PROBLEM SOLVING SKILLS AMONG CHILDREN WITH MILD INTELLECTUAL DISABILITIES: APPLICATION OF QUALITY SAMENESS ANALYSIS

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ABSTRACT
Children with Mild Intellectual (IM) Disabilities are often taught addition and subtraction algorithms through the use of rote learning models which fail to enhance problem solving skills among such students. Recent developments in other curriculum areas suggest that there are alternative process oriented models which may be more successful in ameliorating successful problem solving strategies among such students. This research attempts to contrast one such model, Quality-Sameness Analysis (QSA), with more conventional and currently implemented rote learning systems such as the Computational Skills Program (CSP). In addition it is proposed that the use of calculators to solve conventional algorithms will free cognitive functioning among IM students and enhance the acquisition of problem solving skills. Preliminary results confirm the QSA as a powerful process oriented model with considerable potential in the IM classroom and the major contribution that the use of calculators can make in the acquisition of problem solving skills among IM children.

Researchers in the areas of mathematics education and special education need to cooperate when dealing with mathematics instruction for students with learning difficulties. Some of the recent developments in the field of mathematics education have after all evolved from the need for different approaches to teaching and learning as a consequence of the large numbers of children who either fail or become disinterested in developing mathematical skills. Put simply, in order to promote maths skills in children who "can't do maths". Therefore research in this area must logically relate very strongly to the needs of children with learning difficulties, especially in the areas of specific learning disabilities and mild intellectual disabilities. Of particular interest are those discussions which relate to the development of problem solving skills and the use of the calculator as a major emphasis in mathematics education. The current trends in these areas have a high degree of relevance to maths education for students with learning difficulties.

As early as 1966, Bruner saw as central to the nature of learning and instruction the notion that material to be taught must necessarily be organised in such a way as to optimally facilitate learning, retention, and problem solving. This instructional theory he said "must specify the ways in which a body of knowledge should be structured so that it can be most readily grasped by the learner" (p. 41). Similarly, Carnine, some years later claimed that "the specifics of how to organise and present the content of a discipline must be carefully considered if students are to succeed at higher order thinking" (1991, p. 263).

In order for optimal learning and performance in problem solving to occur, the learner must also possess a learning strategy by which this body of knowledge might best be assimilated. Derry (1989) for example suggested that the most useful direction for research into problem solving was the identification of strategies and training methods that engender both learning and expert use of domain-specific schemata.

It has been further suggested that the learning strategy employed by individuals will enhance their ability to learn, retain material, and solve problems. In this light, a learning strategy might best be defined as "a way of tackling a type of problem, or learning material that may be applied to a whole class of learning's, not just to the particular problem in question." (Biggs & Telfer, 1987, p. 550).

A number of studies have illustrated the importance of employing strategies in attempts at problem solving. Darch, Carnine, and Gersten (1984), demonstrated the advantages in analysing particular domains with reference to essential discriminations and strategies that must be employed to perform adequately. Flavell (1985) looked at memory strategies which rely on relationships such as semantic grouping or categorisation. Similarly Neimark, Slotnick, and Ulrich (1971) identified categorising strategies children used in grouping seemingly discrete items and objects and Chi, Feltovich, and Glaser (1981) observed domain experts grouping and solving problem types in terms of strategies relating to samenesses in the deep structure of the problem.

Recently however, children's learning and problem solving strategies have come under increasing scrutiny. For example, there is evidence that too much time is dedicated to teaching computational skills at the expense of concept understanding and problem solving strategies (Porter, 1989, cited in Engelmann et al., 1991; Engelmann et al., 1991) and that the presentation of problem solving strategies lacks coherence. In effect, the majority of strategies taught are too general to be of any real benefit to low performers.

In response to this, Engelmann et al ., (1991) proposed a strategy known as Quality-Sameness Analysis which they claim is concerned with "designing material in a way that will maximise the amount of teaching that is needed to demonstrate how related concepts are the same and to minimise the amount of teaching required to teach 'differences'" (p. 294). In their view instructors should design problem solving methods which allude to critical details in the same manner. This notion of sameness is largely based on earlier work by Engelmann and Carnine (1982) who proposed two assumptions about learners. First, they have the capacity to learn qualities shown through examples. Second, they have the capacity to generalise to new examples on the basis of sameness of quality. In this way the learner generates rules that indicate which qualities are common among the set of examples used in the teaching of a concept.

