INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

UMI

A Bell & Howell Information Company
300 North Zeeb Road, Ann Arbor MI 48106-1346 USA
313/761-4700 800/521-0600

UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

KAY: A CASE STUDY OF LEARNING DIFFICULTIES IN MATHEMATICS AND READING

A Dissertation
SUBMITTED TO THE GRADUATE FACULTY
in partial fulfillment of the requirements for the
degree of
Doctor of Philosophy

By
KRISTINE K. MONTIS
Norman, Oklahoma
1997

KAY: A CASE STUDY OF LEARNING DIFFICULTIES
IN MATHEMATICS AND READING

A Dissertation
APPROVED FOR THE
DEPARTMENT OF INSTRUCTIONAL LEADERSHIP
AND ACADEMIC CURRICULUM

BY

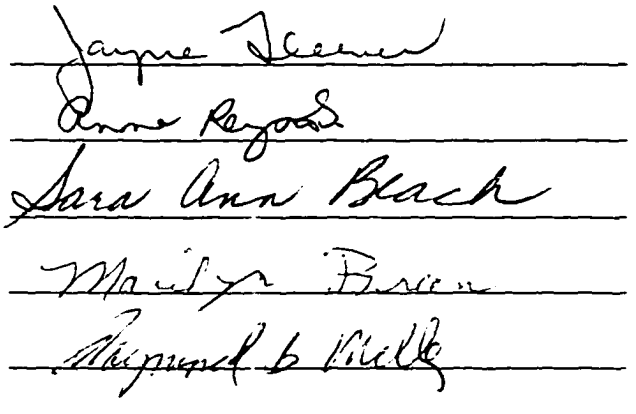


TABLE OF CONTENTS

TABLE OF FIGURES

LIST OF TABLES

USE OF PSEUDONYMS

As requested by the Internal Review Board of the Research Office of the University of Oklahoma the anonymity of any person or institution participating in this study is protected by the use of pseudonyms. No real names are given for either the participants or the localities discussed in this dissertation.

ACKNOWLEDGEMENTS OF GRATITUDE

This study was done under the supervision of Dr. Jayne Fleener and Dr. Anne Reynolds. They have both been invaluable in their support and suggestions in the preparation of this manuscript and the furtherance of my professional education.

I also want to thank the other members of my advisory committee: Dr. Raymond Miller, Dr. Sara Beach, and Dr. Marilyn Breen, each of whom has contributed time, knowledge, and support -- both in and outside of class.

I especially want to thank Dr. Paul Kleine, whose research courses, instructional comments, and encouragement made it possible for me to do this study competently and confidently.

I wish to acknowledge and thank my parents, Gerald and Norma Kowitz , who provided me with the educational and cultural opportunities which have made this achievement possible. I regret that they have both passed away during the time I have been working on this degree and hope that they are aware of my continued gratitude, respect, and love.

I want to thank "Kay" and her family. Without their willing participation and openness none of this would have been possible. "Kay" is an exceptional child in the most positive sense of the term and I feel privileged to have been able to work with her.

And finally I wish to thank my husband, Dwayne, who has patiently and good-naturedly supported me throughout this effort.

ABSTRACT

This case study identified and described the impact of learning difficulties on the life-experiences of a 12 year old student named Kay. The study proceeded with an analysis of how Kay makes sense of her world and copes with her learning difficulties, particularly in the areas of mathematics and reading. Then constructivist, developmental, cognitive, and language/cultural learning theories were examined for elements which might be expected to positively impact Kay's learning process. The identified elements were implemented in an action research design using an intervention protocol during tutoring sessions over the 1996-97 school year.

The results of this study centered around the ten types of interventions which were tried. In chronological order of when they were applied in this study, the ten interventions were:

1. Corrective Feedback
2. The Clinical Interview
3. Use of Visual Aids
4. Pair-Reading with Discussion after Each Paragraph
5. Use of Manipulatives
6. Memory Load Reduction
7. Proactive Teaching
8. Metacognitive Strategies
9. Calculators and Reference Charts
10. Explicit Instruction in Study Skills

In terms of school grades the four most dramatic observed changes were associated with (1) Explicit Instruction in Study Skills, (2) Memory Load Reduction, (3) Proactive Teaching, and (4) Pair-Reading with Discussion. Underlying the success of these interventions was the use of The Clinical Interview which aided in first understanding Kay's thought processes and then identifying appropriate interventions.

The results of this study substantiated aspects of the learning theories which were applied. It was observed, however, that classroom instruction was in many instances not consistent with such theories and in these cases Kay's learning difficulties were acerbated. Grounding of these theories in the exceptional case resulted not so much in revising the individual theories, but in highlighting the desirability of using multiple approaches.

The implications of this study include issues about (1) assumptions about common cultural experiences which are erroneous and therefore hinder the learning process, (2) the continuing disparity between what is known about learning and what actually takes place in classroom practice and (3) making mathematics accessible to students with learning difficulties.

Keywords: mathematics, reading, learning, teaching, intervention, learning disabilities, dyslexia, dyscalculia, case study, culture, language, classroom, equity

CHAPTER I: INTRODUCTION

CONTEXT FOR THE STUDY

Improving the depth and breadth of student learning in mathematics has been a driving concern in U.S. schools over the last fifty years. In the past, this quest has focused on developing and promoting better classroom practices and instructional strategies. In keeping with that goal, most mathematics education research earlier in this century was of a conglomerate nature: comparing group-achievement under one classroom treatment to group-achievement under some other classroom treatment.

In contrast, many recent studies in mathematics education have begun to focus on how an individual student "constructs" (or fails to construct) mathematical meaning. Such in-depth studies attempt to understand the student's learning in terms of the student's own thinking and strategies and then discuss the possible implications for instruction.

This second type of investigation is especially important if mathematics is to be "for all students" as the NCTM Professional Standards (1991) envision. Research cannot be limited to what works best "on the average" if there is truly a concern that mathematics becomes accessible for each and every student. So there is a special need to understand the student for whom learning mathematics is unusually difficult, because it is precisely that student who is left behind academically. As a result, such a student often continues to suffer emotionally, intellectually, and economically throughout his or her lifetime due to deficits in mathematics learning.

The student who has extreme difficulty learning mathematics (dyscalculia) has rarely, if ever, been studied with the intent of understanding how and why learning mathematics is so problematic for that particular student (O'Hare, Brown, Aitken, 1991; Spafford & Grosser, 1996). According to Gross-Tsur, Manor, and Shalev (1996), "Developmental dyscalculia has been relatively neglected by the educational and scientific community. In fact, the DSM-III-R classification states that there is no information regarding the prevalence, familial pattern or natural history of developmental dyscalculia" (p.25).

There is, however, a precedent for this type of research in the area of reading education. Students who have unusual difficulty learning to read (dyslexia) have been an area of interest to reading researchers over the last 100 years. Some of the dyslexia research has been fruitful in areas which may actually be related to difficulties in learning mathematics. Recent research in the medical field has suggested a connection between dyscalculia and dyslexia (Castles and Coltheart, 1996; Davis, 1992; Shalev,1993) and other neurological research has indicated a way that some apparently related neurological deficits may be overcome or at least better compensated for (Blakeslee, 1994, 1995).

This study attempts to put these pieces together through an in-depth case study of an individual student with a school history of learning difficulties in both mathematics and reading. By looking at an exceptional case (dyslexia/dyscalculia) it is hoped to contribute to the understanding of why some students have extreme difficulty learning mathematics and logically relate this understanding to existing theories about the learning process. In this way, it is hoped that improved learning strategies will emerge which are effective for the student in this study. Further, it is hoped that the study, by looking at

learning theory as it relates to an individual extreme case, will be able to suggest ways of identifying specific strategies for other students whose achievement level in mathematics and reading are lagging below grade level.

INITIAL ASSUMPTIONS

The logical foundations of this study are based on four assumptions about learning and educational research. They are:

1. Learning is multi-faceted with many different factors influencing both a student's difficulties and successes. Therefore, in order to understand the learning process of a student, it is necessary to understand the student from a variety of perspectives: for instance, medical and educational history, school setting, family structure and support, personality, diagnostic information, values, and beliefs.

2. Which learning theory is used as a model for interpretation of learning difficulties will directly affect what is identified as the problem and what possible interventions will be considered. Because the student's learning difficulties are pervasive and multifaceted, viewing the situation from several differing learning theory perspectives may provide insights which would not be possible, otherwise.

3. As with the study of disease, treatment cannot be withheld from a student with a learning problem simply to prolong the opportunity to study the problem. Study of a learning problem in an educational setting ethically requires that corrective measures are being attempted concurrent with the actual research. This has also been discussed by Cobb & Steffe (1983) in their description of the research methodology they call the learning experiment.

4. Learning theories should be applicable to the individual case. Where they are not, it is important to study how and why they are not. Better learning theory will result from revision and/or elaboration which is grounded in the experiences of the exceptional case.

RESEARCH PERSPECTIVE

The research perspective of this study consists of four logically interrelated approaches: the use of multiple perspectives, action research, critical theory and case study. The multiple perspectives approach asserts that a complex, multidimensional

problem is best understood by examining the problem from a variety of perspectives. Action research asserts that theory and practice have a reciprocal relationship: theory informs practice, but practice should also inform and revise theory. A theory which is developed through this process is referred to as grounded theory. The critical theorist approach contends that studying a problem is not sufficient, but that the research design should include elements designed to positively impact the problem being studied. The critical theorist position holds that "if you are not part of the solution, you are part of the problem." And finally, the in-depth case study approach provides the researcher with a forum for incorporating the preceding approaches in the exploration of a problem which focuses on understanding an individual student's learning difficulties.

WHY A CASE STUDY?

An investigation of how a student is thinking about mathematics and what may be affecting that thinking process is a topic which lends itself to constructivist-style case study precisely because it is an attempt to understand how the student is constructing (or failing to construct) mathematical knowledge. In terms of the three case study types described by Stake (1994) this study fits somewhere between the intrinsic and the instrumental type of case study. In one sense, it is an intrinsic study designed to understand the complexities and interrelationships involved in this particular student's difficulty learning mathematics. In another sense, the study is an instrumental study looking for insight into how a suspected learning disability may affect mathematics learning and refining existing theories about mathematical learning disabilities.

Case study is a methodology often used in fields which study singular phenomena. For instance, case studies are used in medicine, psychiatry, and psychology to document

interesting, unusual, or unique conditions. Most of what is known about brain physiology and function (prior to the invention of MRI) came from case studies of the subsequent changes in physical, emotional, and mental abilities of persons whose brains had been injured in accidents or by disease. The case study is also used for studying learning disabilities, particularly when the disability type contains heterogeneous patterns of symptoms which can be obscured by aggregate statistical methods (Martin, 1995).

According to Yin (1994) the case study is often appropriate when "how" or "why" questions are being posed. Such case studies may be explanatory, exploratory, and/or descriptive. Yin also provides an extensive discussion of criteria for judging the quality of case study research designs, including issues of construct validity, internal validity, external validity and reliability. These are summarized in Table 1 of the methodology section of this dissertation. About the question of generalizability, Yin writes, "case studies, unlike experiments, are generalizable to theoretical propositions and not to populations or universes. In this sense, the case study, unlike the experiment, does not represent a 'sample,' and the investigator's goal is to expand and generalize theories (analytic generalization) and not to enumerate frequencies (statistical generalizations)" (Yin, 1994, p.10).

A complementary perspective on the case study is presented by Stake (1994). It is his contention that the case study is not a methodology, but rather a choice of research topic. According to Stake, one chooses to do a case study because the case presents opportunities to investigate questions worthy of study. The methodologies the researcher chooses to apply to that case may be qualitative, quantitative, or a mixture of both. The methods should be chosen to best answer the questions under investigation.

The exceptional attributes of this case, the accessibility to this student, the parental support for the project, the school's willing cooperation, as well as the student's unusually long attention span, motivation to succeed, and willingness to invest wholeheartedly in whatever activity is suggested make this a viable and potentially valuable case for such a study.

THEORY BASE

In keeping with the multiple perspectives approach described in the preceding section, this study is designed to flow from a confluence of theories about learning and learners. An emergent part of the study involves matching characteristics of the student to strategies hoped to improve her learning. Deficits in memory, language, computation, and conceptualization were identified by the diagnostic testing done in the preliminary study. Therefore information processing, neurolinguistic, metacognitive, and constructive aspects of learning, as well as theories about specific learning disabilities such as dyslexia and dyscalculia, are expected to inform the study. The same diagnostic report also identified unexpectedly positive levels of self-concept and self-efficacy which will also be explored in terms of those theoretical constructs.

PROBLEM STATEMENT

The purpose of this study is to explore and analyze why learning mathematics is so problematic for a 12 year old student named Kay. The study will employ naturalistic case study methods incorporating multiple perspectives, critical, action and grounded theory research approaches to this problem. The research will be directed towards answering the following questions:

Background questions (case study and multiple perspective approaches):

1. How have Kay's difficulty learning mathematics (dyscalculia) and her difficulty learning to read (dyslexia) manifested? How have they impacted her life (emotionally, socially, educationally, etc.)?

2. How is she making sense of her world – particularly how is she making sense of (or not making sense of) mathematics and reading? What strategies has she developed on her own in order to cope? How well are they working for her?

Theoretical orientation question (action research approach):

3. How can existing learning theory perspectives inform or explain Kay's learning experiences? What alternative strategies or experiences do these theories suggest? What might be expected, according to these theories, to assist Kay in coping with or overcoming these difficulties?

Action question (action research and critical theory approaches)

4. When alternative strategies and experiences are used, how does Kay respond? Are there patterns to the types of new strategies or experiences she adopts and applies? Are any of them effective for her?

