QUANTITATIVE JUSTIFICATION OF SOLO CYCLES

Chris Reading
Centre for Cognition Research in Learning and Teaching
University of New England, Australia

More and more research into student understanding is being undertaken, in which analysis of responses often involves the use of taxonomies to describe hierarchies. Recent use of the SOLO Taxonomy has identified that there can be cycles of levels within each mode in the hierarchy. Most recent research has involved qualitative description of these levels and identification of cycles based on subjective decisions. This report demonstrates how Threshold Values produced by Rasch Analysis can be used, as a quantitative measure, to justify the cycles of SOLO levels. The data used is from a study into statistical understanding, undertaken with Australian school students aged 12 to 18, in which the SOLO taxonomy was used as the framework for developing a hierarchy of student responses to open-ended questions.

INTRODUCTION

As more qualitative research is undertaken in the area of student understanding, hierarchies, expressed in levels, are increasingly being used as descriptive and assessment tools. Structure of the Observed Learning Outcome (SOLO), which has proved useful in a variety of disciplines, is one such taxonomy. A need was identified for some means of quantitatively justifying the cycles of levels that were observed, and discussed qualitatively, in more recent applications of the taxonomy. After outlining background information about the SOLO Taxonomy, the context of the study and the Rasch analysis used, 'threshold values' are defined. Discussion follows on how these threshold values can be used as a quantitative justification of cycles of levels. Some implications for future research are presented after conclusions have been drawn.

SOLO

SOLO originators, Biggs and Collis (1991, pp. 62-65), in a more recent description of the taxonomy, identify 5 basic levels in a learning cycle; prestructural, unistructural, multistructural, relational and extended abstract. Also identified were modes of representation within which students operate, ranging from sensorimotor, through ikonic, concrete-symbolic and formal to post formal. The learning cycle is repeated for each successive mode, the unistructural, multistructural and relational levels being within the mode, and prestructural and extended abstract levels belonging to the adjoining modes. However, more recently, researchers in a variety of disciplines are identifying more than one cycle of levels within each mode. For example, Lawrie, Pegg and Gutierez (2000) in geometry and Reading (2001) in data collection.

Most studies rely on qualitative justification of the levels in student responses. The levels are described, and cycles of levels identified, based purely on the researcher's subjective interpretations of student responses. This report demonstrates the use of Rasch analysis as a quantitative approach to justifying the cycles of levels identified.

CONTEXT

Discussion here is based on data from a study where 180 Australian students, aged 12 to 18, were given open-ended questions on statistical understanding covering four focus areas; Question 1 in the area of data collection; Question 2 in data representation; Question 3 in data reduction; and Question 4 in interpretation and inference. Each question had two parts. Question 1 Part I presented students with a general data collection question while Part II asked a more specific question, where part of the collection procedure had already been specified. Part II, with some prompting, was included to delve more deeply into the understanding of data collection. For Questions 2, 3 and 4, Part I and Part II asked similar questions except that Part I presented the data in a raw form while Part II presented graphed data. Two parts were included in these three questions to determine whether data presentation in raw form or as a graph influenced the level of understanding.

Student responses, including explanations of 'why' the particular response was given, were analysed to establish a hierarchy of eight levels, from Level 1 to Level 8. So few responses were recorded at Level 8 that this level does not appear in the following discussion. The SOLO Taxonomy was then used as a framework for describing these levels and dividing them into three separate cycles. Level 1 and Level 2 fell within the ikonic mode. The first cycle in the concrete-symbolic mode consisted of Levels 3, 4 and 5 and the second cycle, Levels 6, 7 and 8. For more detail about this study see Reading (1996), with specific discussions of each of the four questions in Reading (2001,1999,1998) and Reading and Pegg (1996), respectively. Rasch analysis, used to produce a measure of statistical understanding for each student, also produced threshold values for the various levels within each question.