Various investigators have suggested that quality-sameness analysis be utilised in the many curriculum areas. For example, Dixon (1991) looked at applying sameness analysis to methods of spelling instruction. He claimed that sameness analysis should be given priority over instructional delivery and motivational techniques, and added that this analysis should assist in the generalisation, retention and transfer of material. Kinder and Bursuck (1991) addressed sameness analysis as it related to the social studies curriculum. They saw sameness analysis as developing an holistic understanding of content rather than a battery of isolated facts and information. Accordingly, they studied history under the Problem-Solution-Effect framework which drew out the sameness in the types of problems and solutions occurring throughout history. They concluded that through this analysis students were able to identify and assimilate important information into a network which could be retained more easily than isolated facts. Indeed such an approach might also serve to reduce memory load (Carnine, 1991). Therefore sameness analysis is the process underlying higher order thinking which incorporates the integration of concepts, rules, strategies, schemas etc.

Kameenui (1991) further argued that through sameness analysis the learner has the capacity to link a range of complex concepts. He suggested that it allowed teachers to teach more in less time, and that the samenesses acquired function as "cognitive building blocks" which then led to more complex cognitive structures that could be used for identifying similarities. Indeed, this may explain Chi et al.'s (1981) finding that expert problem solvers employ hierarchically organised knowledge structures based on crucial samenesses.

A further application of quality-sameness analysis has been made in the area of students with special needs and research with these students emphasises the importance of making sameness explicit (Engelmann et al., 1991). Kail (1984, cited in Carnine, 1991) reviewed studies with handicapped children and found they demonstrated longer memory search times possibly due to their inability to identify crucial samenesses. He also noted that special needs students had fewer opportunities to learn and that in view of this, instruction time need to be used efficiently. Other investigators have observed enhanced performance in special needs students using sameness analysis (e.g., Kinder and Bursuck, 1991). Bearing upon Kammeenui's (1991) observation that sameness analysis taught more in less time, such an approach might be advantageous to the special needs student. Kelly, Gersten, and Carnine (1990) taught fraction concepts to high schools students with learning disabilities and found that students who received instruction based on sameness analysis scored higher on post tests than students receiving 'traditional' instruction methods. In another study Darch, Carnine, and Gersten (1984) applied a derivative of sameness analysis to the instruction of division and multiplication word problems to skill deficient mathematics students. Their results demonstrated that students receiving instruction utilising a form of sameness analysis

performed better on post and maintenance tests than students receiving traditional instruction. Their results also showed that the sameness analysis instruction group performed better than students who were exposed to more instruction time using traditional instruction methods. It seems then that special needs students might benefit from the application of quality-sameness analysis primarily because it is time efficient, reduces memory load, seems to 'free-up' cognitive space and enhances performance.
Another variable of interest to the present investigators which promises similar benefits to students with special needs is the use of a calculator. For perhaps fifteen years an increasing number of commentators have called for a shift in emphasis away from laborious computational methods to the use of the calculator.
Girling, as early as 1977 defined basic numeracy as the ability to use a calculator. According to him, pencil and paper algorithms should be taught along with other techniques that will assist in understanding number concepts and not because these algorithms are the 'final word' on numeracy. Indeed, Ginsburg (1977) suggested that despite the emphasis on teaching algorithms, children do not often use them. Girling (1977) added that students unable to perform "useless algorithms" should not be stopped in their progress, rather, in such cases the calculator could provide a pivotal role in their number concept progress. Others as well (Brown, 1981; Maier, 1980; McIntosh, 1990), called for the abandonment of pencil and paper methods in favour of mental computation and calculators.
There are certain advantages incumbent in the use of calculators. For example the calculator provides the student with a better opportunity to concentrate on the processes and principles involved. Further, students using calculators were given more opportunity to study a greater variety of algorithms. Also, slower students were not stopped in their progress due to an inability to perform algorithms, possibly because planned calculator activities can assist children in acquiring mathematical concepts and skills in addition to being a useful motivating tool (Girling, 1977; MacIntosh, 1990).
In view of such advantages The Australian Association of Mathematics Teachers (1987) recommended that calculators be used by all students at all year levels. They suggested that calculators be used as a computational and instructional tool in the process of learning and that the curriculum be changed to accommodate their use. In addition, it was suggested that calculators may be of some benefit to special needs students and may provide students with learning difficulties an opportunity to think about mathematical relationships rather than the mechanics of computation.
Taking these views into consideration, the calculator could prove to offer special needs students more time to understand the concepts and principles involved in number, exposure to a greater variety of problems, enhanced computational accuracy, more immediate reinforcement and more powerful motivation.
In summary then, recent research would therefore suggest that two major areas of weakness for students with learning difficulties in mathematics

are:

1. Students with learning difficulties are unlikely to follow systematic strategies for solving problems.
2. Few students are fully competent at the basic facts. While most can calculate answers using some type of counting strategy, few can readily retrieve answers from memory, even to the basic addition and subtraction facts (Russell & Ginsburg, 1984; Torgeson & Young, 1983).