Analysis question (action research and grounded theory approach)

5. In what ways is Kay's case congruent or incongruent with existing theories of learning? What need for elaboration or modification of existing learning theory is indicated by this case? What grounded learning theory or perspective emerges from this case as interpreted in this study?

DEFINITION OF TERMS AND CONCEPTS

The most critical concept to define in this study is evidence of learning, because the study is motivated by, designed around, and directed towards resolution of difficulties in learning. For the purposes of this study, evidence of learning will be considered to include:

1. school defined achievement as measured or described by school grades and report card, teacher perceptions, and standardized testing.

2. sense-making as assessed through the tutoring interviews, constructivist problem solving tasks and inferences from the student's written work.

3. coping strategies as assessed through (a) professional educational evaluation, (b) observations of student in the classroom, during tutoring sessions, and in other real-life but non-academic settings, (c) interviews with student, parents, teachers, and (d) other psychological measures where available and appropriate.

While in the optimum case all three of these activities coincide, in practice they often radically diverge. For instance, a computation done correctly in most classrooms is considered "successful achievement" whether or not the student has made any sense of why the algorithm works or is able to apply the computation process in a problem solving situation. Likewise, coping strategies such as cheating or giving up represent learning how to survive within the system without either achievement or mathematical sense-making being involved. So achievement, sense-making, and coping are all activities which this study will consider under the general heading of "evidence of learning."

The other two important terms under consideration are dyslexia and dyscalculia[1]. These have varying meanings depending on the type and the age of the literature in which they are used. For instance, dyslexia sometimes refers to a learning disability involving reversals such as writing "b" for the letter "d" or saying "6" but writing "9." This tends to be an older usage of the word and was associated with the belief that the dyslexic's difficulty was related to a visual processing deficit. Most dyslexia research now points towards a phonological processing deficit rather than a visual deficit. However, the criteria of "presence of reversals" is still prevalent, especially among educational diagnosticians and psychometrists.

In the special education literature, dyslexia is often used in the exclusionary form required by federal guidelines PL 94-142 for learning disabilities special funding. In such cases all learning disabilities are restricted to the definition "a disorder in one or more of the basic psychological processes in understanding and using language, spoken or written, but where the disorder is not primarily the result of visual, hearing, or motor handicaps, mild retardation, emotional disturbance or cultural or economic disadvantage" (Silver & Hagin, 1991). In these situations, the term dyslexia is reserved for extreme difficulty learning to read which is not traceable to brain injury, proportionally low IQ, or lack of age appropriate educational opportunity. In this legal sense, all learning disabilities are identified on the basis of a discrepancy between academic achievement and academic expectancy even though this definition poses significant problems in measurement of such a discrepancy (Silver & Hagin, 1991). Other literature, including most of the pediatric medical literature, simply describes dyslexia as extreme difficulty learning to read.

Similarly, dyscalculia is a term which is used for extreme difficulty learning mathematics – particularly deficits in the production of accurate, efficient arithmetic calculations. However, it is also sometimes used for conceptual deficits. Again, some definitions distinguish developmental dyscalculia as not traceable to brain injury, proportionally low IQ, or lack of age appropriate educational opportunity. In the medical literature the term dyscalculia is used in relation to a disturbance in arithmetic performance which is linked to "soft neurological signs" even in the absence of overt brain injury and

---

[1] Appendix A contains a glossary of technical terms.

can involve cases where computational ability is disrupted but conceptual understanding remains intact (Hittmair-Delazer, 1995).

For the purposes of this study, dyslexia will be used to mean unusual difficulty learning to read and dyscalculia will mean unusual difficulty learning mathematics. This is the simplest way these words are used in the literature and provides a basic vocabulary descriptive of the case being studied. The issues concerning the influence of low IQ and/or "soft neurological signs" will be addressed, but will be addressed separately since there are differences both within and among different disciplines in how these are viewed in relationship to the basic difficulties in learning reading and mathematics.

It is important to keep in mind, however, that the terms dyslexia and dyscalculia are used more exclusively in other research arenas and that this study is using their simplest and most inclusive meanings: unusual difficulty in learning to read and unusual difficulty in learning mathematics. Since this study is not directed at adding to the technical knowledge about the conditions represented by these terms, but is rather seeking to match what is already known about these conditions to a particular case, it makes sense to use the inclusive rather than the alternative exclusive interpretations of the terms.

SIGNIFICANCE OF THIS STUDY

It is expected that the study will contribute to the knowledge base of the field by five interconnected processes: (1) providing thick description of an exceptional case in mathematics education, (2) collecting and organizing applicable strategies from the fields of learning theory, mathematics education, special education, educational psychology, and medicine, (3) carefully recording of how these strategies were implemented and developed in this case, (4) through informed reflection about this record, providing further

insight and understanding of one student's difficulties in learning and (5) contributing to the ongoing grounding of learning theory and school educational practices, this time grounding to the exceptional case.

This case study also models the action research cycle of theory informing practice while practice informs theory. While action research has only recently been espoused as a legitimate methodology for educational research in the United States, it enjoys more acceptance in Great Britain. So another unique aspect of this study is that it is a formal implementation of a research methodology which, up until now, has not often been used by the American research community.

LIMITATIONS OF THIS STUDY

The problem in this study originally emerged as a problem in the actual practice of teaching mathematics. It deals with the individual, exceptional case rather than the aggregate trend. As such, its significance is heavily loaded on the practitioner side of the knowledge base. The basic question for practitioners is, "what works for this particular student?" rather than the experimental question which asks, "what is replicable, generalizable, and works in the average case?"

Therefore this study is limited to the knowledge which can be gained from an individual case study: thick description of the case under study, insight and understanding about the case as mediated through the researcher, collection and organization of existing theory and research which may be applicable to the case, and reciprocal reflection of experience onto the existing theory base. It is a naturalistic rather than experimental study and not intended to provide experimental evidence or insure generalizability.

No practice should ever be based solely on the evidence provided by a single study, whether that study is experimental or not. A single study is merely a stepping stone from one link in the chain of evidence to another, regardless of whether that study is qualitative or quantitative. This study is only intended to be such a stepping stone.

CHAPTER II: RELATED LITERATURE

MATHEMATICS LEARNING DISABILITIES

In Current Journals

For the search of the literature in this study, I used both standard and electronic database searching procedures. Much of the background material came from standard texts on learning and neurological disabilities in children such as Bley & Thornton (1989), Silver & Hagan (1990) and Sutaria (1985). The periodical literature sources were derived by electronic searches of three large databases: ERIC, PsychInfo, and Medline. These cover education, social science, and medicine, respectively. The search strategy included pertinent articles which were in English and had publication years of 1990 or later. Details of how those searches were done appear in Appendix B on page 146.

Very few studies of mathematical learning disabilities exist. All but four of those identified in the current professional literature were reports from the medical field. The medical reports will be discussed in a later section. The four articles specifically related to education were all from ***Focus on Learning Problems in Mathematics***. Two were theoretical discourses (Chard & Kameenui, 1995; Montague, 1995) and two others were only descriptions of disabilities (Babbitt & VanVactor, 1993; deBettencourt, Putname, & Leinhardt, 1993). None of these contributed substantially to my understanding of the case in this study.

In Medical Studies

Historically, Gerstmann was one of the first to write about what was later to become known as mathematics learning disabilities. As a neurologist, he was studying

hospitalized patients and became interested in how some of them displayed a disruption of the ability to perform arithmetic while possessing normal abilities in some other intellectual areas. In 1955 he defined dyscalculia as an isolated disability to perform simple or complex arithmetical operations and an impairment of orientation in the sequence of numbers and their fractions (Sutaria, 1985). In his studies, he found that this condition was often accompanied by "soft neurological signs."

Soft neurological signs are conceptualized as minimal neurological deficits, particularly the inability of a child to perform adequately on tasks requiring coordination and synergy. Other soft signs include physiological immaturity in functions such as posture, equilibrium, the development of laterality, praxis, finger-gnosis, and left-right orientation. Immaturity in visual-motor function and auditory sequencing may also be involved. These soft signs are generally considered to be an indication of central nervous system immaturity and are developmentally normal at one age but abnormal if found at a later age (Silver and Hagin, 1990). The longer the soft signs persist past their normal developmental period, the more likely they are due to neurological disorder rather than developmental delay.

Gerstmann attributed dyscalculia to left-right disorganization and hypothesized that the focal point of the "disease" existed in the parietal-occipital region of the dominant hemisphere (Sutaria, 1985). Finger agnosia in particular has been linked to mathematics disabilities and it is hypothesized that the link is due to the importance of finger dexterity and identification by touch to early counting strategies (Fleischner and Marzola, 1987).

Another neurologist and theoretician, Alexander Luria, described what he called parietal dyscalculia which adversely affected the ability to memorize numbers, align rows

of numbers, arrange numbers numerically in order of magnitude, to count backwards, to count by odd or even numbers and to manipulate operations symbols (Luria as cited in Sutaria, 1985).

Luria's whole approach to understanding higher cognitive functions has significant implications for the study and treatment of learning disabilities and especially for development of "logical thought." Luria wrote "a lack of oral communication with others cannot avoid producing a natural retardation in intellectual development, and whilst, with respect to their capabilities, such children remain normal, they begin to lag in development of verbal thought and do not succeed in school" (Vocate, 1987, p. 79).

Others have also highlighted the connection between difficulties in language and difficulties in mathematics. Fleischner and Garne (1987) state that verbal ability is important to mathematical achievement. They argue that verbal ability is necessary in retention as well as organization of mathematical learning. They further claim that language and verbal ability exert a significant influence on the overall arithmetic achievement of both learning-disabled and non-disabled children and they suggest that this may be due to the same language deficiencies which impede reading. They note that the influence of particular language deficits on arithmetic performance is an area which needs to be systematically studied.

Fleischner and Garne also describe several theories which propose that mathematics itself is a specialized language, although considerably different from *ordinary* language, thereby posing a veritable second-language learning dilemma for children (Nesher, 1982, p. 192).

Several researchers have attempted to determine the extent to which mathematics learning disabilities are a heritable trait. Gillis, et al., (1992) report on a twin study which compared disabled and non-disabled twins and their relative reading and mathematics performance. They found that genetic influence accounted for 98% of the observed correlation between reading and math performance within the reading-disabled twin pairs and for 55% of the observed correlation in the control sample (the non-disabled twin sets). They conclude that, while shared environmental influences common to both members of a twin pair also contributed significantly to the variance in math scores in of both groups (c^2 = 0.44 and 0.37), individual differences in both reading and mathematics performance are highly heritable and appear to be caused by many of the same genetic influences. A more recent study by Gillis-Light & DeFries (1995) replicated these results in a twin study which compared identical with fraternal twin pairs in which only one of the twins was disabled.

Other researchers have attempted to determine the relative frequency of learning problems in reading and mathematics. In a study of 1206 British school children, Lewis, et al. (1994) found that 1.3% of the children were diagnosed with specific arithmetic difficulties while 3.9% were diagnosed with specific reading difficulties, and another 2.3% were diagnosed with both specific reading and arithmetic difficulties. This indicates that 48% of those identified as having either specific reading or specific arithmetic difficulties, actually had both. This concurs with the report of Dockrell and McShane (1992) who found that 72% of the children in their sample qualified with specific learning disabilities in more than one academic area. However, in their study, only 13% were diagnosed with both specific reading and math disabilities. This may be a result of their inclusion of

categories such as spelling and social studies which contained neither math nor reading disabilities in their total count.

More recently, Blakeslee (1994,1995) has reported on research by Tallal which suggests that some types of dyslexia may actually be a consequence of unusually slow phonological processing by the brain. Phonological processing refers to the brain's processing of speech sounds. In such cases, phonemes with relatively rapid transition time (40 milliseconds) like ba, da, ga, pa, ta, and ka may easily be confused or missed entirely. Children suffering from such slow processing are hypothesized to either compensate by pulling meaning from context or to struggle through life "living in a language fog." That language fog would necessarily include what goes on verbally in a mathematics classroom – discussion and instruction alike.

Tallal and Merzenich are currently field testing a possible treatment for this condition in which they use computer generated, "processed" speech. The fast-transition phonemes are stretched out artificially and difficult to hear phonemes are emphasized by making them louder and longer, in the hope of making them more salient to the child's brain. The program, in a game format, slowly increases the speed of the speech sounds until the speed of normal speech is reached. The hope is that the children's brains will develop alternative pathways for processing the sounds. The treatment is affectionately referred to as "Glasses for the Ears," which is an apt metaphor describing the type of disability which is suspected (Blakeslee, 1995). In the same article Dr. Merzenich cautioned that dyslexia has numerous causes and that not everyone with reading problems would be expected to respond to this treatment.

Other research studies by Brachacki (1994) and Ackerman (1994) have linked dyslexia with phonological processing deficits, as well. Siegel (1995) has connected dyslexia to deficits in phonological processing while finding evidence of superior ability to process orthographic configurations in the same dyslexics. Orthographic configurations refer to a word's shape (spelling, font, graphic style or distortion) rather than its sound, which is phonological configuration. For instance, an orthographic misspelling of Piaget might be 'Piglet' (keeping the visual configuration intact) while a phonological misspelling of Piaget might be 'PJ' (keeping the phonological configuration intact). Both change an unfamiliar name into some more familiar, but one retains the essential shape, while the other retains the essential sound.

Compared to normal readers at the same reading level, dyslexics show better all around visual memory , better ability for matching of letter-like forms, spelling errors that show a greater accuracy of orthographic aspects, recognition of words or letters are not as affected by orthographic distortions, and faster selection of the correct spelling when presented with a word and a pseudohomophone that has the identical pronunciation but incorrect spelling (e.g., rain-rane). This may indicate a useful method of compensation, particularly the use of visual memory strategies.

