Long Odds: Longitudinal Development of Student Understanding of Odds

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Student understanding of odds is explored by analysis of response data collected in 1993, 1995 and 1997. Students were asked to interpret a newspaper headline, "North at 7-2". Responses included interpreting the numbers as the score, and in three contexts of expression involving chance, frequency of wins, and betting. Levels of responses were assigned according to the SOLO developmental model. Longitudinal development for individuals was observed, and females tended to interpret the numbers as the score, while males were more likely to respond in the context of chance or betting. Levels of response from Grade 6 and 9 students in 1995 and 1997 were lower than in 1993.

Developing understanding about odds is included in the Australian mathematics curriculum as outlined in *A National Statement on Mathematics for Australian Schools*, under the heading "understand and explain social uses of chance processes" (Australian Education Council, 1991, Statement C1, p. 175). Given the widespread participation of Australians in various forms of gambling, the topic of odds has social relevance. It also offers students a different view of probability that admits a subjective judgement, in contrast to dice experiments involving classical assumptions of equal likelihood of outcomes, or to statistical prediction directly based on frequency data.

A model for the development of understanding of odds was proposed by Moritz, Watson and Collis (1996) using the SOLO theoretical model of Biggs and Collis (1982). Students responded to the item shown in Figure 1. Some students offered no response (NR), while some responses were irrelevant, classified as prestructural (P). Many responses interpreted the numbers as the score in the game, and were classified in the ikonic mode (IK), based on experience in the context of football games. Responses in the concrete symbolic mode were those that responded in one of three contexts of expression, including (1) probability/chance expressions, (2) frequency expressions of number of wins for past games or predicted for future games, and (3) social contexts of betting. For each of these contexts of expression, different SOLO development levels were identified in two cycles according to the sophistication of the expression of measurement, as shown in Table 1. The levels distinguished include expressions of basic uncertainty at the unistructural level (U_1), expressions that qualify likelihood at the multistructural level (M_1), and expressions involving quantification at the relational level (R_1). A second learning cycle (U_2-M_2-R_2) accounted for applications of a ratio concept to chance measurement specifically related to the task of interpreting odds. These levels are closely related to those used by Watson, Collis and Moritz (1997) to describe the development of chance measurement in problem solving settings involving tossing a die and random selection from containers.

North at 7-2

But we can still win match, says coach

What does "7-2" mean in this headline about the North against South football match? Give as much detail as you can.

From the numbers, who would be expected to win the game?

Figure 1. Item related to odds from media survey about Chance and Data.

Table 1
Overview of Response Levels by Three Contexts of Expression (adapted from Moritz, Watson and Collis, 1996)

SOLO Level	Summary description	Context of Expression		
		Chance	Frequency	Betting
P/IK	No expression of uncertainty or prediction; irrelevant response; score			
U_1	Simple uncertainty expressed	7-2 chance Likely	Predicted score	Betting numbers for South
M_1	Uncertainty qualified or attempted quantification	% chance 7 in 2 chance	For every 2 pts, 7 pts (predictive) Past score predicts	Odds: no clear ratio idea
R_1	Uncertainty quantified in ratio measure	3.5 to 1 chance	Won 2 out of 7 games	Votes/rating/ratio Odds: ratio clear
U_2	Consolidated ratio as predictor OR part-part-whole ratio	N has 2/7 chance	If play 7, win 2 Played 9 games won 2 or 7	Bet \$2, win \$7
M_2	Consolidated ratio as predictor AND part-part-whole ratio	N has 7/9 chance	If play 9, N win 7 N win 7 every 9 games played	Bet \$2, win \$2 + \$7 (North favoured)
R_2	Predictive ratio with correct favoured direction	N has 2/9 chance	If play 9, N win 2	Bet \$2, win \$7 + \$2 (South favoured)