While most special educators would agree that opportunities to solve 'real life' problems which involve application of their computational skills are beneficial to such students, this aspect of maths is often neglected in special education classrooms and most problem solving tasks are poorly executed by these students.

Another key element in an individuals ability to solve problems in mathematics is computational fluency and accuracy. Becoming proficient at computations has always been difficult for special education students and has required long periods of repetitive practice. There are now strong arguments being put forward for de-emphasising the pencil and paper algorithms common to mathematics teaching in the regular classroom (Brown 1981; French, 1987; Ginsburg, 1977; Girling, 1977; Maier, 1980). The same arguments have even more relevance to special needs students.

These weaknesses point to a real need to develop not only computation skills but also alternative methods for solving 'word' and 'real world' problems. This research reports on a project which offers such alternative methods in order to improve the problem solving abilities of students with Mild Intellectual Disabilities (IM) through teaching addition and subtraction relationships and interrelationships using the Quality-Sameness Analysis developed by Engelmann and Carnine & Steely (1991). An additional aim was to show that access to a calculator for computations has a positive effect on maths problem solving abilities. The way in which problem solving is taught in schools today (particularly word problems) can lead to a range of misconceptions among students usually formulated from the presentation of limited, restricted samples in step by step teaching, particularly with low achieving students (Engelmann et al., 1991). The Quality-Sameness Analysis which we use in this project is an attempt to design curriculum procedures that can virtually eliminate the development of such misconceptions.

In the Metropolitan West Region of Sydney children with Mild Intellectual (IM) disabilities are often taught addition and subtraction algorithms and their application to problem solving situations through rote learning and practice models such as the Computational Skills Program (CSP) developed by Macquarie University. This research aims to contrast a process oriented model, Quality -Sameness Analysis (QSA) with CSP to establish whether it is superior in raising achievement levels in problem solving for children with IM disabilities. In addition, it attempts to establish whether the use of a calculator in conjunction with either model has positive benefits for the development of problem solving skills in children with IM disabilities.

To test the hypotheses that one method of instruction was superior to another and that the use of calculators would ameliorate the capacity for learning for this group of students, four experimental groups and one control group were required. Two of the experimental groups, one under each instructional type, were allowed to use calculators while the other two and the control groups were not. This design allowed the investigators not only to compare across groups but also to compare the performance of those who used calculators against those who did not, and to compare performance based on the type of instruction received, CSP or QSA.

Method

Subjects

Five schools in the Metropolitan West region of the NSW Department of School Education in Sydney were approached to participate in this study. The five schools reflect similar characteristics in terms of student backgrounds and teachers in these schools were all aware of the Computational Skills Program (CSP) promoted by Macquarie University. In addition, each school had a class of children with Mild Intellectual (IM) disabilities.

Five qualified teachers who are students in the postgraduate program in Special Education at the University of Western Sydney, Nepean volunteered to act as instructors for each of the experimental and control groups. The instructors received a formal training session from one of the researchers on the appropriate methodology required to instruct children through the use of either CSP or Quality-Sameness Analysis (QSA).

A total of 74 children (51 male and 23 female) from five schools (one class within each school) and identified as having Mild Intellectual Disability, here defined as those with IQ's in the range of 55 - 75, participated in the study. The sample was purposive because intact classes were used. These children ranged in age from 10 yrs. to 12 yrs. 6 mths. with an average of 11 yrs. and a standard deviation of 0.78 Although the sample of participants was purposive, instructors were randomly allocated to the schools.

Design

In order to test our theory four experimental groups were defined. Each methodology was used with two groups, but with only one of each of the groups allowed to use calculators to perform mathematical operations. Therefore the four experimental groups included CSP with calculator; CSP without calculator; QSA with calculator; and, QSA without calculator. In addition, there was the Control group which was taught using the CSP method as it is normally applied in schools within the region.

This design facilitated analysis through the use of Analysis of Covariance with the pretest as the covariate and age and sex as possible moderator variables. It also allowed for analysis based on instruction type (QSA vs. CSP vs. Control) and calculator use (With Calculator vs. No Calculator vs. Control).

All participants were required to complete a range of addition, subtraction, and word problem pretests. A parallel form of each pretest was also completed at the end of the experimental sequence, ten weeks of instruction or the equivalent of one school term in NSW.