DIAGNOSIS OF MATHEMATICS LEARNING DISABILITIES

Mathematics learning disabilities are diagnosed in a variety of ways and for a variety of purposes. Children with mathematics learning disabilities are much less often referred for diagnosis than reading disabilities, even though it appears that they occur at least as frequently. Many times they co-exist with reading disabilities and may in some

cases stem from the same underlying causes (Cawley. 1985; Dockrell & McShane, 1993; Sutaria, 1985).

Diagnosis is usually done by one or more of three methods: (1) neurological examination, (2) assessment of ability vs. achievement discrepancy or (3) error pattern analysis.

Neurological Methods

Neurologists continue to find the same brain structures implicated in both dyslexia and dyscalculia research. In particular, the corpus callosum and the area responsible for phonological processing have been repeatedly implicated.

Hynd (1995) and his colleagues studied the morphology of the corpus callosum, which is believed to be the link which transmits information between the two sides of the brain. In this study, MRI scans were obtained from children with developmental dyslexia and from matched control children and measurements were examined to determine if there were any regional differences between the groups. They found subtle neurodevelopmental variation between the groups in the morphology of the corpus callosum.

In contrast, Larsen, et al., (1992) found that MRI showed no gross morphological abnormalities of the corpus callosum or spenium in the 19 dyslexics they studied compared to 17 children of normal reading ability. All 36 children were 14.5 years old, to control for developmental differences. It is indicative of MRI brain research at this point in time to report conflicting evidence like this since the MRI field is so new that there is not a yet a solid base of data about what might actually be "normal" vs. "abnormal" in the images.

In a separate study Larsen reports significant differences in the size and symmetry of the plana temporale between a group of 19 identified dyslexics and a group of 18

matched controls. All of these subjects were 15 years old at the time. Larsen makes the point that this area is associated with phonological processing and may indicate a neuroanatomical basis for a characteristic symptom of linguistic processing deficiency in developmental dyslexia.

One fascinating neurological finding came from the study of vertigo in the field of otolaryngology (the medical specialty dealing with the ears and throat). Risey and Biner (1990) reported a distinct and incredibly strong relationship between vertigo of central origin and a particular error process familiar in the study of dyscalculia.

These researchers became intrigued by their observations of several patients undergoing routine electronystagmographic (ENG) evaluation of vertigo who demonstrated identical type counting errors. This counting error consisted of skipping decades when asked to count backwards from 100 by 2's (i.e., . . . 94, 92, 80, 88, 86, 84, 82, 70, 78 . . .) Counting backwards by a specified amount is a common neurologic assessment usually used to test attention and concentration. While this particular counting error had been previously reported by Deloche and Seron (cited in Risey, 1990) as part of a linguistic component of acalculia, it had not previously been associated with vertigo. Note that this is also one of the errors identified by Luria in his 1966 description of parietal dyscalculia (Sutaria, 1985).

Risey and Briner studied this phenomena using three groups. The first group consisted of 14 patients who presented to the otolaryngology clinic with both a primary complaint of vertigo and who also demonstrated the counting error. The second group consisted of 7 patients complaining of vertigo but who did not produce the counting error. The third group consisted of patients who neither complained of vertigo nor

produced the counting error. These patients, while free from both vertigo and the counting disorder, suffered from tintinnitus, a common otologic complaint involving the same general vestibular area of the ear/brain.

There were no significant age or educational differences between the groups. All three groups were given a battery of cognitive assessments and finally administered the ENG to determine how these assessments might correlate with the classification of type of vertigo. The three classifications of vertigo were (1) none, (2) centrally located, and (3) not centrally located. The distinction between centrally and non-centrally located vertigo can be assessed with relative certainty by the ENG.

None of the subjects found to have non-central vertigo exhibited the counting error while all subjects with the counting error were found to have the central type of vertigo with demonstrable vestibular abnormalities as determined by the ENG results.

Risey and Briner take pains to point out that the patients were not preselected for the type of vertigo. Rather they were simply classified according to the presence or absence of the counting error, and the presence or absence of vertigo in general. The type of vertigo was not determined until the ENG was performed as the last step of the assessment.

The group with central vertigo also performed significantly less well than the other two groups on all but one of the other cognitive tests. Digit span forward was the exception in which all three groups performed equally well. The group with the counting error believed they had performed the counting-by-2's-backwards task correctly. Even when their responses were shown to them in written form, they were unable to detect the decade skipping error. The authors conclude that the error described is associated with

central vestibular vertigo. They believe that the error is not due to a dysfunction of the vestibular system alone, but is associated with a disorder common to both the vestibular and higher cognitive systems, and may be detectable using audiometrics (testing the auditory system). This is one of the few neurologic studies which has been able to tie specific mathematical dysfunction to a specific area of the brain in such a tightly consistent fashion. It once again implicated the phonological processing areas of the brain.

Ability vs. Achievement Discrepancies

Special education assessments in U.S. public schools usually involve a comparison of Achievement Test scores with Intelligence Test scores. In mathematics, this would mean demonstrating a significant discrepancy between a child's actual achievement on a mathematics achievement test and the comparable achievement expected of an average person that child's same age and having that child's same IQ. While on the surface this sounds like a direct and easily assessable criteria, it is in fact full of contradictions and inequities.

Some researchers question whether the existing IQ tests can reasonably be used to assess the abilities of learning disabled individuals because the characteristic LD weaknesses are what are measured by some of the subtests, necessarily pulling down the overall score. In the chapter "Clinical Assessment of Children's Intelligence with the Wechsler Scales," Reynolds and Kaufman (1985) specifically question whether the WISC can give an adequate estimate of the abilities of students who have learning disabilities .

Other questions involving the use of ability-achievement comparisons based on IQ include:

- Is IQ fixed or malleable – can it be "improved"?
- Is IQ a single, global trait, or is it composed of many independent traits – multiple intelligences?
- Are the instruments used to determine IQ culturally biased? Gender biased?
- Is there a difference between "school" smart and "street" smart?
- Does IQ actually predict success in life beyond the classroom?
- Do test-construction methodologies requiring validity checks with reference to already existing tests prevent the creation of better tests which attempt to tap additional components of IQ?
- Does what is perceived as "intelligent" differ from culture to culture?
- Is IQ hereditary or environmentally determined?
- How do personality traits moderate the effect of IQ?
- Can tailoring instructional methods to a student's strengths and weaknesses improve the student's achievement, regardless of IQ score?
- Is there a hidden agenda in using IQ measures which seeks to maintain social, economic, and ethnic stratifications?
- Is IQ an adequate measure of a person's value to society?

Each of these issues has implications for how learning disabilities are perceived, defined, and treated.

Error Pattern Analysis

Knowing a student's ability or performance level as compared to other students does not always supply the type of information needed to adapt instruction to the student's needs nor does it suggest strategies for how the student may improve his or her performance. What is needed is an awareness and understanding of how the student is thinking and how that is being translated into performance.

Error pattern analysis provides a front line strategy for accomplishing this type of diagnosis of children's mathematics learning difficulties and for developing suitable instructional interventions. Common manifestations of learning disabilities in the classroom include difficulty in one or more of the following:

- Figure-Ground Perception
- Discrimination
- Spatial/Temporal Perception
- Motor Coordination
- Memory
- Tactile-Kinesthetic (Haptic) Perception
- Sequencing
- Integrative Closure
- Expressive Language
- Receptive Language
- Abstract Reasoning.

Any of these difficulties in learning may adversely affect the student's performance in mathematics (Bley & Thornton, 1989). The following section contains a brief description of each one of these categories of disabilities.

Figure-Ground Errors (Bley & Thornton, 1989; Sutaria, 1985)

A figure-ground disturbance refers to an inability to pick out form from its surrounding background. It involves the skill of focusing on selected objects and screening out or ignoring the irrelevant ones.

Students with the visual figure-ground deficit may exhibit this difficulty in mathematics class by:

- not finishing all their work
  -- leaving out sections
  -- starting, but not finishing a problem which looks like others on the page
- frequently losing his or her place on the page or within a problem
- including extraneous numbers in computation (for instance including the problem number as part of the actual problem or using a number from above or below the part of the problem being worked)
- make "careless" mistakes when copying problems from the book
- mix up parts of problems and often copy wrong symbols
- difficulty with multi-operation procedures such as long division, where several operations are embedded in the same algorithm – for instance inability to focus on the subtraction problem within a long division problem
- difficulty reading multidigit numbers

Students with the auditory type of figure-ground deficit may experience difficulty attending in the classroom or have trouble hearing patterns when counting out loud as when learning to skip-count. They may also appear to be daydreaming or disruptive in class because they miss auditory cues about what is going on and what is expected of them.

Discrimination (Bley & Thornton, 1989; Cumming & Elkins, 1994; Sutaria, 1985)

Visual discrimination errors may cause students to misread numbers. Developmentally, the visual discrimination necessary to write numbers without reversals is not fully in tact until about age seven. Up until that time it is not surprising that a child might reverse the orientation of number symbols, particularly 2, 3, or 5. Children with discrimination difficulties may exhibit this tendency more frequently and/or beyond the normal developmental stage. Copying numbers or writing them from dictation can be especially difficult for these children because they often lose their place or get so far behind that they do not "catch" all of what was written or said.

Telling time or recognizing coins can also be difficult for children who are unable to discriminate size difference. This may cause them to work more slowly on such tasks than their classmates, for instance, because they must consciously locate the smaller hand on the clock while their peers are able to locate it automatically. Mercer (as cited in Sutaria, 1985) also associates visual perceptual deficits with reversals or inversions in number recognition and confusion among operation symbols.

Auditory discrimination errors often result in counting errors in which children mishear their own verbalizations (external or internal) of the counting patterns. Bley and Thornton (1989) give the example ". . . 9, 10, 11, 12. 30, 40, 50, 60, 70, 80, 90, 20."

Notice that what appears to be a bizarre switch from counting by ones to counting by tens is actually a substitution of sound-alike items and that the actual counting series, when assessed in that way, is intact. (30 was substituted for 13; 40 was substituted for 14 . . .)

Spatial and Temporal Disabilities (Bley & Thornton, 1989; Sutaria, 1985)

Spatial and temporal organization greatly affect a child's mathematics performance and ability to apply what he or she knows outside of the classroom. Spatial disabilities are characterized by difficulty locating position in space – distinguishing right from left, up from down. This makes number alignment in arithmetic computations extremely difficult. What appears to be careless, sloppy or even defiantly written work may actually be a result of difficulty in spatial organization. Difficulties may also be present in writing decimals, fractions, and word problems. In decimals, the placement of the decimal point and especially "moving the decimal point" may be confusing simply because relative positions. For example, left-right or forward-backward are difficult for the student due to perceptual difficulties rather than difficulty understanding the meaning or concepts involved. Likewise placing digits in the correct positions in fractions or mixed numbers can present a problem for students with this kind of impairment. A word problem involving order or sequence which appears to be based on everyday common sense (for instance "if you take five steps forward and then 8 steps backwards, where do you end up?") is actually quite problematic for students with these types of disabilities.

Likewise lack of intuitive time sense may cause students to work unusually slowly, appear to be daydreaming, and interfere with their ability to plan and execute projects or practice schedules. Temporal deficits may also adversely affect development of before-after concepts and the use of the number lines and signed numbers (Sutaria, 1985).

Motor Deficits (Bley & Thornton, 1989; Kennedy & Tipps, 1991)

Slow, laborious writing may indicate motor deficits which greatly affect a student's ability to perform in school. Sometimes this includes a perceptual component which makes it difficult for the child to relate what they see to what they write. As arithmetic computations become longer and more involved, these children find it extremely difficult to complete written assignments. What appear to be careless errors may also occur frequently during this overly-concentrated effort to write carefully. The student may be expending so much time and energy retrieving from memory the necessary finger movements for number formation that the student forgets where he/she is in the problem or what original operation was.

Tactile-Kinesthetic (Haptic) Perception (Sutaria, 1985)

Tactile perception refers to the sense of touch Kinesthetic perception deals with the sense of body movements and muscle sensations. Together they are considered the haptic sense. They provide information about object qualities, bodily movements, and their interrelationships. They form the basis of perceptual-motor movement. Chalfant and Scheffeling (Sutaria, 1985) found that haptic processing difficulties corresponded to difficulties relating to a sense of geometry, texture, pressure, pain, temperature and whether the body is in motion or not.

Memory Deficits (Bley & Thornton, 1989; Brody, 1985; Gregg, 1995; Sutaria, 1985)

Memory difficulties are often confused with comprehension difficulties. It is possible for a child to understand and even accurately apply concepts and information on one day and on the next day appear never to have learned the material at all. This can be a factor when students do well in class and on homework, but do not do well on the test.

Memory deficits also hinder the learning and recall of math facts, performance of mental calculations, and remembering the steps involved in multi-level or multi-process problems. These deficits alone are sufficient to prevent a child from experiencing success in the traditional arithmetic class (Sutaria, 1985).

Children with this type of problem are often accused of not listening, of copying a friend's work, of being careless, or not actually having "constructed" the concepts in the first place. In fact, it is strongly believed in some arenas that failure to construct and make meaningful connections is the cause of "not remembering" at a later time (Gregg, 1995). While this may be the case in some instances, in others a child may be able to demonstrate he or she has adequately "constructed" a meaningful understanding but then at a later date, no longer be able to do so without considerable time spent in "reconstruction." This type of student may require training to acquire ways of remembering what he or she has come to understand. For many students this takes the form of overlearning in order to retrieve a concept or skill.

Sequencing (Bley & Thornton, 1989)

Sequencing-memory deficits are particularly detrimental to learning mathematics. Many sequences that the rest of us take for granted as obvious, or are not even consciously aware of (like the steps involved in reading time on an analog clock) may present a hefty challenge for persons with sequencing-memory deficits. A child with long term memory and sequencing-memory deficits may leave problems unfinished, not because of carelessness or inattention, but because those tasks place excessive demands on the child's retention and sequencing abilities.