The classification of response levels shown in Table 1 forms the framework for exploring various research questions concerning longitudinal development of student understanding of odds. Are there changes in the SOLO levels or the contexts of expression of responses of individual students assessed longitudinally during the four-year interval 1993-1997, and during the two-year intervals, 1993-1995 and 1995-1997? Are there gender differences in this longitudinal development? Cross-cohort comparisons concern the impact of recent curriculum reform and implementation on student understandings. Have SOLO levels or the contexts of expression of student responses from comparable grades changed over the years 1993, 1995 and 1997? Cross-sectional comparisons address the question of gender differences and change by grade for the pooled data set. The results of Watson and Moritz (1998) addressed these questions for chance measurement in other settings. Responses of individuals generally improved to higher SOLO levels, indicating broad support for the developmental framework. No consistent differences were found between different years at comparable grades. Gender differences favouring males were evident for some secondary school grade levels. As the current study concerns a closely related topic, similar results would be expected. In particular, gender differences favouring males would be expected because odds are commonly used in sports settings which generally seem to have greater following by males.

Method

A media survey (Watson, 1994) using newspaper extracts covering different topics in Chance and Data was originally administered in 1993 to 312 Grade 6 students and 393 Grade 9 students in Tasmanian government schools during 45 minutes of class time. The survey included the item analysed in this study, shown in Figure 1. Only students who attempted this or later items in the survey were included in the analysis. Results were reported by Moritz et al. (1996). In 1995 and 1997, the longitudinal aspect of the study involved surveying the same students where they could be traced in

schools two and then four years later. The cross-cohort aspect involved surveying new cohorts of Grade 6 and 9 students in 1995 and 1997. Students in these new cohorts from 1995 were also followed longitudinally in 1997. In some schools, entire classes were surveyed including both new and repeat-survey students, while other schools included only repeat-survey students. Fewer new students participated in 1997 due to increasing time demands on students' school time from other sources.

Responses were analysed using the language analysis software NUD•IST (Qualitative Solutions and Research, 1995). A NUD•IST script (Moritz, 1995) was used to sort all responses for each year, the output of which was checked and manual corrections made in the classification of selected responses. Thus all responses were assigned SOLO levels, and responses in the concrete symbolic mode were also assigned contexts of expression. For responses that included aspects of multiple contexts, the dominant context of the response was used, that is the context of the aspect with the highest SOLO level, or if the levels were equal, then the context most clearly expressed at that level. Analyses involving scoring of responses used a scoring scale of 0 for NR, P and IK, 1 for U_1, 2 for M_1, 3 for R_1, 4 for U_2, 5 for M_2 and 6 for R_2. For longitudinal analysis, the difference in scores between two years for each individual student was used as a measure of longitudinal change. For cross-cohort and cross-sectional comparisons, mean scores were evaluated for all relevant sub-groups.

Results

Responses generally interpreted the headline as a score, or within one of three different contexts of expression: probability expressions, frequency expressions and social context expressions. Responses ranged from irrelevant responses (prestructural for this task), to those at the R_2 level. The results are divided into three sections. The first section explores longitudinal development of responses of individual students repeatedly assessed in different years. Examples of levels of responses are given to explore the nature of the longitudinal development in terms of the development model in Table 1. The second section of results considers cross-cohort comparisons of different students in comparable grades to explore the impact of curriculum change between 1993 and 1997. The third section explores a cross-section of grade levels, and explores gender differences in relation to grade level.

Longitudinal Development

To portray the nature of the developmental change for selected students over time, examples are given to illustrate responses from the same student offered in 1993, 1995, and 1997. The following student's responses illustrate increasingly sophisticated responses, all within the chance context of expression.

U_1: [Chance] South are more likely to win than North (b: South). [Grade 6]

M_1: [Chance] It is more likely that North wins than they lose because there is 7 chances of them losing and 2 chances of them winning (b: South). [Grade 8]

R_1: [Chance] It means that North will have 2 chances to South's 7 chances to win the match. Usually it's x-1 but because x is not a whole number, they have to make the second number 2 to make the 1st number whole (b: South). [Grade 10]

Some students changed the context of expression over the years. The following student initially had no structure for understanding the numbers in the concrete symbolic mode, and considered the numbers as a date. In later years, the student identified the chance context, and then quantified this in a frequency ratio.

