

# A REVALUATION OF NEWMAN'S ERROR ANALYSIS

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*Newman (1977, 1983) defined five specific reading skills as crucial to performance on mathematical word problems. They are reading, comprehension, transformation, process skills, and encoding. Newman's Error Analysis (NEA) has experienced a reawakening in New South Wales and has been included in a number of programs such as the Counting On program. This paper will discuss the developing use of NEA as a diagnostic tool linking numeracy and literacy using an interview involving five prompts. The paper will also develop an understanding of how teachers have used NEA as a remediation and general classroom pedagogical strategy for primary and secondary schools.*

## **Background**

The Counting On program conducted by the New South Wales Department of Education and Training (NSW DET) was implemented in 1999 to address the needs of students who were struggling with mathematics in the middle years of schooling because of a lack of understanding of and proficiency with the early school mathematical knowledge.

The initial program was designed for students in the first year of secondary school (Year 7) who had not achieved specific New South Wales Stage 3 (Years 5 -6) mathematics outcomes by the time they commenced secondary school. It was later extended to include the primary school students and older secondary students (Years 7 - 9).

The Counting On program has a solid research foundation starting with the Counting On Numeracy Framework (Thomas, 1999) which was an extension of work by Cobb and Wheatley (1988), Beishuizen (1993), Jones, Thornton, Putt, Hill, Mogill, Rich and van Zoest (1996) and relates to the Count Me In Too Learning Framework in Number (LFIN; Wright, 1998; Wright, Martland, & Stafford, 2000).

This theoretical base was further supplemented by an increasing research base provided through the regular Counting On evaluation studies (Mulligan, 1999, Perry & Howard, 2000, 2002a, 2003; White 2008, 2009). In 2007 the program underwent a major revision and was implemented in 122 schools across the state grouped into 30 clusters with each cluster supported by a mathematics consultant. It was based on the previous models but included changes designed to simplify and encourage further and ongoing involvement of schools. Features of the revised model included: a simplified assessment instrument; the inclusion of Newman's Error Analysis (NEA); a revised Counting On CD; formation of School clusters; a facilitator's conference; and a facilitated professional development model. It is the inclusion of NEA that is the focus of this paper.

## **Newman's Error Analysis**

In Australia, NEA was promoted by Clements and Ellerton (1980, 1982; Ellerton, & Clements, 1991; Clements & Ellerton, 1992; Ellerton, & Clements, 1996; Marinas, & Clements, 1990) during the 1980s and 1990s although there were others (Watson, 1980). In NSW the initial momentum for NEA declined and its reawakening and inclusion in the Counting On program in 2007 was via an unusual path. Clements left Australia and became a professor at the University of Brunei Darussalam. Among other projects, he became heavily involved in a national professional learning program for primary teachers titled, Active Mathematics In Classrooms (AMIC; White & Clements, 2005). The program involved nine key mathematics learning areas that were presented via workshops and resources to primary school teachers. The teachers then implemented the program in their school. One of the nine key mathematics learning areas was NEA.

In 2005 the AMIC program was reported in the NSW primary journal, *Square One*, for the Mathematics Association of New South Wales. An article on NEA from *Square One* (White, 2005) was selected and added to the teacher reader section of the NSW DET's website in 2006 which created a renewed interest by teachers. In 2007 it was added to the Counting On program.

The reasons for the inclusion of NEA in the 2007 and 2008 Counting On programs were primarily to assist teachers when confronted with students who experienced difficulties with mathematical word problems. Rather than give students ‘more of the same’ involving drill and practice, NEA provided a framework for considering the reasons that underlay the difficulties and a process that assisted teachers to determine where misunderstandings occurred and where to target effective teaching strategies to overcome them. Moreover, it provided excellent professional learning for teachers and made a nice link between literacy and numeracy.

NEA was designed as a simple diagnostic procedure. Newman (1977, 1983) maintained that when a person attempted to answer a standard, written, mathematics word problem then that person had to be able to pass over a number of successive hurdles: Level 1 Reading (or Decoding), 2 Comprehension, 3 Transformation, 4 Process Skills, and 5 Encoding. Newman defined five specific reading skills as crucial to performance on mathematical word problems. They are reading, comprehension, transformation, process skills, and encoding. She asked students the following questions (prompts) as they attempted problems.