Integrative Deficits (Bley & Thornton, 1989; Piaget, 1985)

Integrative deficits show up as an inability to pull information together, draw conclusions, make associations, or build on previously learned information. Some deficits which fall into the integrative category include difficulties in closure, expressive language, receptive language, and abstract reasoning. Again, this is an ability which is closely related to what is often called "intelligence." It is particularly correlated with Piaget's conception of intelligence. In his book, ***Psychology of Intelligence*** (1973), Piaget equates intelligence with the process of "equilibration" which he describes as the ability to assimilate or accommodate new experiences and information together with the ability to choose appropriately which of these methods to use.

Closure (Bley & Thornton, 1989)

In mathematics learning, closure difficulties show up as an inability to group digits logically when reading numbers or an inability to state which number comes next, given only a single number to start from (as opposed to giving the student a sequence of numbers and asking for the next number in the sequence). It may also present as an inability to characterize numbers by their properties, for instance, to group together even numbers, prime numbers, or multiples of a particular number. This relates to the inability to find similarities, which is a more difficult process for all learning disabled students, regardless of the specific disability.

Expressive Language Problems (Bley & Thornton. 1989; Vocate, 1987)

Children with expressive language deficits are not able to verbalize clearly, if at all, what they actually understand. They may not be able to express in words what they are thinking. They often require visual cues in order to retrieve the necessary words. This

includes needing cues to retrieve the sequence of necessary steps. Often these students can distinguish between right and wrong processes while not being able to verbally explain how they know.

Receptive Language Difficulties (Bley and Thornton, 1989; Sutaria, 1985; Vocate, 1987)

Children with receptive language deficits have difficulty associating meaning with words. The children are often heard to ask, "What do you mean?" or simply, "What?" in response to verbal explanations or directions. They frequently have difficulty following directions. In mathematics they have particular difficulty with terms which have content specific or multiple meanings such as "sum," "times," "difference," "carry," or "factor." They almost always have difficulty solving word problems.

These children can appear to be very literal. They may not understand simple jokes and may find it difficult to make sense of much of what they hear or read. They often appear to function in the "here and now" and may have trouble generalizing information beyond the immediate situation. They may also experience difficulty verbalizing what has been learned or observed, associating what is happening with symbolic representations, and/or understanding auditorially or receptively what is being explained or demonstrated.

Abstract Reasoning (Sutaria, 1985)

The development and use of mathematical concepts is often equated with the ability to reason abstractly. Conversely, mathematical disabilities, more than any other disability type, are associated with an inability to reason abstractly. Often abstract reasoning deficits are related to the inability to make associations. In turn, making

associations may be more difficult when language is not being understood or readily available to make associations with. Students with these types of difficulties may exhibit erratic, far-fetched reasoning or have difficulty understanding cause-effect relationships.

Behavioral Disorders (Sutaria, 1985)

Learning disabled students often show certain behavior patterns which are detrimental to their performance in mathematics. Mercer (as cited in Sutaria, 1985) names three in particular: impulsiveness, perseveration, and short attention span. Impulsive behavior tends to be associated with careless mistakes, rushing through written work, and frequent wild guesses at answers just to get the work finished. Perseveration refers to a tendency to have difficulty switching from one type of operation to another. A short attention span results in an inability to stay on task and complete assignments.

Summary and Implications for Further Research

Review of this literature indicates two areas of concern:

(1) gaps in understanding how students' learning disabilities may affect the students' experiences in the mathematics classroom and

(2) gaps in knowledge of what methods or strategies may be used to help such students adapt and compensate for those disabilities within the context of doing mathematics.

Several of the sources commented on how mathematics disabilities do not receive the attention that reading and language disabilities do (Silver & Hagin, 1990; Spafford, 1990; Sutaria, 1985). Bley and Thorton (1989) note that in the upper grades mathematics disabilities are frequently dismissed entirely as a simple lack of ability.

Hutchinson (1993) questions how the NCTM professional standards can truly promote mathematics for all students when the learning disabled do not appear in the

NCTM's list of groups who have previously been denied access to educational opportunities nor do any of the vignettes modeling the professional standards include working with learning disabled students. She expresses concern that the NCTM vision has overlooked the learning disabled student.

While much of the research in this review of the literature describes and classifies mathematics learning disabilities, little of it is concerned with determining which strategies work when faced with which deficits. O'Hare, Brown and Aiken (1991) point out the need for assessments which can indicate what specific learning disorders are associated and choosing the most appropriate tool to bypass the child's difficulties.

In conclusion, it seems that an in-depth study of the learning and motivational characteristics of a student exhibiting multiple learning difficulties would serve to begin to fill some of these gaps. With an emphasis on planning and assessing educational interventions rather than simply classifying errors, it is hoped this study will assist the student involved while providing data contributing to the ongoing exploration of the complex interrelationships among physical, emotional, social, and intellectual conditions and the student's learning.

CHAPTER III -- METHODOLOGY

INTRODUCTION

This study is a qualitative case study employing ethnographic, multiple perspective, action research and grounded theory methodologies. Since the case exists within overlapping family, school, and medical contexts, those contexts must also be examined. For example, Kay's learning problems cannot be investigated fully without considering both the nature and the impact of the medical and learning problems of the other members of her family.

This approach stems from a desire to know what might work for this student, rather than, what, "on the average" works for most students. As with so many other low-achieving students, we already know that what "works" for most students is not "working" for this one particular student. Therefore. I propose to study this one student and her entire life-situation as it relates to her learning difficulties in hopes of finding strategies which work for her. By extension, it is hoped that this study will also suggest modifications to learning theory which would help regular classroom teachers better accommodate students such as this one.

FOCUS OF THE STUDY

The focus of this study consists of one student with learning difficulties and her entire educational and family environment. It is a wholistic study rather than an experimental study based on a random sample. Rather than investigating how 300 students fair educationally under one teaching regimen as compared to another, I am looking at one student, in depth, in context, and from multiple theoretical perspectives in

order to better understand why this particular student is having difficulties and how those difficulties might best be alleviated.

This student has several special characteristics in addition to having learning problems in school. These include: (1) she has strong support at home and her parents are willing to have her involved in an extended project of this kind, (2) she has not yet given up, as so many students in her position do, but is still striving to succeed in school, (3) the school she attends is willing to cooperate with this project, (4) the student has siblings whose own difficulties in school may help identify patterns and possible connections, and (5) the parents, who also had difficulty in school, are now successful, productive members of society.

ETHNOGRAPHIC VARIABLES

A qualitative (inductive) study does not have variables in the same sense that a quantitative (deductive) study does. In a quantitative sense, a variable is anything which can take on different values. So variables in a quantitative study define the parameters of the experiment – what is to be controlled, what is to be manipulated, and what is to be measured.

Alternatively, variables in the qualitative sense represent the "unknowns" – what the researcher is trying to identify and describe. For instance, variables which might be explored in terms of physical influences on Kay's learning include genetics, health, physical environment and physical development. The purpose would not be to control, manipulate or quantify these variables, but rather to identify and describe them as they relate to the guiding questions of this study. Appendix C contains a more complete list

of anticipated ethnographic variables. Appendix D contains a list of anticipated variables organized around the research questions.

ACTION RESEARCH VARIABLES

Action research is done by the practitioner while in the field. It has a great deal in common with ethnographic research in that it is done in a natural rather than controlled setting, and uses a purposive rather than random sample. As such, action research practices descriptive rather than experimental design. However, since the practitioner is interested in moving the learning situation in specific directions, it makes sense to talk about dependent and independent variables, even though they are descriptive rather than experimental variables.

With this understanding, the dependent variable of this study may be considered to be learning. As stated before in the definition of terms section, evidence of learning in this study will be considered to include (1) school-defined achievement (2) sense-making and (3) coping strategies. School-defined achievement will be assessed by (a) grades on individual assignments and report cards, (b) teacher perception, and (c) standardized testing. Sense making will be assessed through the tutoring interviews and inferences from the student's written work. Coping strategies will be assessed through (a) professional educational evaluation, (b) observations of the student in the classroom, during tutoring sessions, and in other real-life but non-academic settings, (c) interviews with student, parent, and teacher, and (d) other psychological measures where available and appropriate.

Similarly, a large part of this project involves making inferences about what conditions might possibly affect the learning (as defined above) of this student. These

"independent variables" cannot be predetermined but will have to emerge from the study itself. When an apparent learning problem is pinpointed, the question will be asked, what do various learning theories have to say about a problem like this? What conditions might be expected to ameliorate this problem? In this way, the situation as viewed from multiple learning theory perspectives will be used to generate alternative conditions which might be expected to enhance the student's learning. Those conditions or experiences will then be introduced into the tutoring sessions and the results carefully recorded.

DATA COLLECTION PROCEDURES

Data for this study will include, but not be limited to:

a. educational history of student and immediate family
b. medical and family history
c. educational assessment testing
d. observation of student at home and school, in academic and recreational activities
e. written school work and school achievement assessments
f. interview with student's teacher
g. written and oral work done in tutoring sessions
h. observations of student when presented with new experiences and or strategies
i. research literature on learning disabilities, learning theory, and metacognition
j. reflections of researcher on any of the above, comments from the student, the family, the school teacher, the researcher's committee members and other consultants.

The preliminary study included ten hours of intensive tutoring during the month of July and once a week tutoring sessions during the 1996 fall semester. Home observations, one psychometric evaluation, and conversations with the mother were also done during this preliminary time period. The data collection intensified during the Spring 1997 semester to include tutoring twice a week throughout most of the semester

and school observations arranged at the convenience of the school. Data from the preliminary study will be included as part of the continuous record of data.

ACTION RESEARCH PROTOCOL

During the preliminary study, a protocol emerged which provides a systematic way to record this process of generating and implementing the action research interventions. The components of this protocol include the following steps:

1. Identify the problem
2. Probe the nature of the problem
3. Review options from applicable theories and literature
    a. special education
    b. neurological
    c. cognitive
    d. constructivist
4. Analyze the applicability of these options in terms of data
5. Specify requirements for intervention based on analysis of options
6. Generate such an intervention strategy
7. Describe the strategy
8. Describe the outcomes
9. Record tentative thoughts and conclusions

The following is an example of how this protocol was used to plan, organize, and record an intervention strategy used in the preliminary study.

SAMPLE INTERVENTION PROTOCOL RECORD

1. Identified Problem: Kay habitually confuses the rules for addition, subtraction, multiplication, and division of fractions. While she is usually able to do each constituent step accurately, she confuses the procedures in mixed practice. She adds when the problem is subtraction, or multiplies when the problem is addition or division. Sometimes, apparently at random, she uses the correct procedure and successfully completes the problem.

2. Preliminary Probing of Problem: If asked before working a problem, what operation is required, Kay consistently responds correctly. When going through a page of mixed practice and only asked to name the operation. she is 100% accurate in naming the operations. Once she has begun work on a problem, however, she is often unable to state correctly the operation asked for in the problem, even when interrupted and specifically asked. This confusion seems to increase, the more problems she is asked to work.

3. Applicable theories:

- Special Education: According to Bley and Thornton (1989) this is a common problem for students with mathematics learning disabilities. Their suggested solutions include writing the signs larger and direct instruction on both vertical and horizontal presentations of each operation to develop conceptual flexibility.
- Neurological explanations include the idea that this is a specific developmental reading disability which is identified by varied patterns of information processing deficit and, as such, is not a memory problem but a problem in perception of the world and decoding that information (Silver & Hagan, 1990). Their suggestion is that remediation must begin at this lower level of perception and decoding rather than at higher levels of memory (p.217).
- Cognitive processing theory suggests a problem with memory load may be involved and that by reducing the active memory load necessary at each step of the problem, more accurate processing may result.

- Constructivist theory would suggest that she really doesn't understand the operations or she wouldn't be making those kinds of mistakes. Further work on constructing the idea of fractions in the context of addition and subtraction is indicated.

5. Analysis of options: Because she can correctly name the operations when that is all she is called upon to do, it appears that this is not initially a problem in perception. Because she can, in some instances, follow the procedure through to the correct solution, it does not appear to be a matter of random response as in a situation where no "construction" of the necessary concepts has been made. Because there is no consistent pattern to when she applies which operation, it does not appear to be a matter of having constructed a faulty rule. (She may very well not have an extensive construction of "fraction," but this is not what is preventing her performance of the procedure taught in her classroom.) Therefore, the hypothesis of a memory load problem seems to best fit the evidence, in that, during working the problem more must be kept in the working memory than when simply naming the operation, and it is when this additional memory load is introduced that she has difficulty.

6. Requirements for an intervention strategy (based on the analysis above):

Something is needed to reduce the working memory load and keep her focused on the operation required by the problem. If possible, it needs to be something she can generate herself when she needs it, so that she can operate with it in the regular classroom. It also needs to be mathematically consonant with the concept of "fraction" and easy to remember, since memory appears to be the root of the problem.

7. Generation of such an intervention strategy: Organize the operations on fractions in ways that make it plain how each operation is similar and each one is different. Accentuate similarities to reduce memory requirements. Accentuate differences to improve accuracy. Provide an easy to remember structure in which she can generate this organization for herself.

8. Description of strategy: (a) Organize fraction operation procedures as follows. Do examples following the procedures outlined in the box. Discuss similarities and differences in procedures. Note patterns and especially note where the patterns change.