P: [None] Date. (b: Don't know). [Grade 6]

U_1: [Chance] North has a 7-2 chance of winning the footy game (b: The other team). [Grade 8]

U_2: [Frequency] They will win 2 of 7 games. Not much chance. (b: The other team). [Grade 10]

Similarly, the following student's responses changed from describing a score, to a chance expression, to a betting context involving money gained for a win.

IK: [Score] 7-2 means 7 goals to 2 goals. (b: North). [Grade 6]

U_1: [Chance] 7-2 means the chance it has of winning. 7-2 is an OK chance (b: South). [Grade 8]

U_2: [Betting] Is the odds of winning. If you were to put a bet on it, for every $2 you put on it you would receive a $7 profit (b: South). [Grade 10]

Another student built upon the concept of betting to later offer a chance expression.

U_2: [Betting] $7 for every $2 bet (b: Better). [Grade 6]

U_2: [Betting] If a person bet $2 that North would win they would receive $7 in return (b: No response). [Grade 8]

R_2: [Chance] This means that there is 7/9 chance of losing and 2/9 chance of winning (b: South). [Grade 10]

There were some students whose responses reverted to lower levels in later years. For the following student's responses, the third response does not clearly distinguish whether or not the return of $7 includes the $2, that is it does not clearly distinguish whether "7-2" is a part-part or part-whole ratio. Hence it is classified at the U_2 level.

U_2: [Score] 7-2 means that North has 7 points and South has 2 points. (b: North). [Grade 6]

R_2: [Frequency] If 9 games were played North would win 2. (b: South). [Grade 8]

U_2: [Betting] If North wins, punters will be paid out $7 for every $2 they bet on North (b: South). [Grade 10]

A summary of results for these four-year longitudinal data is shown in Table 2. At all grade levels, the modal response for females was to interpret the numbers as the score in the game, while males offered responses at higher SOLO levels, particularly using betting and chance contexts of expression. These differences favouring males resulted in significant differences of mean scores at Grade 6 ($t_{99} = 3.01$, $p = 0.0034$), Grade 8 ($t_{99} = 3.69$, $p = 0.0004$) and Grade 10 ($t_{99} = 3.15$, $p = 0.0021$). Both males and females improved from Grade 6 to Grade 8 ($t_{99} = 2.63$, $p = 0.010$), and from Grade 8 to Grade 10 ($t_{99} = 3.89$, $p < 0.001$), and there were no gender differences for improvements, nor differences in the improvements between the two two-year periods.

Table 2

Four-Year Longitudinal Comparisons of Percentage of SOLO Levels, Mean Scores, and Percentage of Contexts of Expression by Gender

SOLO	Grade 6 (1993)		Grade 8 (1995)		Grade 10 (1997)	
Level	Female	Male	Female	Male	Female	Male
NR/P	23	18	11	16	5	4
IK	61	31	55	11	48	16
U_1	7	24	13	27	5	7
M_1	4	11	14	22	16	22
R_1	-	2	-	5	5	11
U_2	5	13	7	16	14	36
M_2	-	-	-	2	2	2
R_2	-	-	-	2	4	2
Mean Score	0.36	1.07	0.70	1.71	1.41	2.51
Context						
NR/P (None)	23	18	11	16	5	4
IK (Score)	61	31	55	11	48	16
Betting	2	22	13	29	16	40
Chance	11	20	14	36	18	24
Frequency	4	9	7	9	13	16
N	56	45	56	45	56	45

Exploring further the changes in individual students' responses in 1993, 1995 and 1997, it was found that 34 out of 101 responses decreased in SOLO level over one of the time intervals. Of the 34 reversions, 13 were to other levels in the concrete symbolic mode, 16 to the ikonic score interpretation, and 5 to no response. In considering the dominant contexts used in individual students' responses, 28 students used more than one of the three contexts, 50 offered one context only (20 betting, 19 chance, 11 frequency; 39 included the ikonic score interpretation in at least one year, 11 did not), and 23 used no context (non-response, prestructural, or ikonic score categories). These results must be interpreted with respect to the high percentage using the ikonic score interpretation. In particular, use of one context only (50 responses) does not represent consistent use of the context in responses for each of the three years, but rather use of just one of the three context in at least one of the three years.