Instrumentation

Addition Test

This test comprised of 20 questions and included 6 one digit (3 sums requiring double digit answers), 8 two digit (4 sums requiring regrouping), and 6 three digit sums (4 sums requiring regrouping). These algorithms were constructed in parallel form so that the subjects were performing identical algorithmic calculations but in a different order.

Subtraction Test

This test was similar to the addition test in style and include 6 one digit , 8 two digit (4 requiring regrouping), and 6 three digit subtractions (4 requiring regrouping, 2 containing a zero in the numerator). Again the algorithms were structured so as to ensure that subjects were performing identical algorithmic calculations on pre and post testing.

Word Problems

The word problem test included a combination of sixteen problems requiring the application of a variety of addition and subtraction algorithms. The experimenters included 4 simple, 4 classification, 4 sequence of events, 4 comparison word problems as outlined by Engelmann, Carnine & Steely (1991).

Calculators

Two of the experimental groups were supplied with Casio MS-7 desktop calculators which are solar powered, have a large viewing screen and easy to operate numerical and function buttons. The ease of use and low maintenance were considered to be essential qualities in encouraging students to make proper use of this equipment.

Wall Charts and Workbooks

All participants using the CSP model were supplied with the appropriate workbooks and instructions together with a variety of word problems for each of the skill levels of this program, and appropriate independent worksheets. Those who were being instructed through the QSA method had access to individual and wall tables of the number families, arrow cards and a variety of word problems for discussion and independent work.

Procedure

Initially permission was sought from Metropolitan West Region of the DSE to conduct the study in selected schools in the region, those with IM classes. Once this permission was granted five schools which were known to the experimenters were invited to participate. Teachers and parents were informed on the nature of the experiment and it was emphasised that the researchers wished to determine which method of instruction was most successful in improving student performance. Each of the experimental schools was then guaranteed an additional experienced and qualified teacher to implement the program in their school. The teacher in the control school that we were interested in problem solving and allowed to continue with his normal classroom practices. All five programs involved exactly the same amount of face to face contact with the students, one hour per session and three sessions per week. Over an eight week period this amounted to approximately twenty hours of instruction taking into account various school activities and absences which disrupted the planned programs.

The program of instruction in both modes CSP and QSA was devised to take place over one school term, the third term of the 1992 school year in NSW. The first and last weeks of the term were used to administer the pretests and posttests. The CSP program was conducted with strict adherence to the guidelines set out in the manuals provided. Word problem probes were added to each skill level using the same types of problems taught using QSA. Instruction in these followed traditional methods. QSA on the other hand required the development of an instructional strategy and appropriate teaching materials.

Once student volunteers were assigned to each of the five participating schools, each instructor received three hours of instruction prior to the presentation of instructional material together with ongoing instruction as the research progressed. The pretest was conducted in the five schools by a research assistant and the instructors who followed the same protocols in each school. The control group was found to perform significantly better on the pretest than the other four groups which were found to be of similar ability. All students were tested again at the completion of the program, in the last week of the term. Each instructor and the research assistant were responsible for administering and collecting this information.

The pretest and posttest scores were checked and entered into a data set

for further analysis. The results are reported in the following section.

Results

Analysis of covariance (ANCOVA) was used to determine whether there were any significant differences based on performance on the word problem posttest. Although gender and age were used as moderator variables, there was no significant main effect found in the analysis due to either variable. The experimental variable, instructional type however, was found to be a significant ($p< .001$) contributor to the variance of posttest results in both the two group and four group instructional modes . Further analysis of these results through the use of Newman-Keuls tests are outlined below according to analysis type. Table 1 outlines means and standard deviations for all groups and combinations of groups.

Table 1: Raw data means and standard deviations on word problem pretest and posttest scores by group type.

Group Type	QSA(1)		CSP(2)		Total		Control	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Calculator	m=1.33	10.36	1.92	10.10	1.63	10.24		

sd=2.50 2.91 1.73 2.03 2.12 2.47
n=12 11 12 10 24 21
Non-calculator 3.36 9.83 1.88 7.13 2.55 8.29 4.35 5.47
3.27 2.89 1.45 2.96 2.51 3.18 3.38 3.04
14 12 17 16 31 28 20 17
Total 2.42 10.09 1.90 8.27
3.06 2.90 1.54 2.71
26 23 29 26
Grand Mean 2.81 8.18
2.83 3.41
73 66

Note: (1) QSA--> Quality-Sameness Analysis
(2) CSP--> Computational Skills Program

Five Group Analysis

In comparing results it is clear that all of the experimental groups performed significantly better on the posttest than the control group. The two QSA groups (with and without calculator) and the CSP group (with calculator) significantly ($p<.05$) outperformed the CSP group and all four experimental groups significantly (CSP - with calculator, QSA - with and without calculator, $p<.01$; and, CSP - without calculator, $p<.05$), outperformed the control group on the posttest (Table 2).