1. Please read the question to me. If you don't know a word, leave it out.
2. Tell me what the question is asking you to do.
3. Tell me how you are going to find the answer.
4. Show me what to do to get the answer. “Talk aloud” as you do it, so that I can understand how you are thinking.
5. Now, write down your answer to the question.

While working through a word problem it was always possible for students to make a careless error and there were some students who deliberately gave incorrect answers due to a lack of motivation to answer to their level of ability.

There have been adaptations by both researchers and teachers. For example, the transformation level has been renamed by many NSW teachers as the ‘mathematising’ level. It is these modifications that are of interest to this paper. In the next section two researcher modifications will now be briefly described.

## **Modifications**

The first is by Casey (1978) who modified the interview procedures used by Newman (1977). In a study of the errors made by 120 Grade 7 students in a single high school, the interviewers were required to help students over errors. If a pupil made a Comprehension error, the interviewer would note this and explain the meaning of the question to the pupil,

and so on. So, in Casey's study, a pupil could make a number of errors on the one question and thus it is difficult to compare Casey's interpretations with Newman's. A number of NSW teachers have preferred this modification as it resonated more closely with their perceptions of the role of a teacher.

The second adaptation is by Ellerton and Clements (1997) who used a modified form of the Newman interview method to analyse the responses by students in Grades 5 through 8 to a set of 46 questions. They challenged the view that correct answers equated to understanding, thus all responses, both correct and incorrect, were discussed. A correct answer which, after analysis, was not deemed to be associated with an adequate understanding of the main concepts, and/or skills and/or relationships tested by a question, would be associated with a Newman error category, even though the answer was correct. Ellerton and Clements' modification led to the adoption of a slightly different definition of "Careless" error from that previously given by elements.

While there are other theoretical approaches available to teachers, NEA has become popular with NSW teachers because it is easy to understand, to use and to adapt. NSW teachers have reported that NEA has contributed to improved student learning outcomes. In the next section, data from the 2007 and 2008 evaluation reports (White, 2008, 2009 in press) will examine the student learning outcomes and the teacher uses of NEA.

## **Student Learning**

The 2008 program was implemented in 99 schools across the state. An assessment instrument based on the LFIN was administered by the class teacher as a whole class schedule covering place value, addition, subtraction, multiplication, division, and word problem tasks. The assessment schedule was closely linked to the learning framework and the results were used by the teacher to identify the student target group. The target students were then tested at the start and finish of the program. The teachers were asked to record the results of the target group assessment process involving a minimum of 5 students per class on an excel spreadsheet supplied to them. The spreadsheet recorded the initial level on the LFIN and NEA for the targeted students before the program was implemented and again following 10 weeks of targeted activities.

In 2008 data was collected from 74 schools with 55 primary schools, 16 secondary schools and 3 central schools. There were 1213 students with 954 primary students (78.6%) and 259 secondary students (21.4%). Only one of the two questions involving Newman's

Error Analysis in the assessment instrument was recorded for each student. The NEA scale from 1 to 5 was used, and a category 6 was added to represent those who could complete the word problem successfully. Table 1 below shows that the majority of students have improved by 1 or more levels (56.6%), with a sizeable group improving two levels (15.6%). There are a small group of students who improved by 3 and 4 levels as there are some who decline by 1, 2 or more levels.

Difference	Frequency	Percentage Frequency
- 4	3	0.2%
- 3	6	0.5%
- 2	14	1.2%
- 1	52	4.3%
0	452	37.3%
1	385	31.7%
2	189	15.6%
3	79	6.5%
4	27	2.2%
5	6	0.5%
Total	1213	100.0%

*Table 1. The Difference In Newman's Error Analysis Level*

The descriptive statistics record an increase in the mean from 2.52 for the initial level (SD = 1.096) to 3.37 for the final level (SD = 1.254). Using a paired sample T-Test, the results indicate that the improvement in the student outcomes for mathematical word problem levels at the start and finish of the 10 week Counting On 2008 program was statistically significant.

The 2008 data collected for the pre and post program student learning outcomes indicated that a statistical significant improvement existed in student learning outcomes between the start of the program and the completion of the program in mathematical problem solving involving word problems. In a short program as this it is unrealistic to expect that all students will make great leaps up the NEA levels. These targeted students have been struggling for some time with their mathematical and literacy levels and have developed judgments of their own ability. To improve 1 level, especially for the NEA scale which could involve the improvement of reading or comprehension, is quite remarkable in such a small time frame.