Table 3 shows students assessed longitudinally over a two-year interval for Grades 6-8, 8-10 and 9-11. Data for Grade 6-8 and Grade 9-11 are combined for the periods 1993-1995 and 1995-1997, as there were no significant differences of scores for responses or improvements between these periods. Data for Grade 8-10 from 1995-1997 are combined for both new Grade 8's in 1995 and those repeating from Grade 6 in 1993, as no repeat effects were evident. The table shows grade differences and gender differences at all levels ($p < 0.01$ in each case), except Grade 11 where females do not differ from males. Over the two-year period improvement occurred at all levels, with no gender differences except from Grade 9 to 11, where females improved more than males ($t_{143} = 2.27$, $p = 0.0247$), evident in Table 3 where mean score for males did not change (2.47 at Grade 9 to 2.49 at Grade 11) while females in the two-year period caught up to the male mean score (1.56 at Grade 9 to 2.38 at Grade 11).

Of the total 648 pairs of responses over two year intervals, 21% decreased in SOLO level, 39% remained at the same level, and 40% increased. For the contexts these students used over the two years, 18% used the same context twice (9% betting, 7% chance, 2% frequency), 18% used two of the three contexts, 24% used a context in the second year after using no context or the ikonic score interpretation in the first year, 11% changed from a context to no context or the ikonic score interpretation, and 30% offered none of the three contexts in either year. Of 303 students who used one of the three contexts in the first year, 76% subsequently used a context, 17% changed to the score interpretation, and 8% subsequently used no context.

Table 3
Two-Year Longitudinal Comparisons of Percentage of SOLO Levels, Mean Scores, and Percentage of Contexts of Expression by Gender

SOLO	Grade 6 - Grade 8				Grade 8 - Grade 10				Grade 9 - Grade 11			
Level	F	M	F	M	F	M	F	M	F	M	F	M
NR/P	22	19	14	11	13	13	4	7	3	5	2	17
IK	59	38	51	25	48	16	47	21	43	20	16	10
U_1	5	18	14	18	11	25	10	13	9	5	10	3
M_1	5	14	13	21	19	21	15	21	22	19	31	25
R_1	4	2	2	9	2	7	6	9	1	10	10	7
U_2	5	8	7	9	5	13	16	23	13	31	15	24
M_2	-	-	-	2	1	4	2	1	1	8	10	2
R_2	-	-	-	1	1	2	2	5	7	2	3	12
Mean Score	0.45	0.86	0.71	1.34	0.84	1.69	1.38	2.08	1.56	2.47	2.38	2.49
Context												
NR/P (None)	22	19	14	11	13	13	4	7	3	5	2	17
IK (Score)	59	38	51	25	48	16	47	21	43	20	16	10
Betting	3	17	12	26	15	31	15	37	24	37	42	39
Chance	11	22	17	26	19	34	22	23	20	24	30	17
Frequency	5	5	7	8	6	6	12	12	9	14	9	17
N	133	125	133	125	124	121	124	121	86	59	86	59

Cross-Cohort Comparisons

Cross-cohort analyses compare the same grade level assessed in different years to monitor cohort changes, which may provide evidence of changes in effectiveness of curriculum implementation. Table 4 shows the comparisons of Grade 6 and 9 students in 1993, 1995 and 1997, and of Grade 8 and 11 students in 1995 and 1997. The score interpretation of the headline was again dominant at Grades 6 and 8, while Grade 9 and 11 students were more likely to offer responses at higher levels, using expressions in betting, chance or frequency contexts.