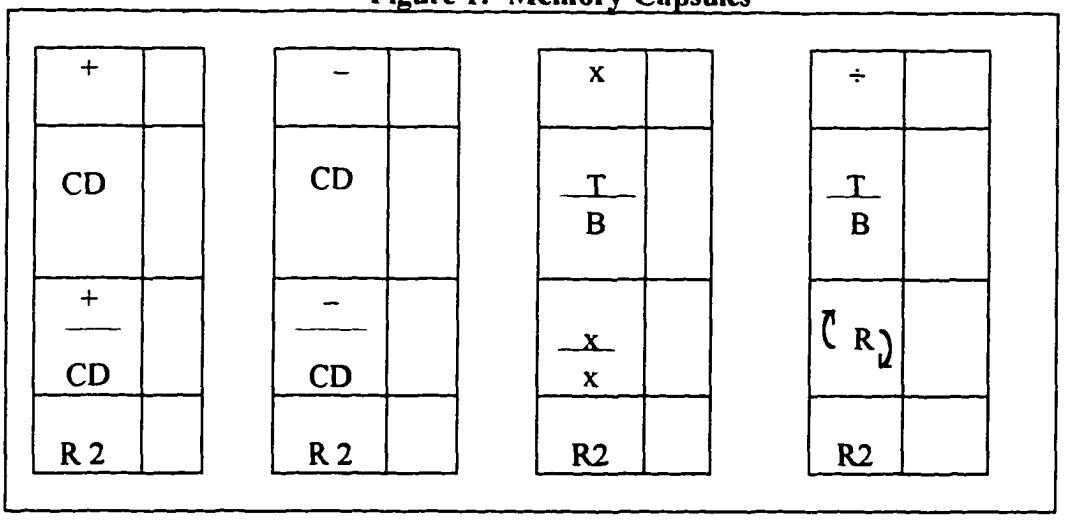
Table 1: Comparison of Fraction Procedures

	What do I need?	Do the operation.	Reduce
+	Common Denominators	+ straight across keep CD	regular or top heavy
-	Common Denominators	- straight across keep CD	regular or top heavy
x	Top and Bottom Fractions	x top and bottom	regular or top heavy
÷	Top and Bottom Fractions	x reciprocal	regular or top heavy

(b) Have student work mixed set of problems with the table in hand.

(c) Reduce table to a simple structure she can reproduce easily when needed. A simple 4x2 matrix can be made for each operation. The second column is to remind her to double check each step after problem is finished and check off the box when she is sure she has done that step correctly.

Figure 1: Memory Capsules



(d) Have her practice with only the empty table which she has to fill in.

(e) Stop drawing the boxes in for her. Bring them back if the problem redevelops.

Description of outcome: Kay seemed interested in the explanation for this activity as "a way to organize yourself so you don't have to remember as much." She chuckled and grinned at me. (Organization is one of her identified strengths whereas memory is an identified weakness.)

When we first filled out the table, she could not tell me accurately what the procedural steps were for any of the operations. After filling out the table, we discussed the patterns: When do you need common denominators? When do you need top and bottom fractions? Once you have common denominators, what do you do with them? What two ways must you always check for reducing a fraction (by a common factor, or changing an improper fraction to a mixed number). Patterns seemed to take root easily. After 15 minutes of working with the table this way, she had no difficulty filling out a blank one with all of the procedures.

Then we abbreviated the table to the simple structure. I was afraid that the abbreviations and symbols might be a difficult transition, but contrary to my expectation, she picked up on the abbreviated forms immediately. The only one she had trouble with was the reciprocal for division of fractions. We talked about different ways to represent it and she decided on two curved arrows: one pointing bottom to top and the other pointing top to bottom. By the end of the session, she was able to fill out the simple structure table for any of the four operations and use it to work a problem. There were occasional errors in arithmetic of incorrectly making the equivalent fractions. Once she initially added in a subtraction problem, but she caught it herself when she went back and checked herself in the second column of boxes. Twice she forgot to reduce until she checked herself in the second column of boxes, but both times she caught it and corrected it. I left her blank forms for her to do 3 problems a day this way during the week. She turned them in to me the following session. They were all correct. Below is a time-interval frequency chart of operation sign errors in fraction problems surrounding the time of this intervention.

Table 2: Results of Memory Load Reduction Intervention

2 wks before	1 wk before	during lesson	practice papers	week after	2nd week after
5/11	8/15	2/15	0/18	1/12	0/14
45%	53%	13%	0%	8%	0%

Tentative thoughts and conclusions: This was a good strategy for Kay. There is evidence that her accuracy with these type problems has improved significantly, even though it may not be concluded from just this episode that the use of the strategy caused

the improvement. However, there is strong evidence that Kay was able to use the strategy to good effect when it was presented.

If, in the future her accuracy once again declines (when she stops writing out the simple structure chart each time) this procedure would be worth trying again. If there is a second improvement immediately after using this strategy, there would be stronger evidence that the strategy is indeed linked to the improvement.

If in the future, her accuracy does not decline, evidence that the strategy is involved in the continued accuracy might still be gained if she can still produce the simple structure when asked, or if in some other way she indicates that she is still using it as an organizational tool, even without writing it down each time. Another possible indicator would be if similar strategies for other computations also show similar improvement. The ultimate goal would be for her to learn to develop, on her own, similar simple structures to help her remember other procedures. She would then not only have improved her computational competence, but she would have learned to create her own metacognitive strategies, making her a more independent learner.

CRITERIA FOR INTERPRETING DATA

Because this is primarily a descriptive, qualitative study, data must necessarily be interpreted through the sense-making of the researcher. My criteria for sense-making include the following:

1. Have all the available, pertinent sources of data been examined?
2. As data was gathered, are alternative hypotheses proposed and examined? Are all findings considered, not just those congruent with the researcher's original propositions?
3. Have the thoughts, opinions, and observations of others with special knowledge (either of the case itself or of the educational issues involved) been solicited, considered, and addressed?

4. Has the researcher's own theoretical orientation and philosophy been made explicit?[2]
5. Has the researcher carefully examined and reported the "subjective I's" (Peshkin, 1988) which emerged in this study? [3]
6. Have those being studied had an opportunity to review the interpretations and make comments on perceived validity? Is this information included in the study?
7. How much of the raw data is presented? How well does it support the researcher's interpretations and conclusions?
8. How do the findings of this study relate to what is already known in this area of inquiry? How well are congruencies and incongruencies explained?
9. How well developed and reasonable is the logic which is used to link the data to the propositions?

According to Stake (1994) the issue of validity in a case study is most often a concern with the validity of the communication. While operating within a constructivist atmosphere encourages tolerance for ambiguity and pluralism, it is expected that the meanings of the case situation will come through with a certain degree of correspondence. Methods for avoiding misinterpretation include (1) redundant data gathering, (2) procedural challenges to explanations, (3) triangulation using multiple sources to clarify meaning, (4) identifying different ways the phenomenon is being seen, and (5) allowing the subject to read and comment on the accuracy of the field notes and interpretations.

Yin (1994) suggests a more formal approach to validity and reliability concerns. Table 3 on the following page shows Yin's development of the concepts of validity and reliability as they may reasonably be applied to the case study methodology.

---

[2] See Appendix E
[3] See Appendix E

Table 3: Case Study Methodology (Yin, 1994)

Traditional Quantitative Requirements	Corresponding Case Study Tactic	Phase of Research in which the Tactic Occurs
Construct Validity – establishing the correct operational measures for concepts being measured	--use of multiple sources of evidence (**triangulation**) --establish a chain of evidence --have key informants review the draft case study report	--data collection --data collection --composition
Internal Validity –for explanatory or causal studies only—(not for descriptive or exploratory studies) establishing a causal relationship whereby certain conditions are shown to generalize to other conditions	--do **pattern matching** --do **explanation building** --do **time series analysis**	--data analysis --data analysis --data analysis
External Validity— establishing the domain in which a study's findings can be generalized	--use **replication logic** in multiple-case studies	--research design
Reliability -- demonstrating that the operations of a study—such as the data collection procedures—can be repeated with the same results	--use **case study protocol** --develop **case study data base**	--data collection --data collection

QUALITATIVE METHODOLOGY vs. MEASUREMENT

In general, quantitative measurement is not a part of a qualitative study. However, in this case, there are parts of the data which do lend themselves nicely to quantification. In particular, the single-subject, pre-post learning experiment, time ordered frequency counts on types of errors or other salient behaviors, and standardized test data may be of value.

On the other hand, care must be taken that the traditional drive for quantitative measurement does not overpower the basic premise of this study, which is that the questions being studied are complex, multi-faceted, and deeply rooted in the individual situation. While quantification can in some instances contribute to the understanding of these issues, it is in no way sufficient to provide the kind of understanding and synthesis being pursued in this study. Therefore it should be considered as only a small, contributory part of the methodology of this study.

Another difference which stems from the qualitative methodology proposed for this study is that the research questions proposed may evolve during the study. Since this study is essentially an exploration of unknowns, it is not possible to completely predict ahead of time either the form or the content of what may be found. The research questions are guiding lights, not fixed railway tracks. While the study will attempt to address all of the research questions included in this proposal, the study is not intended to be strictly confined to those questions. Table 4 indicates at what stage in the research these questions are expected to be answered.

Table 4: Plan for Answering Research Questions in Final Document

Question	Where to be Answered	Research Methodology	Data Sources/ Data Forms	Precautions Used to Protect Validity and Reliability
Background 1. How manifested? How impacted?	Report of Results	Case Study Multiple Perspectives	Ethnographic Diagnostic	**All methods apply to all questions** --triangulation from multiple sources --have informants read and comment --have experts/advisors read and comment --challenge explanations
Theoretical 3. Applicable learning theory perspectives?	Literature Review and Report of Results	Collection and Organization of Applicable Theory and other Literature Action Research	Literature Advisors Consultants	
Action 4. Strategies Used? Responses? Effectiveness?	Report of Results	Action Research Intervention Protocol	Intervention Protocol	--use intervention protocol --keep data log
Analysis 5. Congruent with Existing Theories? Suggest Elaboration or Modification? Grounding to Actual Cases	Discussion	Action Research Grounded Theory	Analysis and Reflection	--make personal research philosophy and subjectivity explicit --build logical connections

CHAPTER IV: DISCUSSION OF RESULTS

INTRODUCTION

The Case Log

The purpose of the case log is to create a record of the case study which, as closely as possible, makes the experiences of the researcher accessible to others who would review the case. This necessitates organizing the raw data in such a way that it can be cited in the final report. The case log in this study is organized in three large ring-binders of written data and two boxes of audio tapes. The first binder contains transcripts of tutoring sessions. The second binder contains Kay's school papers. The third binder contains other written materials such as: a copy of the math scores from Kay's mathematics class, diagnostic reports, my personal journal entries, the school observation notes, interview transcripts, consent forms, and analysis notes. Tapes are labeled and filed by date and type of session. Three types of sessions were taped: tutoring sessions, classroom observations, and individual interviews.

Description of Data Collected

Tutoring sessions were conducted at least once a week for 8 months during the 1996-97 school year excluding school holidays. During the first semester, all sessions were recorded, transcribed and then analyzed by the researcher. Selected analysis sections were also shared with experts in the field to gather alternative points of view and suggestions. Those comments and suggestions are also included in the data log as part of the interpretational data. A total of 28 taped tutoring sessions were completed between

July, 1996 and April, 1997. All of these sessions were reviewed by the researcher but not all of them were completely transcribed. The tapes have been kept intact in case there are questions arising about the untranscribed sessions.

Classroom observations were done at Kay's school during the second semester of the study. Classes observed include mathematics, reading, Bible, and PE. Those sessions were taped and all data related to academic instruction were transcribed. Careful longhand notes were kept during these sessions in order to capture non-auditory information such as mood, attitude, facial expressions and other body language as well as the physical setting of the classroom. The written notes became part of the data log and the tapes became part of the taped record. In all, twelve mornings were spent at the school during March and April of 1997 observing Kay in her classes.

Individual interviews were conducted with Kay, her mother, her father, her 6th grade teacher and her PE teacher. Interviews were transcribed, analyzed and placed in the data log.

Kay's mother also collected all the graded class work which was sent home during the school year. Math and reading papers became part of the data log. Kay's teacher made a copy of the mathematics section of her grade book for the first 3 quarters of the school year. Names were deleted, but Kay's scores were highlighted. This also became part of the log.

Three sets of diagnostic testing information were available about Kay. The first was from 1993 when she was tested for special education eligibility. The second was during the summer that this study began (August 1996) and the third was at the end of the study (April 1997). All three reports are included in the data log.

About Kay and this Study

Kay is an example of how complex the process of learning can be and how many interrelated factors affect the process even within a single individual. Finding reasons for her learning difficulties is easy. But explaining her successes -- her resilience, academic overachievement, motivation, emotional stability, acceptance by peers, coping and organizational skills -- requires a much deeper analysis.

The purpose of this study is to do such an analysis and attempt to identify ways in which the educational process may promote the kind of resilient progress which Kay has demonstrated. The following sections will attempt to present a thorough description of Kay as a developing human being and learner. These results are organized around the first four guiding questions of the study. Because of the interpretational nature of these questions this section forms part of what is traditionally the "discussion" section in a dissertation. The case data log, reasoning, and opinion are used as the bases of discussions in this chapter. The fifth guiding question, involving the relationship of this study to existing theory and the need for further research will be discussed in the following chapter.

QUESTION 1: BACKROUND AND CASE HISTORY RESULTS

1. How have Kay's learning difficulties in mathematics and reading manifested? How have they impacted her life emotionally, socially, educationally, spiritually, etc.?

Kay's School History – Manifestations of Her Learning Difficulties

Kay's learning difficulties in mathematics and reading have overshadowed her life ever since she started school. She attended public school for grades K, Transition, 1, 2, and 3. Her progress early in school was very slow, and resulted in her having to repeat

kindergarten in the "Transition" class. After being retained in Transition, she became excessively anxious and perfectionistic. By second grade she was diagnosed by her pediatrician as having a stress-related peptic ulcer. According to her school records she continued to work below grade level, began to withdraw socially and to miss school more often [diagnostic report, 4/8/93].