## Teacher Use

The 2007 evaluation reported the majority of teachers were strongly positive about the inclusion of NEA into the program. Many primary teachers reported on how they had adapted NEA across other key learning areas and other stages. It was observed that there was a divide between primary and secondary teachers. NEA appears to resonate more easily with primary teachers and with the issues of 'numeracy across the curriculum' and 'every teacher being a teacher of literacy'. However, it did spread across secondary schools and a teacher reported that 'One head teacher has adopted/adapted it to assist senior students in Stage 6 mathematics' (White, 2008, p. 12).

Clements (1980) reported two large studies in which 6595 errors made by 634 children were analyzed using NEA. Resonating with Newman's original study, Clements reported that 70% of errors belonged to reading, comprehension, transformation or carelessness categories. The first three accounted for 40% and there were approximately 30% careless errors. The mathematics procedure level of process skills registered 25% and encoding only accounted for about 5%. NSW teachers were finding similar results and developed strategies to address their students' difficulties. The 2008 evaluation report described how teachers had extended the use of NEA beyond a diagnostic tool to a pedagogical and remedial tool. The five prompts were displayed in the classroom by poster and provided a structured process for the students who were expected to work through the NEA levels for all mathematical problems. This helped to reduce the careless errors. In a whole class setting, selected students worked aloud in order to scaffold the learning of those struggling with one of the levels. Teachers also used the NEA interview prompts as a problem solving approach: "The Newman's error analysis and follow-up strategies have helped students with their problem-solving skills, and teachers have developed a much more consistent approach to the teaching of problem-solving. Not only has it raised awareness of the language demands of problem solving, but through this systematic approach, teachers can focus on teaching for deeper understanding" (teacher response, White, 2009, p. 42).

The NSW DET has also supported teachers in assisting their students who are having difficulty at the transformation or mathematising level by developing resources focused on the use of tape diagrams. The tape diagram provides a diagrammatic representation of the word problem, helping the students to manage all the information, and providing direction for a solution.

## Conclusion

The Counting On program was a success in improving both teacher and student learning outcomes and NEA made an important contribution to these gains. The data revealed a statistical and educationally significant improvement existing in student learning outcomes between the start and the completion of the program involving mathematical problem solving using word problems. As well NEA is being used by teachers as a remedial classroom strategy and as a wider classroom pedagogical strategy. NEA is a powerful diagnostic assessment and teaching tool.

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## References

- Beishuizen, M. (1993). *Mental strategies and materials or models for addition and subtraction up to 100 in Dutch second grades*. Journal for Research in Mathematics Education, 24(4), 294-323.
- Clements, M.A. (1980). *Analysing children's errors on written mathematical tasks*. *Educational Studies in Mathematics*, 11 (1), 1-21.
- Clements, M.A. (1982). *Careless errors made by sixth-grade children on written mathematical tasks*. Journal for Research in Mathematics Education, 13(2), 136-144.
- Clements, M. A., & Ellerton, N. F. (1992). *Overemphasising process skills in school mathematics: Newman analysis data from five countries*. In W. Geeslin & K. Graham (Eds.), *Proceedings of the Sixteenth International Conference on the Psychology of Mathematics Education* (Vol. 1, pp. 145-152). Durham, New Hampshire: International Group for the Psychology of Mathematics Education.
- Cobb, P. & Wheatley, G. (1988). *Children's initial understandings of ten. Focus on Learning Problems in Mathematics*, 10(3), 1-28.
- Ellerton, N.F. & Clements, M.A. (1991). *Mathematics in language: A review of language factors in mathematics learning*. Australia: Deakin University Press.