RASCH ANALYSIS

The Rasch model was used to produce an estimate of statistical understanding on a logit scale, for each student, which incorporates the information from the questions covering all four focus areas (Reading, 1996, pp. 93-94). Masters' (1982, pp.157-

158) partial credit Rasch model for polychotomous data (where responses can be coded according to an increasing, or decreasing, degree of 'correctness') considers the individual difficulty of each successive step from one level to the next in the question, using a formula for calculating the probability of a student responding at a particular level of a particular question. The advantage of the partial credit model is that the parameters are separable, making it possible to produce sufficient statistics for person ability (understanding) and for step difficulty within each question. Masters (1982, pp. 163-166) used a maximum likelihood procedure to estimate the parameters, overall ability for each student and difficulty for each question, in the model. In the study, appropriate measures indicated that the questions were all consistent in testing the same underlying construct, 'statistical understanding', and that the data fitted the Rasch model well (Reading, 1996, p170). Although the study reported on measures of overall understanding, question difficulty and threshold values (Reading, 1996, pp. 170-190), this report only discusses the thresholds values.

THRESHOLD VALUES

Threshold values, produced by the Rasch analysis for the various levels in each question, were used to justify the arrangement of levels within the cycles described in the study (Reading, 1996, pp. 178-181). These values are estimates of the score a student would need to attain a 50% chance of having his or her response coded at that level. For example, the threshold value of 0.15, for Level 5 of Question 2 Part I, means that a response from a student with an estimate of statistical understanding of 0.15 has a 50% chance of being coded at Level 5 for that particular question.

The results are presented graphically in Figures 1 to 4. No threshold value is shown for Level 1 because there is no information about performance at a level below this to allow estimation of the better understanding needed to be able to be coded as Level 1. Each graph shows the threshold values for Part I and Part II of a question. In each graph, the trends as indicated by the shape of the graph, for Part I and Part II are similar. This reinforces the authenticity of the trend. Following is a discussion using these threshold values to justify the cycles of levels.

CYCLE JUSTIFICATION

The study provided insufficient responses at Levels 1 and 2 to make detailed judgements about SOLO levels, or cycles of levels, within the ikonic mode and so discussion is centred on the two cycles of levels within the concrete-symbolic mode. These corresponded to Levels 3, 4 and 5 within the first cycle, and Levels 6, 7 and 8 within the second. As previously mentioned, there were too few responses at Level 8 to justify including the threshold values in the figures presented.

It was anticipated that once a student is able to function within a cycle there is not as great a change in the level of understanding needed to be able to progress from one level to the next within that cycle. This would be indicated by similar threshold values for the levels within a cycle, for example in the move from Level 3 to Level 4 and the move from Level 4 to Level 5. Then, with the move into a new cycle, presumably a complex transition for many students, the threshold values should be greater. Thus greater jumps in threshold values, indicated by steeper segments of the graph, would demonstrate movement from one cycle to the next. For example, with the Level 3,4,5 cycle, steeper segments would be expected from Level 2 to Level 3, moving into the cycle, and then from Level 5 to Level 6 moving out of that cycle into the next.

RESULTS

The threshold values for three of the questions (figures 2, 3 and 4) tend to confirm that cycles, indicated by flatter sections of the graph, exist but those for Question 1 (figure 1) suggest that all movements from one level to the next were reasonably complex for students, with no clear indication of cycles. Next is a consideration of the threshold levels in more detail.

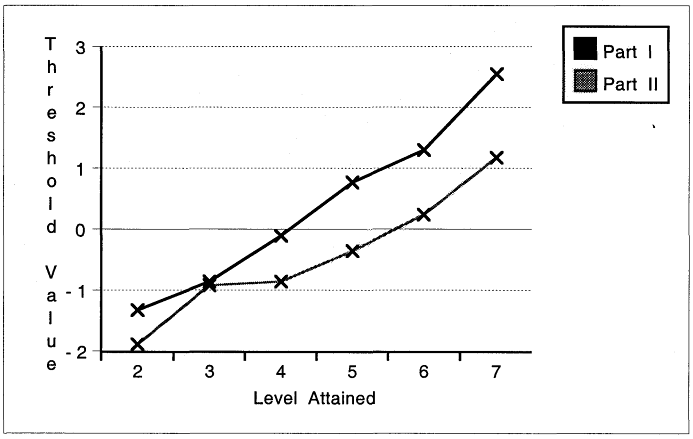

Figure 1 - Thresholds to Attain Levels - Question 1- Data Collection

As indicated earlier, the similarity of shape of the graphs for Part I and Part II in each question confirms the trends indicated, but what of the gap between the graphs for Part I and Part II? The threshold values for Part II of Question 1 are consistently lower, except for Level 2, than for Part I. This is not unexpected as some prompting as to the data collection details was given in the second part of the question.