In 1993, when Kay was beginning second grade, her mother and her pediatrician both requested she be tested for learning disabilities. Kay's teacher wrote on the referral form that Kay was "diligent but very slow to complete (her work)," "academic performance was below grade level" and "she appears to be unhappy almost to the point of being depressed" [diagnostic report, 4/8/93]. Kay's pediatrician wrote the school district requesting that the testing be done as soon as possible because she suspected stress from school was a factor in the ulcer.

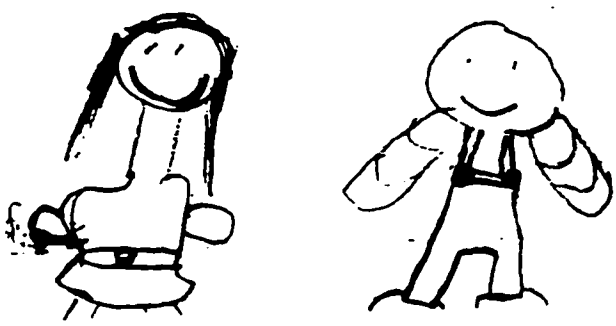
In terms of her social development the same diagnostic report describes her behavior within the family this way: "attempts to control other family members, often stubborn, but loving, thoughtful, rebels against homework.". Her behavior within the community was stated to be "quiet but within normal range." She is described as having poor concentration but not easily distracted.

Samples of her written school work at this time which were attached to the referral report show patterns of phonetic spelling, logical story progression, but also a strong sense of loneliness and lack of control over her world. Figure 4.1 contains some of these samples of her writing and drawing from second grade.

Figure 2: Work Samples from Second Grade

One day sarah had a firend cod
Nobcd. we plaxed, her mom cou
her she had to go to socker
wen she got back she looked
she coderlot find him soon it
was nitgh she looked went it
was morning she Fald him
in her clos-. she went back
to socker

FEB 2 3 1993



The following school year, her 3rd grade year, continued to be difficult for Kay but she progressed academically, albeit below grade level. At this time a major curriculum change was instituted at her elementary school and she and her brothers began having even more difficulty. Her mother recalls the situation this way:

> We left Taft Elementary because they were teaching OBE (Outcome Based Education). . . the school was in turmoil . . . and my kids weren't . . . their test scores were coming back low and . . . you know, when Mrs. Adams isn't talking to Mrs. Baker and the Principal isn't talking to either one of them and some teachers stay in their rooms at lunch hour because they're ostracized by the others . . . you know . . . it was just a mess.
>
> Matt (Kay's older brother) in particular was in fifth grade and his teacher was nominated Teacher of the Year . . .I thought she was so far off track that it was ridiculous. She was doing poetry and illustrations . . . he never had a spelling test, he didn't bring spelling words home on Monday, he had no math . . . there was no structure . . . it was all real gray and real . . . I guess kind of artistic or something, maybe . . . but that was not working for him. He was just . . . he was not managing . . . and I would go up there and say, "oh look, here's the paper" . . . and I'd pull the paper out of his desk that he didn't have a grade for and give it to her and be back the next week and find out she never recorded that particular paper, so she wasn't managing in her own system either. . .
>
> Basically, that was . . . and I felt like they were . . . getting away from the structure . . . structure that we in particular need. We have to have that consistency even now. Like when my brother came to town, or my parents get sick . . . if we get off track just a little bit, things go hay wire here. You know, there's something that gets . . . you know someone is going to get a zero that week . . . we just have got to keep consistent.
>
> I know some children flourish under that system, but other's didn't and if you happen to be one that doesn't . . . you have to try something else . . . [mother's interview, from pp. 15- 18]:

As Kay's mother indicated above, the result of this distressing situation was that the family moved all three of their children from the public schools to a local private Christian school. This particular Christian school has been in the community for ten years

and has a reputation for high academic standards. The school's reputation in the community is based on the fact that many of the students score two or more grades above grade level on achievement tests. The school is fully integrated, having at least a representative number of black children for the area. According to Kay's teacher [interview 2/20/97] most of the forty-three faculty are state certified. The school runs from 3-year old preschool up through 12th grade and has a total of seven hundred sixty students. It is a non-denominational Christian organization not connected to any church and is overseen by a private school board of parents, administrators and teachers. Parent and teacher positions on the school board are filled by election. The curriculum consists of a series of worktexts produced by Beka Book Publications.

The tuition is $2,000 per student per year which is substantial compared to the otherwise low cost of living in the area, especially for families like Kay's who send more than one child to the school. Kay's mother, who owns her own business as a private investigator, notes that she must accept more jobs than she would like in order to meet the children's tuition. This keeps her so busy that she is sometimes unable to provide the kind of consistency at home that she would like for them to have. This became a major concern late in the study when she was out of the home for more than a month. Consistency and home support are major factors identified in the discussion section as having an impact on Kay's learning situation.[4]

Kay attended 4th and 5th grades in this private school setting and became increasingly less withdrawn and depressed. Her grades continued to be good in areas such

---

[4] See Chapter IV, Question 2: "Structure"

as Bible, Singing, Art, and Handwriting. Academic subjects continued to be more difficult for her.

Despite this impressive achievement relative to her measured IQ, the school wished to have her repeat the 5th grade. Kay's mother strongly objected to this suggestion, citing the harmful psychological effects Kay had experienced at her previous retention (1st grade Transition). Her mother felt so strongly about this that she said she would home school before she would allow Kay to be retained. A compromise was agreed upon in which Kay was to be tutored over the summer and then take a test in mathematics which would decide whether she would be retained or not. I was asked to tutor Kay the summer after 5th grade. Kay passed the test, but only barely. She was allowed to go on to 6th grade with the condition that she continue to receive tutoring. As a result I worked with her as part of this study throughout her 6th grade school year. The summer and fall semesters comprised the pilot study and the spring semester completed the study.

Evidence of Specific Learning Disabilities from Diagnostic Testing

Three sets of diagnostic testing information were available about Kay. The first was done in 1993 when her parents and pediatrician requested testing for learning disabilities. The 1996 set were done at the beginning of this study at my request and the 1997 set were requested by her parents as Kay moved once again into the public schools, in hopes that she would qualify for supportive services.

As stated previously, Kay did not qualify under the federal guidelines for classification of "learning disabled" in 1993 because she was overachieving for her IQ and technically, her IQ was in the "slow learner" range rather than the "normal range." Still, in all three sets of testing, the diagnosticians found evidence that both Kay's strengths and difficulties were clustered around certain specific skills.

The diagnostician concluded the 1996 report saying that there was "support for a diagnosis of a Reading Disorder and a Mathematics Disorder." According to that same report, Kay's strengths clustered in the performance section of the WISC-R . The diagnostician noted in her report that Kay's scores "showed relative strengths in perceptual organization and spatial visualization." Her scores peaked on the subtests involving part-to-whole contexts and visual organization: picture completion , picture arrangement, block design, and object assembly.

On the verbal section of the test, her scores were consistently lower than on the performance section. But within the verbal section, her higher scores were all on context-oriented subtests: Information, Similarities, and Comprehension. Later in the report the diagnostician reported, "Although Kay appeared to use effective strategies for solving numerical operations, she exhibited poor processing speed on the timed math tasks . . . in the Sentence Repetition test her performance was within normal limits and this suggests she is able to use short-term memory skills when words are within a meaningful context."

Her weaknesses clustered in the areas which provide little or no context from which she could derive meaning and which depend primarily on unassisted memory: Coding, Vocabulary, and Digit Span were her lowest subtests. The diagnostician particularly noted that Kay "demonstrated a relative weakness on the Vocabulary subtest,

a measure sensitive to language development and concept formation. She also showed relative weaknesses on subtests assessing concentration, processing speed, and short-term memory (Coding and Digit Span)." In the Word Fluency test, which asks the examinee to make verbal associations to selected letters of the alphabet, Kay's score "was significantly below that of same age peers (about 2.5 SDs below the mean). Her relatively poor performance indicates a weakness in her ability to form verbal associations." Notice that this is also a task which is without context and depends on the initial letter sound. Therefore this weakness is congruent with the phonological processing hypothesis which will be discussed in the next section.[5]

In the conclusions section of the 1996 report the diagnostician states that Kay's "low scores on tasks assessing concept formation, processing speed, and verbal fluency, and her tendency to incorrectly identify words during testing provide further support for a diagnosis of a Reading Disorder and a Mathematics Disorder. It is important to note that a deficit in verbal ability is likely affecting Kay's poor mathematical performance."

Relation of this Case to Current Dyscalculia Research

Kay and her family fit five of the profile points which Gross-Tsur, Manor, and Shalev (1996) have recently established regarding the familial pattern and natural history of developmental dyscalculia[6]. First, Kay's scores in arithmetic show that she has a relative weakness is in areas of number facts and complex calculations [keymath

---

[5] See Chapter IV, Question 5 "Phonological Hypothesis" and Question 2, and "Fuzzy Perception.

[6] Developmental dyscalculia is dyscalculia not due to brain trauma occurring at or after birth. In this document, the terms dyscalculia and dyslexia refer to the developmental types, and not those due to physical trauma to the brain.

diagnostic assessment, 1997] while her other diagnostic assessments have consistently indicated that her ability to reason with information presented visually, spatially, and/or in familiar contexts is average or even above average.

Second, Kay's family fits the profile of lower educational levels (less than 13 years education) for each of her parents. Third, there is a preponderance of first-degree relatives with learning disabilities including both her brothers and her father. The younger brother was recently diagnosed ADHD [1997 diagnostic testing] which is especially prevalent among the male students in Gross-Tsur's study.

Fourth, epilepsy is common in the families in the Gross-Tsur study and Kay's older brother was diagnosed with epilepsy and is currently on medication. Developmental dyscalculia is the most frequently encountered learning disability in children with epilepsy, fragile X carriers, Turner's syndrome, and phenylketonuria and also correlates highly with ADHD, developmental Gerstmann's syndrome, and developmental right hemisphere syndrome (Gross-Tsur, *et al.*, 1993; O'Hare, Brown, Aitken, 1991).

When evaluated using the Gerstmann procedures described in Silver & Hagin (1990, pp. 158-165) Kay demonstrated one instance of finger agnosia, which ordinarily completely disappears by the age of 9 (Kay was 12 at the time). In fifth grade, Kay was identified at school as having problems with left-right discrimination difficulties [school papers, "PowerLine", before tutoring began]. When asked to raise her arms out straight to shoulder height, both arms appeared to droop, with her left arm elevated slightly higher than her right [tutoring notes, 11/96]. These are all classic "soft signs" of neurological impairment identified by Gerstmann and part of the Gerstmann Syndrome.

The fifth evidence of diagnosis of developmental dyscalculia, according to Gross-Tsur (1996) is that Kay's performance IQ is consistently higher than her verbal IQ by nearly 10 points. A discrepancy of 9.86 or more is significant at the .05 level for this age group (Weschler 1974).

Dyslexia was found concurrent with dyscalculia in 17% of the children with dyscalculia according to the Gross-Tsur study (1996) while it was found in 64% in the Lewis, *et al.*, (1994) study. The Gross-Tsur study was done in Israel in the Hebrew language while the Lewis study was done in England in English. Other studies have achieved rates between these two values (Castles and Coltheart, 1996; Davis, 1992; Shalev, 1993) and have discussed the possible relationship between forms of dyscalculia and dyslexia. Gross-Tsur (1996) found that dyscalculia is equally prevalent in males and females, which is congruent with both Kay and her brothers experiencing similar difficulties.

Therefore, Kay does exemplify a significant number of symptoms and familial patterns congruent with a diagnosis of dyscalculia as well as evidence of language disability which is characterized by clusters of relative strengths and weaknesses.

QUESTION 2: HOW KAY IS MAKING SENSE OF HER WORLD

> How is Kay making sense of her world – particularly how is she making sense of (or not making sense of) mathematics and reading? What strategies has she developed on her own in order to cope? How well are they working for her?

Fuzzy Perception

Several patterns of language difficulties and deriving meaning from context emerged within the tutoring sessions. The most pronounced was Kay's difficulty making a

spontaneous verbal description, even of something concrete. For instance, when asked to describe a figurine I had brought to the session, Kay had difficulty even understanding what I wanted her to do. Looking at a figurine of a woman playing a cello, which had the arm broken off, she never did notice that the arm was missing. She began describing the figurine only after much prompting [tutoring, 9/23/96]. At first she described it in terms of context and phrased her answer as a question: "she's probably in music class?". This is consistent with the notion that she infers meaning from context and function.

Then the following conversation ensued:

M: What would you call this (pointing at the figurine)?

K: What do you mean?

M: It's sitting on a shelf and you tell somebody to go pick it up.

What would you call it?

K: Um. A statue of a girl playing music. I don't know.

Then after much prodding and no more response from Kay, I showed her the broken-off piece – the arm holding the bow.

M: What do you think that is?

K: An arm.

M: An arm?

K: Oooohhhhh!!!! (tone of wonder, discovery)

M: Oh what???

K: Her arm's missing and the stick thing she plays the music with.

M: OK. So you think that arm goes with her?

K: Yes.

M: How would you check?

K: (Sigh-laugh . . . she held the arm up to where it had been broken off.)

M: Does it fit?

K: Yeah. (looks at me questioningly)

M: You tell me. Do you think that is her arm?

K: Yeah.