- Ellerton, N. F., & Clements, M. A. (1996). *Newman error analysis. A comparative study involving Year 7 students in Malaysia and Australia*. In P. C. Clarkson (Ed.), *Technology and mathematics education* (pp. 186-193). Melbourne: Mathematics Education Research Group of Australasia.
- Ellerton, N. F., & Clements, M. A. (1997). *Pencil and paper tests under the microscope*. In F. Biddulph & K. Carr (Eds.), *People in mathematics education* (pp. 155-162). Waikato, NZ: Mathematics Education Research Group of Australasia.
- Jones, G. A., Thornton, C. A., Putt, I. J., Hill, K. M., Mogill, T. A., Rich, B. S., & van Zoest, L. R. (1996). *Multidigit number sense: A framework for instruction and assessment*. *Journal for Research in Mathematics Education*, 27(3), 310-336.
- Marinas, B., & Clements, M. A. (1990). *Understanding the problem: A prerequisite to problem solving in mathematics*. *Journal of Science and Mathematics Education in South East Asia*, 13(1), 14-20.
- Mulligan, J. (1999). *Evaluation of the pilot Counting On Year 7 numeracy project*. Sydney: NSW Department of Education and Training.
- Newman, M. A. (1977). *An analysis of sixth-grade pupils' errors on written mathematical tasks*. *Victorian Institute for Educational Research Bulletin*, 39, 31-43.
- Newman, M. A. (1983). *Strategies for diagnosis and remediation*. Sydney: Harcourt, Brace Jovanovich.
- Perry, B. & Howard, P. (2000). *Evaluation of the impact of the Counting On program: Final Report*. Sydney: NSW Department of Education and Training.
- Perry, B. & Howard, P. (2001a). *Counting On: An evaluation of the learning and teaching of mathematics in Year 7*. Eighteenth Biennial Conference of the Australian Association of Mathematics Teachers. Canberra, January.
- Perry, B. & Howard, P. (2001b). *Counting On: A systemic program for Year 7 students who have experienced difficulty with mathematics*. In J. Bobis, B. Perry, & M. Mitchelmore (Eds.), *Numeracy and beyond* (pp 410-417). Sydney: Mathematics Education Research Group of Australasia.
- Perry, B. & Howard, P. (2001c). *Arithmetic thinking strategies and low achieving junior high school students in Australia*. In R. Speiser, C. A. Maher, & C.N. Walter (Eds.), *Proceedings of the Twenty-third Annual Meeting of Psychology of Mathematics Education – North America Group* (pp 273-280). Columbus, OH: ERIC Clearinghouse for Science, Mathematics and Environmental Education.



- Perry, B. & Howard, P. (2002a). *Evaluation of the impact of the Counting On program during 2001: Final Report*. Sydney: NSW Department of Education and Training.
- Perry, B., & Howard, P. (2002b). *A systemic program for students who are experiencing difficulty with mathematics as they transition from primary to high school*. In B. Barton, K.C. Irwin, M. Pfannkuch, & M.O.J. Thomas (Eds.), *Mathematics Education in the South Pacific: Proceedings of the Twenty-Fifth Annual Conference of the Mathematics Education Research Group of Australasia* (pp. 543–550). Auckland, NZ: MERGA.
- Perry, B. & Howard, P. (2003). *Evaluation of the impact of the Counting On program 2002: Final Report*. Sydney: NSW Department of Education and Training
- Thomas, N. (1999). *Levels of conceptual development in place value. The pilot Counting On numeracy project*. Sydney: NSW Department of Education and Training.
- Watson, L (1980). *Investigating errors of beginning mathematicians*. *Educational Studies in Mathematics*, 11(3),319-329.
- White, A. L. (2009). *Counting On 2008: Final report*. Sydney: Curriculum K-12 Directorate, Department of Education and Training.
- White, A. L. (2008). *Counting On: Evaluation of the impact of Counting On 2007 program*. Sydney: Curriculum K-12 Directorate, Department of Education and Training.
- White, A. L. (2005). *Active Mathematics In Classrooms: Finding Out Why Children Make Mistakes - And Then Doing Something To Help Them*. *Square One*, 15(4), 15-19.
- White, A. L., & M. A. Clements (2005). *Energising upper-primary mathematics classrooms in Brunei Darussalam: The Active Mathematics In Classrooms (AMIC) Project*. In H. S. Dhindsa, I. J. Kyeleve, O. Chukwu, & J.S.H.Q. Perera (Eds.). *Future directions in science, mathematics and technical education* (pp. 151-160 ) (Proceedings of the Tenth International Conference). Brunei: University Brunei Darussalam.
- Wright, R. J. (1998). *An overview of a research-based framework for assessing and teaching early number*. In C. Kanes, M. Goos, & E. Warren (Eds.), *Teaching mathematics in new times* (pp. 701- 708). Brisbane: Mathematics Education Research Group of Australasia.
- Wright, R. J., Martland, J. R., & Stafford, A. (2000). *Early numeracy: Assessment for teaching an intervention*. London: Sage / Paul Chapman Publications.