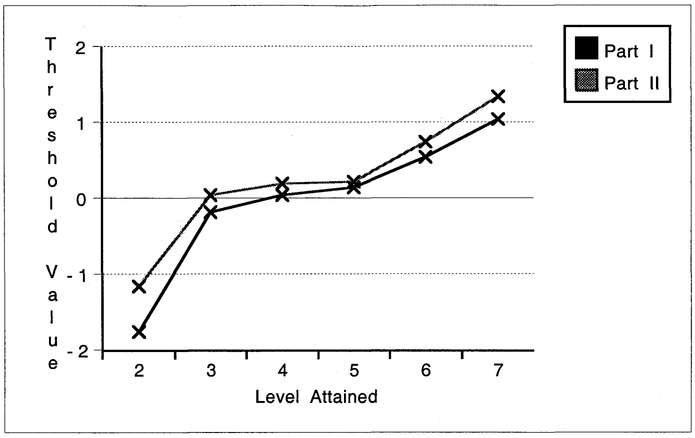

Figure 2 - Thresholds to Attain Levels -Question 2-Data Tabulation and Representation

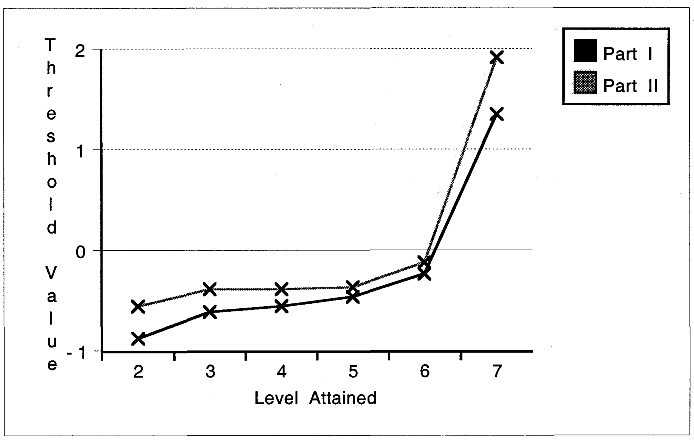

Figure 3 - Thresholds to Attain Levels - Question 3 – Data Reduction

For the other three questions (figures 2, 3, and 4) the threshold values for Part I and Part II are sufficiently similar to suggest that there is little difference between the results whether the data is presented in a raw form or in a graph. For Questions 2 and 3, the Part II thresholds are slightly higher suggesting that, for the tasks of data tabulation and representation and reduction, to respond at a certain level may require a little more understanding when the data are presented as a graph rather than in raw form. However, the differences between the values for Part I and Part II are only slight. For Question 4, Part I and Part II values are almost identical, suggesting that for interpretation and inference the form of presentation of the data does not appear to affect the level of understanding required to present responses at specific levels. How then does the shape of these graphs aid in the justification of cycles of SOLO levels?

For Question 1 (figure 1) there is a steady increase in the threshold value required to attain each of the levels. The threshold values are not necessarily supportive of the cycles identified by the study, although the Part II results do show some flattening out of the change in threshold vales moving between Levels 3, 4 and 5. It is possible that these students find the progression through levels, even within cycles, difficult in the data collection focus area because in the Australian Secondary schooling curriculum there are fewer opportunities to engage in meaningful activities for data collection than the other three focus areas.