Table 4

Cross-Cohort Comparisons of Percentage of SOLO Levels, Mean Scores, and Percentage of Contexts of Expression, by Grade and by Year

SOLO	Grade 6			Grade 8		Grade 9			Grade 11	
Level	1993	1995	1997	1995	1997	1993	1995	1997	1995	1997
NR/P	19	29	17	15	14	9	15	6	11	6
IK	47	41	60	36	42	25	29	42	14	15
U_1	14	16	10	17	18	13	14	19	9	9
M_1	10	7	7	17	13	21	15	9	27	36
R_1	3	3	2	4	5	6	7	6	11	4
U_2	8	4	3	8	8	17	17	9	18	19
M_2	-	-	-	2	-	3	2	1	5	2
R_2	-	-	-	1	-	5	1	9	4	9
Mean Score	0.73	0.55	0.45	1.12	0.91	1.90	1.48	1.49	2.19	2.32
Context										
NR/P (None)	19	29	17	15	14	9	15	6	11	6
IK (Score)	47	41	60	36	42	25	29	42	14	15
Betting	12	5	7	21	15	24	26	14	36	43
Chance	16	23	14	24	22	28	22	31	27	21
Frequency	6	2	2	5	8	14	8	8	11	15
N	301	223	177	352	171	355	324	101	197	47

Significant differences between the mean scores for different years were found for Grade 6 ($F_{2,698} = 4.189$, $p = 0.0155$) and Grade 9 students ($F_{2,777} = 5.335$, $p = 0.0050$). In both cases the mean score of students in 1993 was higher than those in 1995 and 1997, indicating a reduction in performance over the years, as shown in Table 4. For Grade 8 and 11 students, the numbers of new and repeating students differed across the years, making interpretation more difficult. Using data from both years, a positive effect of repeating was found at Grade 11 (new students mean score 1.75, repeat student 2.48, $t_{242} = 3.169$, $p = 0.0017$), but there was no such effect at Grade 8. No differences between mean scores in 1995 and 1997 were found for Grade 8 or 11 students, irrespective of whether using the entire data or only repeating students in each year.

For the three contexts of expression, Grade 6 and 8 students most commonly used the chance context, followed by the betting context and the frequency context, as shown in Table 4. A similar pattern of contexts was used by Grade 9 students in 1993 and 1997, while in 1995, and for Grade 11 students in all years, the betting context was most common, followed by the chance context and the frequency context.

Cross-Sectional Comparisons

A cross-sectional profile of student development by grade level was created by pooling all data collected in 1995 and 1997, as shown in Table 5. The 1993 data, collected from Grade 6 and 9 students, were eliminated from this analysis because they were significantly different to that values in 1995 and 1997, as discussed above. Data at Grade 8 included both repeat and new students as no differences were observed between the mean scores of these groups. For Grade 10, only 14 students had never done the survey before, and data from these students were combined with those of students repeating the survey once or twice from previous years, as no effects of

repeating were found for these groups. For comparison purposes with the Grade 10 data, all Grade 11 responses were included despite the repeat effect (see cross-cohort analysis above). Thus the results in Table 5 include all data except from 1993, with the proviso on interpretation that Grade 10 and 11 results may be inflated due to effects of repeating the survey previously. The table shows the score interpretation of the headline was dominant at younger grade levels, while older students responded at higher levels. Analysis of variance found significant effects for grade ($F_{4,1854}$ = 552.29, $p < 0.0001$) and gender ($F_{1,1854}$ = 94.08, $p < 0.0001$), but no significant interaction. Males outperformed females at all grade levels, mainly due to the larger numbers of females who interpreted the headline as a score. Mean scores for groups when responses interpreting the headline as a score are eliminated from the analysis are shown in the bottom row of Table 5. No significant differences between mean scores of females and males are found at any grade levels, indicating that there are gender differences for the interpretation of the headline as a score, but not for response levels once students appreciate the numbers refer to one of the three contexts of expression.