This was a major breakthrough for both Kay and me. With it, I began to realize just how limited Kay was verbally and also how important context was to her. In our discussions after this conversation, I explained to Kay that the purpose of this exercise was to get her to start telling me spontaneously what she was thinking. I told her,

> The reason that I wanted to do that was I wanted to get you so that you don't just sit there and silently think . . . because when you are silently thinking I don't know what you are thinking . . . so I don't know how to help. I want you to get to the point where . . . and I know in class you can't just talk to yourself. . . but here you can. And it will probably help both of us if you would. So if you are looking at something and it looks like "gee, I don't even know what that symbol means!" instead of just looking at it silently, tell me that. . . That's what I want you to do – do more talking – and we're not talking about right or wrong here. I need to be able to understand what you are seeing, or not seeing . . . or thinking . . . or understanding or not understanding. So the more you talk to me, the more I'm going to be able to follow what is going on.

Kay was able to increase her verbalizations of her thinking and even began initiating discussions after this [tutoring, 9/23/96; 1/28/97, p. 11]. This figurine incident also indicates that Kay guesses from context what is wanted in any particular situation. It appears that she operates out of a "fuzzy" perception of the world and makes guesses

about what is expected of her based on context clues. It is similar to the way in which someone with hearing or visual impairment might attempt to follow a conversation by picking up cues. Her "mistakes" have a similar out-of-sync flavor to them.

This may relate to the kind of phonological processing difficulty studied by Tallal and described by Blakeslee (1994, 1995). It would account for Kay's difficulty distinguishing between similar sounding number words such as five...fifteen....fifty...fifths which occurred in several of the tutoring sessions [tutoring 9/23/96, 1/27/97, 1/28/97, 2/3/97]. The episode with fractional names ending in "th" was especially significant in Kay's progress in mathematics and is discussed extensively in the intervention section.[7]

This phonological processing difficulty would also account for the "red colt" incident reported by Kay's teacher [teacher interview, 2/20/97]. Mrs. Cline, the teacher, had read a story to the whole class about George Washington borrowing a horse when the 'Red Coats' were coming. Two things about Kay's answers on the questions about the story bothered Mrs. Cline: first, that Kay wrote about a 'red colt' that was not even in the story, and then second, that she answered some questions, then skipped some, and then answered more questions all the way down the page. Mrs. Cline explained:

> C: I read the story . . . and I had pages of questions that they had to answer as I was reading. They were listening and they were answering the questions as I was reading . . . Some of her answers to the questions were very odd. I wondered where she had got them from . . . what she had heard that would make her think that the answer she gave was correct . . . and then a lot of them she just left blank. . . Where the red colt came from, I don't know. The term "red colt" is not even in the story. So I was wondering where she got that. I wondered if she . . . the story is about Gen. Washington and the Red Coats, so I was wondering . . .

---

[7] See also Chapter IV, Question 4, "Clinical Interview"

Although Mrs. Cline even pinpointed the word substitution, she had trouble believing that 'red colt' had come from 'red coat'. She also had difficulty believing that Kay couldn't write answers and listen to the story at the same time, although that would explain why Kay's answers and blank spaces were alternated equally down the page.

All of this, however, points to the same kind of processing and verbal comprehension difficulties identified by the formal diagnostic report. One can imagine how difficult school, with its predominately verbal instructional environment, would be with a processing difficulty which so readily confuses word-sounds. It would explain Kay's hesitancy to respond in even the most simple situations and would also be congruent with her experience of the world as somewhat fuzzy and indistinct.

Reading Cues and Context

As a compensating strategy for this fuzzy perception of the world, Kay has learned both to be cautious and to pay close attention to visual and context cues. At the beginning of any interaction, Kay was slow to answer and very conservative in what she would volunteer. In our first session together [tutoring, 7/25/96] I asked her to show me a math problem she was sure she could do. She hesitated, asked me what I meant, and then wrote the following two basic multiplication facts. She did <u>not</u> include the answers until prompted.

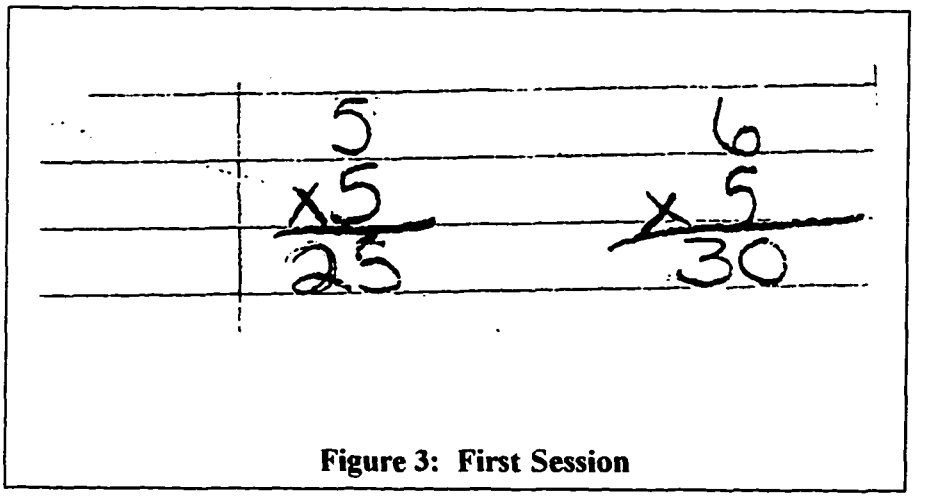


Figure 3: First Session

The same reticence was obvious in the classroom observations [classroom, April, 1997]. In the twelve mornings I observed her classes, she never once volunteered an answer or even raised her hand. When I asked her if she thought my presence observing the class had kept her from volunteering, she responded hesitantly in the negative. I also checked with her teacher, Mrs. Cline, who stated that this was normal behavior for Kay in her class. Likewise, in tutoring, Kay would frequently give the correct answer followed by saying "I don't know" which demonstrates her tentativeness rather than self-assurance about her own perceptions and thoughts.

As noted in the diagnostic testing [10/10/96], she did better on context laden items such as sentence repetition than on items such as isolated vocabulary. In that same testing report the diagnostician interpreted Kay's prolonged silences as "choosing not to respond" rather than possible confusion. In my experiences with her, however, Kay never "chose" not to participate. She simply waited for more cues about what she was supposed to do.

Kay's strategy of reading the context was evident in the previously mentioned figurine episode [tutoring, 9/23/96]. She couched her initial description of the figure,

"she's probably in music class?", both tentatively as a question and in terms of the functional context of playing an instrument. Although in looking at the figurine, she had not noticed that the arm was missing, she was immediately able to recognize the broken piece of the figurine as the "arm and stick thing (bow)" even though the broken off piece, by itself, looked quite puzzling.

Similarly, on the apperception test [diagnostic. 10/10/96] all of Kay's stories about the pictures began with "probably" and went on to pick up the functional context of what was going on in the picture. In the same report, the diagnostician made special note of Kay's deductive abilities writing that "she recognizes cause and effect relationships even when presented with tasks beyond her reading ability . . it is noteworthy that her ability to deductively reason in this manner may have accounted for her elevated Oral Expression score (73rd percentile)."

Another pattern of cue reading ran throughout the tutoring sessions. Whenever I asked a follow-up question about something she had done, Kay assumed that her answer was incorrect and began trying to change it [tutoring 9/23/96 and following]. I began purposely questioning correct answers so that she would get comfortable with questions and not assume that her answers were wrong when questioned. This strategy was quite effective. Kay became willing and able to defend her responses when she was sure about them [tutoring 9/23/96, 9/30/96, 1/28/97, 2/3/97].

The problem of misgraded math papers presented a more difficult obstacle for Kay. When her math papers were misgraded, she assumed that her answers were wrong, when frequently they were actually correct. (The reverse also happened, although much less frequently.) This added to the "fuzziness" of her world and her own insecurity about

whether she was reading the world correctly or not. Math papers were often graded by other students or a student aide and therefore answers had to match the book exactly or were marked wrong. For instance, length and width measurements for a floor plan were marked wrong [papers, 1/28/97; teacher interview 2 /20/ 97] simply because they were written in reverse order from how they were in the teacher's edition (width by length instead of length by width). Another example was when Kay had the fraction answer of 3/4 and was counted wrong when the answer was .75 in a problem using both fraction and decimal forms of numbers.

Visual Organization

In the first tutoring sessions, Kay showed signs of visual reversals of symbols which I thought might be related to some type of dyslexia and contributing to her fuzzy world-view. In the 7/25/96 tutoring session, she substituted a 9 in copying a problem containing the digit 6. She was unable to find this error on her own. When I circled the two digits and asked her to point to the one which was the "six," she put her pencil on the 6 and then moved it to the 9 – she did this twice, the confidently erased the 9 and replaced it with a 6 and corrected the rest of the problem. When I asked her what she was doing going back and forth between the 6 and the 9 she couldn't tell me. I asked her if this was a familiar kind of mistake and she looked at me with a little half-smile and nodded yes.

Another visual error which occurred frequently early in the study was "losing" the left hand digit in a subtraction problem which had fewer digits in the subtrahend than in the minuend. In the 7/25/96 session she worked 2030-920 and got 110. Her borrowing

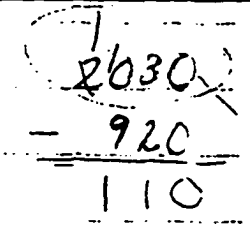


Figure 4: Subtraction Problem

was written out correctly, she just hadn't picked up the 1 left in the thousands place of the minuend. I had her do the addition check. She knew which numbers should match, but when they didn't, she started going over and over the original problem looking for the error. This time there really was something she hadn't seen – the one in the thousands place. She never did find it. Finally I pointed to it. She immediately corrected the problem and then corrected the check without prompting.

So at first it looked like a visual problem, but later analysis seemed to indicate that the problem was actually a combination of a figure-ground and/or memory difficulty. In the same session she completely "forgot" a problem in the middle of a crowded page, which Bley and Thornton (1989) cite as a common figure-ground error.

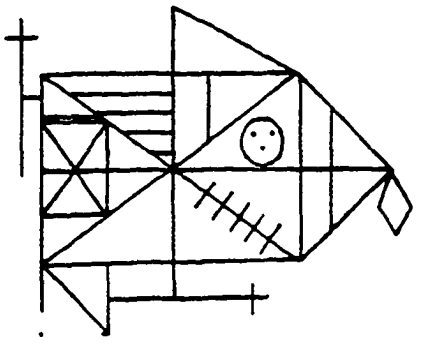
Kay was aware of her difficulty with similar looking symbols. In one session she erased an "s" and carefully reformed it so that she could tell that it was a "5." When I asked her why she had erased and rewritten, she replied that it looked too much like an s and might be confusing [tutoring, 9/23/96, p.9].

At the beginning of 6th grade, Kay did not seem to be having as much trouble with her basic arithmetic in school as she had during the summer. In talking with her, she mentioned that it was easier for her that year because she had the worktext rather than a

textbook from which she had to copy the problems. That made sense because many of her errors during the summer were "miscopying" errors of some kind.

In following up on the possibility of a visual processing difficulty, I had Kay do a Rey-Osterrieth Complex Figure. It took Kay six and a half minutes, but her copy of the figure was precise and it was one of the few exercises which she started without hesitation and self-corrected throughout the process[9/30/96, p. 2,6].

Figure 5: Rey-Osterrieth Complex Figure Stimulus



Stimulus

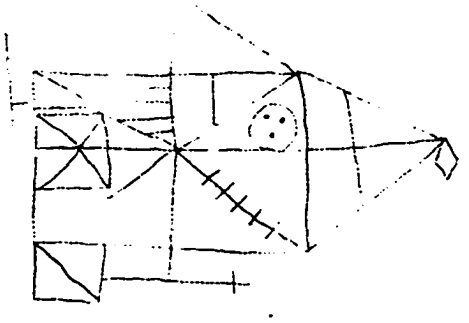


Figure 6: Kay's Drawing

Because Kay did so well at the Rey-Osterrieth Complex Figure and seemed to do well on items in her math class which were visual in nature, such as geometry and interpreting graphs, I shifted my focus from suspecting a visually centered disability to the possibility of memory and phonological perception difficulties.

One interesting episode related to visualization occurred during the tutoring sessions. Kay had been having trouble remembering the term "right angle" for several sessions. She recognized them when they were present in figures but had difficulty remembering the standard term. I built a house of cards using index cards and then we talked about how a right angle was the right kind of angle for keeping the walls upright. Other angles were "not right" and let the walls fall down. Kay looked intently at the cards, grinned, and did not again have trouble remembering the term "right angle" throughout the rest of the study [tutoring, 1/27/97].

Multiple Meanings

As might be expected for a child dealing with a "fuzzy" perception of the world, any type of word or symbol which had multiple meanings or possibilities was difficult for Kay to handle. For instance when asked to list the factors of 24 [tutoring, 9/23/96] Kay wanted to stop at 2 x 12. The idea that there were several possible pairs of factors was confusing to her and we struggled for several weeks thereafter with the idea of listing all the whole number factors for numbers.

In the scale drawing unit, Kay had difficulty with the concept that a scale drawing could be either larger or smaller than the actual object [tutoring, 1/26 & 27/ 97]. Part of her difficulty was the frame-of-reference nature of the terms "smaller" and "larger." The actual paramecium was "smaller" than the paper drawing, but the scale drawing was

"bigger" than the paramecium. This shifting of focus from object to drawing as the standard by which "smaller" and "larger" were determined was quite confusing to Kay. While this could indicate a developmental gap between concrete and abstract conceptualization, it could also be a problem specific to the use of abstract language to describe concepts which are developed, but cannot be adequately described because of language deficiencies.

Another such episode occurred in the diagnostic testing [10/6-10/96] which the diagnostician referred to as a "reversal." Kay was asked "why is a hardback book better than a paperback" and she answered backwards, telling instead why a paperback was better. If such words which describe relationships are difficult for Kay, it would be difficult to determine if she is having trouble with the concepts or with the verbalization.