Three Group Analysis by Instructional Type

In order to determine whether the type of instruction given had any effect on performance, the data was combined into three groups, those who were given CSP instruction (with and without calculators), those with QSA instruction (with and without calculators) and the Control group. Further analysis of the ANCOVA revealed that both instructional types resulted in a significantly ($p<.01$) better posttest performance than the Control group but no difference between Instructional types (Table 3).

Three Group Analysis by Calculator Use

The data was also combined in accordance to the use of calculators thus comparing, through ANCOVA, posttest results of the group who received instruction with the use of calculators, to those of the group who received instruction without the use of calculators and the Control group. Further analysis indicated a strong effect due to the use of calculators with both groups significantly ($p<.01$) outperforming the Control group on the word problem posttest but the Calculator group significantly ($p<.01$) outperforming the Non-calculator group (Table 4).

Table 2: Five group analysis of covariance by instructional type with pretest as the covariate

Source of Variation	sum of squares	df	mean square	F
Main Effects				
Group	283.6	4	70.9	9.9*
Age	36.6	2	18.3	2.6

Gender 5.4 1 5.4

Two way interactions
Group by Age 37.9 8 4.7
Group by Gender 6.9 4 1.7
Age by Gender 4.1 2 2.0
Three way interactions
Group by Age by Gender 39.1 4 9.8 1.4
Residual 279.4 39 7.2

Note: * p<.001

Table 3: Three group analysis of covariance by instructional type with pretest as the covariate

Source of Variation sum of squares df mean square F

Main Effects
Group 213.1 2 106.5 13.0*
Age 30.5 2 15.3 1.9 Gender 4.3 1 4.3
Two way interactions
Group by Age 17.8 4 4.4
Group by Gender 1.7 2
Age by Gender 6.9 2 3.5
Three way interactions
Group by Age by Gender 17.6 2 8.8 1.1
Residual 402.2 49 8.2

Note: * p<.001

Table 4: Three group analysis of covariance by calculator use with pretest as the covariate

Source of Variation sum of squares df mean square F

Main Effects
Group 253.4 2 126.7 17.6*
Age 30.7 2 15.4 2.1 Gender 7.7 1 7.7 1.1
Two way interaction
Group by Age 20.6 4 5.1 Group by Gender 1.7 2
Age by Gender 6.1 2 3.0
Three way interactions
Group by Age by Gender 42.0 4 10.5 1.5
Residual 338.2 47 7.2

Note: * p<.001

SUMMARY AND CONCLUSIONS

It was clear from these results that both the use of calculators and the implementation of Quality-Sameness analysis are potent strategies in achieving success on problem solving for a group of IM children. While the use of calculators was demonstrated to be a successful strategy on its own, the fact that QSA was so potent either by itself or in tandem with the use of calculators is indicative of the power of the process oriented model.

In today's technological age there seems to be an ever decreasing argument for the rote learning strategies that have been dominant for so long in our educational systems. The fact that students classified as low in ability were able to dramatically improve their capacity to solve problems adds further support to the proponents of QSA as a viable alternative methodology across curriculum areas.

In our efforts to implement the programs of study, especially those which required the use of calculators, it was evident that at the primary level very few of the IM students were even aware of how to use a calculator. Given the availability of the technology and the relative low cost, it is difficult to surmise why more educational systems do not take advantage of its availability. There are many aspects of normal daily tasks which have been simplified and made available to the masses through ever developing technology, for example, the availability and relative ease of driving a motor vehicle in contrast to the skills required when they first became available. No one expects those same skills to be mastered by today's drivers yet, in educational terms, we fail to accept that the development of concepts required to become good problem solvers may be more important than the mastery of computational skills easily implemented through the use of a calculator.

Our research and its success with a group of students who are often doomed to failure does suggest that creative process oriented approaches can work. The study was limited by the method of sample selection and the difficulty in rigidly controlling learning sequences within schools. Nevertheless, despite a variety of difficulties there were clear experimental effects. Similar research needs to be carried out with larger groups and at a variety of age and ability ranges before we can make definitive statements but the body of evidence continues to grow in support of Quality-Sameness Analysis as a viable alternative to more rote oriented models of learning for students with mild intellectual disabilities.

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problem solving among children with mild intellectual disabilities:

Application of quality samaness analysis
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