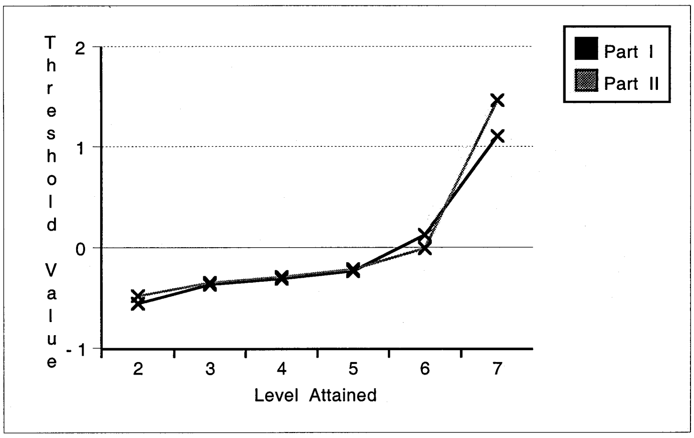

Figure 4 - Thresholds to Attain Levels - Question 4 – Interpretation and Inference

For the other three questions (figures 2, 3 and 4) there is a levelling off of threshold values within one cycle, especially apparent for the first cycle in the concrete-symbolic mode. For each question the threshold values moving from Level 3 through Level 4 to Level 5 only show a slight increase. This suggests that once a student can respond at Level 3 it is likely that they will experience little increase in complexity when responding at Level 4 or Level 5. Also, for each question, the step into the cycle from Level 2 to Level 3 and the step out of the cycle, from Level 5 to Level 6, are steep suggesting movement between two different cycles. These results help to confirm that the three Levels, 3, 4 and 5, are in fact one cycle within a mode, in this case the first cycle identified in the concrete-symbolic mode.

In these three questions, the justification of the second cycle is not as clear. The threshold for Level 6, the entry level for the second cycle, is steep enough to indicate that the first cycle is complete and a new cycle is being entered. However, the increase in threshold value from Level 6 to Level 7, is still quite high in Question 2 and significantly higher in Questions 3 and 4. Although this suggests that the Level 6 and Level 7 are not within one cycle, it should be remembered that the second cycle actually had three Levels 6, 7 and 8 and that with limited responses at Level 7 and virtually none at Level 8, there is probably not sufficient data to confirm or deny the existence of the second cycle at this stage.

CONCLUSION

The use of threshold values has proved a useful tool in quantitatively justifying the previously qualitative arrangement of SOLO levels into cycles. Small differences in threshold values between levels indicate a movement between levels within a cycle while a large difference indicates a move from one cycle into the next. The similarity of threshold values for Levels 3, 4 and 5 suggests strongly the existence of a cycle of levels, at least for three of the focus areas. The jumps in threshold values from Levels 2 to 3, into the cycle, and out of the cycle, from Level 5 to 6, add to the justification of identification of a cycle of levels here. This is the first cycle within the concrete-symbolic mode as identified earlier.

The second cycle, coded qualitatively in the study, is not so clearly identifiable from the threshold values available. The increased thresholds for Level 6 demonstrate the entry point for the second cycle but the move into the next level in the cycle, Level 7, does not show the slight increase in threshold value, as expected. In fact, the threshold values show that in all questions, except Question 2, the step into Level 7 required even more understanding than the step into Level 6. However, as there were fewer responses at this upper end of the hierarchy, further research may help to clarify the existence and character of this second cycle in the concrete-symbolic mode.

IMPLICATIONS

Implications for future research of this quantitative analysis exist both within the narrower context of this particular study and within the broader context of the use of the SOLO Taxonomy. From this study, there are still many unanswered questions. Analysing responses from students younger than 12 would provide more information to describe the levels, and perhaps cycles of levels, within the ikonic mode. Similarly, responses from students over 18 would help to clarify the second cycle in the concrete-symbolic mode. This would involve new studies at the Primary and Tertiary level of education. It is also necessary to delve more deeply into analysis of responses in the data collection area to clarify the cycle structure.

In the broader context, these threshold values should prove useful to those who want to justify cycles of levels identified when using the SOLO Taxonomy. Researchers should be aware, though, that this would not form part of the process when using the qualitative descriptions of the hierarchy to assess individual students. The relevance of this tool would be in larger studies when hierarchies are first being created and justification for the identified cycles of levels is needed.

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