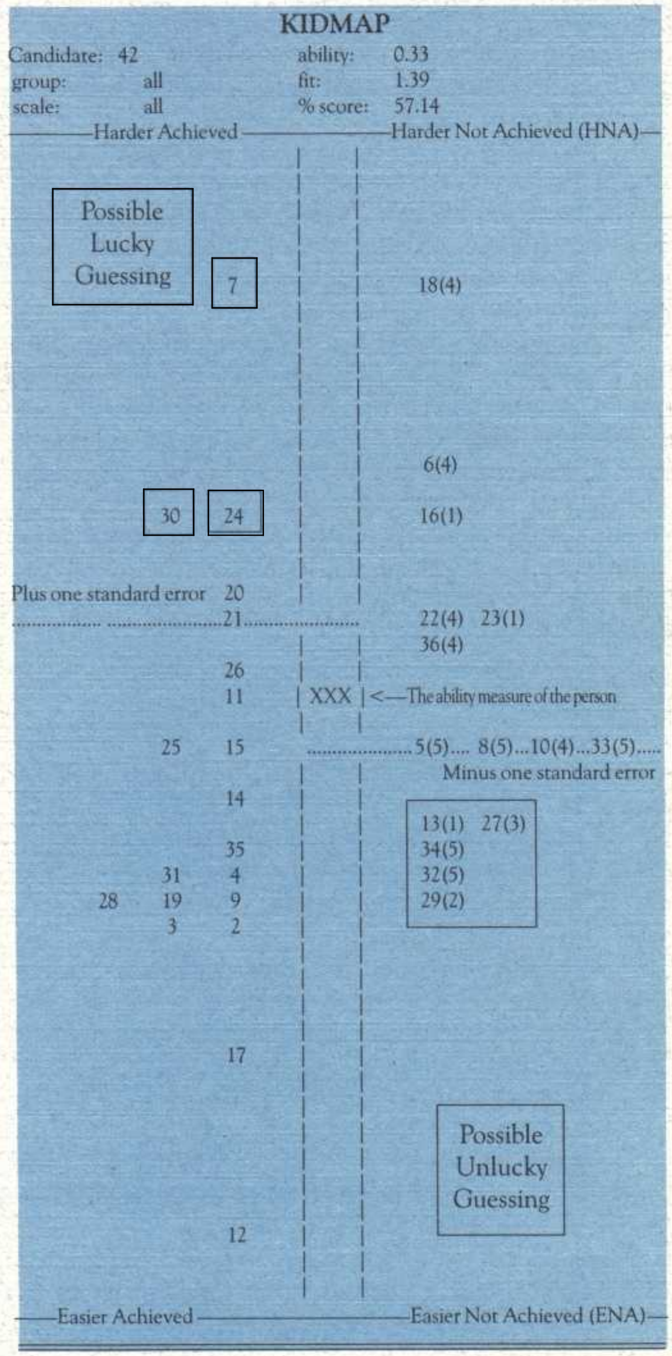

Figure 3. KIDMAP of Case number 42 who exhibited probable guessing behavior in answering the achievement test.

Conclusions

These results show that the graduate biology teachers (holding the General and Honors degrees) in Singapore had a reasonably good grasp of content in evolution and ecology. The ability measures from 52 teachers ranged from 3.53 to -0.56 logits (M= 1.12 logits, SD= 0.97); that of senior high teachers from 3.53 to 0.33 (M=79.4% or 1.86 logits, SD=1.0), and for junior high teachers from 3.01 to -0.56 (M=66.6% or 0.89 logits, SD=0.9). Senior high teachers had a significantly bet-

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ter grasp of content than junior high teachers over the test as a whole ($p<0.005$) and over the subsection on evolution ($p<0.001$). There was no significant difference with regard to the section on ecology.

We recommend the Rasch model as a simple but valuable tool in the teacher's everyday repertoire of test data analysis. In this example Rasch allowed the objective determination of the levels of comprehension of evolution among teachers. We do not see any difficulty in using this method to elucidate ability levels of students as well.

Among other things, Rasch analysis can perform scoring, simple descriptive data analysis, and detect case and item 'misfits.' Though the relatively high levels of knowledge in local biology teachers were a cause for satisfaction, we discovered a number of alternative ideas or misconceptions, especially among junior high teachers. The QUEST KIDMAPs furnish valuable feedback to respondents in terms of showing their ability levels with respect to item difficulties, and can help detect the individual's pattern of answering and misconceptions.

References

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Note: Part of the findings were from a Master's thesis in education submitted in December 1997 by the first author. It was titled 'Comprehension of Biological Evolution by High School Biology Teachers in Singapore.

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Hertz, the "German physicist who first verified James Clerk Maxwell's electro-magnetic equations by demonstrating the existence of radio waves" said that "One cannot escape the feeling that these mathematical formulae have an independent existence and an intelligence of their own, that they are wiser than we are, wiser even than their discoverers, that we get more out of them than was originally put into them!" (Dyson 1969: 99)