Table 5
Cross-Sectional Comparison of Percentage of SOLO Levels, Mean Scores, Percentage of Contexts of Expression, and Mean Scores Excluding Score Interpretations, by Grade and by Gender

SOLO	Grade 6		Grade 8		Grade 9		Grade 10		Grade 11	
Level	F	M	F	M	F	M	F	M	F	M
NR/P	24	23	13	16	13	14	4	6	7	14
IK	59	39	50	25	39	25	47	20	17	11
U_1	8	20	14	21	15	15	9	13	11	7
M_1	5	9	14	18	14	14	14	21	30	28
R_1	2	3	3	7	5	8	5	9	10	9
U_2	2	6	6	9	11	18	16	24	15	22
M_2	-	-	<1	3	-	3	1	1	7	2
R_2	-	-	<1	1	3	3	3	6	2	8
Mean Score	0.35	0.69	0.78	1.34	1.23	1.72	1.42	2.14	2.11	2.32
Context										
NR/P (None)	24	23	13	16	13	14	4	6	7	14
IK (Score)	59	39	50	25	39	25	47	20	17	11
Betting	2	11	12	26	14	31	15	35	36	38
Chance	14	26	19	27	26	22	21	25	30	22
Frequency	2	2	6	6	8	8	13	13	9	15
N	220	180	268	255	208	217	136	136	127	117
Mean Score	0.84	1.14	1.54	1.78	2.02	2.31	2.68	2.67	2.55	2.62
(excl. IK-score)	n=91	n=110	n=135	n=192	n=127	n=162	n=72	n=109	n=105	n=104

Discussion

Longitudinal development was observed for student responses assessed over two-year and four-year intervals, with general improvement in SOLO levels, and increasing use of the three contexts of expression. These results suggest the developmental model shown in Table 1 is a useful model for assessing student development in understanding odds from upper primary school through the secondary school years. One test of the model is the number of reversions to lower levels in subsequent years. For the two-year longitudinal change, of 303 students whose responses involved a context in the first year, 136 (45%) reverted to lower levels, higher than might be expected. It should be noted, however, that only 62 of these (20% of the 303) reverted to lower SOLO levels in the concrete symbolic mode, while 23 (8%) reverted to a prestructural or non-response, and 51 (17%) reverted to the ikonic score interpretation. The latter may not surprising given that teaching odds in applied settings such as this newspaper headline is unlikely to be universal or consistent across the secondary school years. Some

teachers express anxiety about teaching the topic and occasionally say they would not do so (Watson & Moritz, 1998b). Hence students might be expected to offer an ikonic response as an alternative interpretation more readily in the sporting setting than they would in more conventional mathematics settings.

Gender differences favouring males were generally observed, except at Grade 11. This follows similar findings favouring males for selected grades or questions for comparison of odds (Green, 1991) and for chance measurement (Watson & Moritz, 1998a). These differences were particularly in the use of the ikonic score interpretation, and after eliminating these alternative responses from the analysis, there were no gender differences in levels of concrete symbolic responses — that is, once females understood the headline was about odds, they interpreted it at the same levels of sophistication as males. This result highlights the importance of appreciating the context in which mathematics is set in the classroom. It would appear that females are disadvantaged until the later years of schooling by the setting of odds in a sporting context. The solutions to this dilemma are in the hands of teachers and curriculum planners.

The higher scores observed for 1993 than 1995 and 1997 samples at Grades 6 and 9 deserve particular attention. It is important to note that the same NUD•IST script was used, thus the categorisation method was consistent across years. The 1997 Grade 9 sample was reduced in number due to some schools not offering new students because of other time commitments. Thus a school bias for Grade 9 may have reduced results for 1997. If, however, the 1995 Grade 9 sample and the 1995 and 1997 Grade 6 samples were truly representative of students at those grade levels, it would appear that a reduction in performance has occurred in understanding of odds. Further analyses of other survey questions are awaited to see if this result is of more widespread concern.

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