That would fit with the observation the diagnostician mentioned in her report [10/10/96] that one of Kay's problems in school was probably related to the lack of flexibility in her use of language. The diagnostician stated that this lack of flexibility in language could cause problems any time there was variance in the way the words were used.

This same problem showed up when Kay was given open-ended tasks or questions. Her hesitancy to tackle such tasks may be due to both the unfamiliarity of such a format and to the lack of verbal ability to deal with more than one possibility at a time. For instance, she did not volunteer information but readily answered questions like "How old are you? What grade are you in?" She did not answer open-ended questions like "How do you feel right now?" and "What did you think when you went back and forth between those two numbers with your pencil?" Such questions seemed to puzzle her.

This made working with physical models and manipulatives a very slow process. Certainly they were not immediately "transparent" for Kay. Relating such models to ideas and concepts was a long and involved process of discovery and discussion. For instance, Kay experienced difficulty using color tiles to model both area and perimeter at the same time. In the end, we had to add coffee stirrer sticks around the outside edges of the design in order to model the perimeter with a separate manipulative from the area [tutoring 2/11/97].

Still, when pressed, Kay struggled to be able to make sense of physical models and manipulatives and verbalize meaningful relationships. This process is discussed in depth in the interventions section.[8]

Structure

Kay's current school has more structure than the average public school. In addition to a dress code and more school wide rules than most schools in the area, they also have school-wide procedures for notifying parents of current assignments, missing work, and low grades. Kay brings home a folder every Monday with all her graded work for the previous week and a sheet indicating any missing work or work which needs to be redone. Likewise, her schedule at school is routine, usually covering one lesson a day from the prescribed worktexts.

This consistent routine helps Kay keep track of what is expected of her at school [school observations 3/97; teacher's interview, 2/20/97; mother's interview]. Also she picks up cues by watching the students around her. She does best when she is seated in

---

[8] See also Chapter IV, Question 4, "Visual Aids", "Manipulatives" and "Clinical

the center of the class surrounded by her friends [teacher's interview, 2/20/97]. This isn't because of passing answers back and forth, since talking during class time is strictly prohibited. Rather she watches what others are doing and picks up cues that way [classroom observations, March through April 1997].

Procedures both in and out of the classroom seem to assist Kay by giving her the consistency she needs to be able to manage her otherwise fuzzy perception of what is going on around her. There is a parallel factor from the instructor's experience; it is easier to work with Kay in a structured, procedural way because it is easier to communicate and assess whether she has "understood" that way. While Kay is able to learn in a less structured environment like the Cuisinaire Rod session, it becomes exceedingly difficult to follow exactly how she is making sense of such an experience because of her language difficulties. Therefore the temptation in teaching is to return to verbally explained procedures because it is easier to guide and correct that way than the open-ended situations. The down-side of this is that emphasizing procedures by themselves often ends up masking the real difficulty, as I discovered in the Cuisinaire Rod episode with Kay.[9] The significance of this comfort zone for the teacher is further discussed in Chapter V.[10]

Motivation

Kay attempts to construct meaning by relating to her previous experience and understanding. When she is unable to do that, she constructs "I don't really understand "

Interview"

[9] See also Chapter IV, Question 4, "The Clinical Interview"

[10] See also Chapter V, "Disparity between Theory and Practice. . ."

and makes a "best guess" relying primarily on memory [tutoring 11/4/96]. But her construction includes the belief that "not understanding" is only a temporary condition which can be remedied by studying and "finding out how to do it" [tutoring 2/3/97]. It is apparent that Kay attributes learning success to effort and attaining "understanding" and believes that she can succeed by doing both. This modified form of self-efficacy may partially explain her unusually positive attitude towards learning. She sees success as being the result of activities she is capable of, given enough time and support. This would also explain Kay's complacence about the test she had to pass in order to be promoted to the 6th grade. She approached it with the attitude that she would keep at it until she succeeded. Her mother's attitude certainly supported this belief.

Her 6th grade teacher, Mrs. Cline, gave this description of Kay's motivation and attitude in her interview:

> I've seen her work on a problem or a situation in her academics and she'd get frustrated and get tired, but she never really quit. She knew enough to quit and walk away from it for a little while, but then she would come back to it. She always had an attitude that she wanted to learn. She never gave an attitude like "I don't want to do this"[interview, 2/20/97, p. 10].

Time Sense

It seems as though Kay lives in a timeless sort of world -- very much in the present. When involved with an activity, she is wholeheartedly present for as long as it takes. Tutoring sessions tended to go on longer than the 90 minute tapes being used to record them. She simply kept at it until whatever we were doing was completed. She

never complained of being tired or bored, and only once in all the time I worked with her did she seem to be daydreaming [tutoring, 2/3/97]. When I asked about it, she said she was daydreaming and when I mentioned this unusual behavior to her mother, the mother explained that on that particular night Kay was going to a special social event after tutoring and was probably thinking about that.

Kay invariably hands her daily assignment in on time, but getting long-term assignments turned in is incredibly difficult for her. Without constant supervision from her mother, those sorts of assignments do not even get started until the day before they are due. All three book reports so far this year were completed either immediately prior to or after the reports were due. This may be partially a matter of procrastination since reading is still not her favorite activity. But it is odd that she is able to use her organizational skills to recognize patterns and develop procedures, but not to plan ahead in order to have long-term assignments prepared on time. This could be the result of overload: perhaps the demands of each day require all her energy and nothing is left for planning ahead.

It seems that whatever she is able to do right now is what is important to her. What is coming up in the future isn't really important until it becomes a present necessity. Unfortunately, this often becomes a matter of family crisis when the large assignments come due. For instance, Kay stayed home from school the day before her science fair project was due in order to put it together and her father had to stay home from work that day to help her.

In the same way, she was always glad to see me and worked diligently while I was there, but never took the initiative to call and ask for additional help, even though I had instructed her to do so if she found something difficult on an evening I did not tutor. It is

as if my assistance is "out of sight—out of mind." Like her long-term assignments, assistance which is not present "in the moment" is overlooked.

I have seen little indication of future orientation. She was able to address scheduling problems such as whether she could come to tutoring on Wednesday and was also able to tell me she might go to Disney World over spring break, but I saw no evidence of proactive scheduling at all. Deadlines like the book report and science fair seemed to surprise her when they arrived, even though she had talked about having the assignments. In one sense this is very much congruent with a learning goal orientation as opposed to achievement goal orientation. She simply does her best in the present situation and lets the future take care of itself. However it severely limits the available strategies for success available to her, since most metacognitive strategies involve projecting ahead and preparing.

Dealing with Failure

At the same time she is bothered when she makes poor grades. When she got back her math test in class she tried to hide her failing score with her hand, changed hands to keep the score hidden when she needed her right hand to write something down, and eventually pulled out her calculator and placed it over the grade [classroom observations, April 97] . Still, her strategy doesn't seem to be denial or devaluation, but delay. She wants to fix it and make it better.

Her anxiety about not doing things right is also apparent in the diagnostic story she told about the picture of the boy walking in by mistake on a girl taking a shower. She identified with the boy – with the *faux pas* – the embarrassment of not reading the situation correctly, and so doing something wrong by mistake. This is unusual because the

common response is to identify with the girl and the embarrassment of being caught exposed and vulnerable [diagnostic 10/96].

Problems Related to Coping Too Well

One of the difficulties I observed both in Kay's classes and in tutoring is that she does a good job of looking as if she understands. By doing this, she wards off extra help from which she would probably benefit. After the first session with her, I wrote the following in my personal log about my own reaction to Kay's seeming self-assurance despite her difficulties:

> *Here she was: quiet, clean, a little bit shy. She was not at all what I had expected. Usually students who come to me for tutoring have a frayed, hunted, almost vicious edge. It is as if they view their difficulty with school math as the result of a malicious conspiracy against themselves and arrive for tutoring, tense and battle-ready – not ready to conquer their difficulties with mathematics, but ready to fight off any threat to whatever defense they have erected to cope with impending failure.*
>
> *But from the very start Kay was different. She didn't look despondent. In fact she didn't look like someone who was faced with being retained in school for the second time in six years if she didn't pass the upcoming test. She looked serene – a little distant, maybe, but calm and composed. Where was the fear, the anger, the frustration? Where was the self-doubt? The excuses and blaming? The belligerent challenge of "you can't make me learn it"? Or the hopeless "this isn't going to help, either, because I'm just too dumb to do math"?*
>
> *Why was there no outward sign that something was wrong?* [personal log]

It was this incongruence between her attitude and situation which first piqued my interest in doing this case study. Identifying her motivations, attributions, and goal orientations became a major challenge in the study.

In contrast, there are also factors in Kay's belief system which magnify Kay's difficulties with her school work. For instance, Kay considers "understanding" and

"getting the right answer" as the same thing [tutoring 2/3/97]. This leads her to be satisfied as long as her answers are correct and so she does not, voluntarily, go on to try to make sense of the processes or seek relationships among ideas that she is working with.

She is also held back by the belief that other students can do complex computations in their heads and that she should be able to, as well. In tutoring it was always difficult to get her to use scratch paper to do intermediate computations in working longer problems [tutoring; 9/23/96; 2/3/97]. She seems to believe that the answers "just come" to the other students and they ought to "just come" to her as well [tutoring, 9/23/96, p. 29; 1/27/97, p. 10; 2/3/97, p. 24]. She resists using scratch paper, just as she resists letting on that she doesn't understand or isn't sure what is being asked. Since she is unable to maintain several digits or computations in her head at once, this makes the accuracy of her computations precarious.

In the same way Kay's good behavior and consistency turning in her daily assignments keep her teacher from realizing in time that Kay needs assistance. For instance, Mrs. Cline frequently did not realize that Kay still didn't understand until she performed poorly on the test [teacher interview, 2/20/97]. Another problem is that with all the diagnostic testing and reports, it looks like Kay is getting all kinds of help, but in fact, it is all just paper shuffle. Neither the school nor Kay's parents have been able to make use of the diagnostic information to any appreciable degree. The school simply isn't that flexible and Kay's parents as well as her teacher really don't seem to grasp what the diagnostic testing means in terms of how Kay operates and what she needs in order to successfully learn [personal log].

Coping Strategies in Reading

In reading, Kay at first thought that word calling was reading. It seemed to be an entirely new idea to be told that she should be able to tell the story after she had read a paragraph. Even her mother said she had never thought of asking Kay to do that [mother's interview].

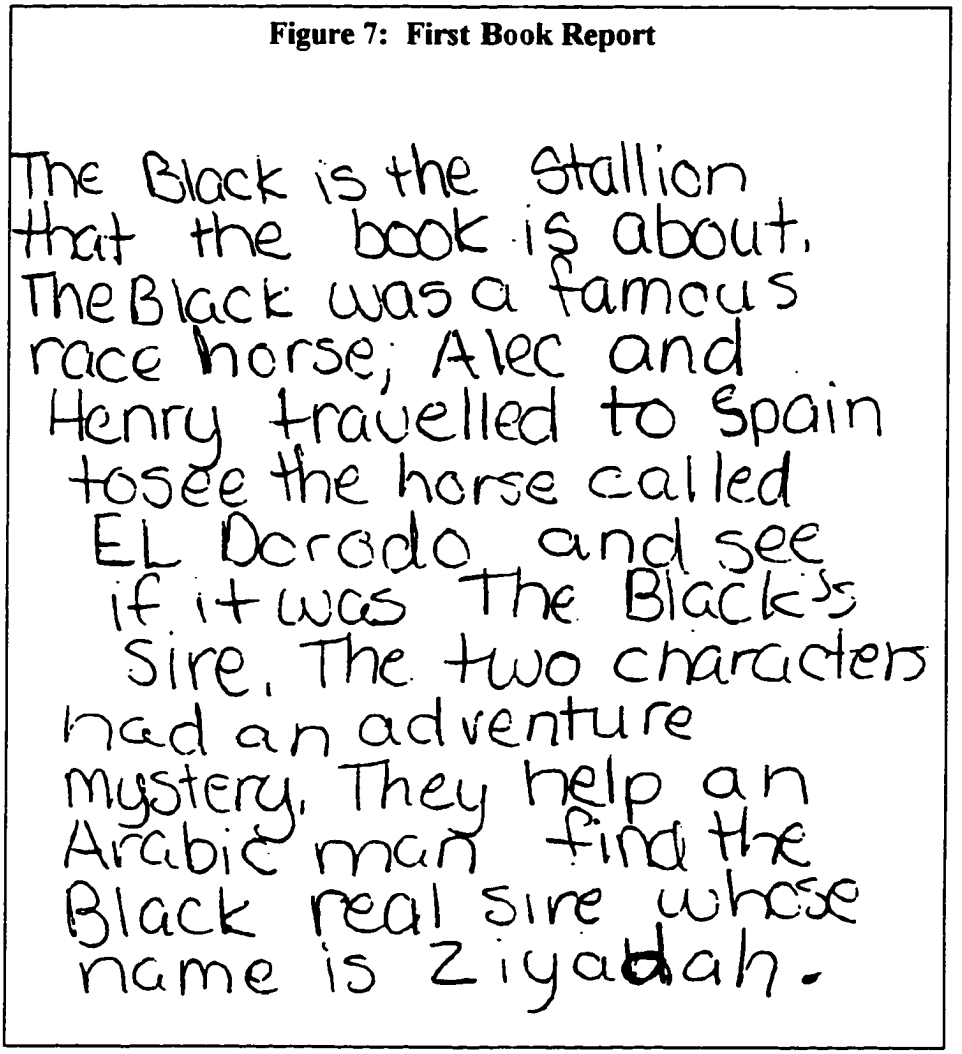
When I first introduced this reading procedure, Kay tried to tell the story by repeating it verbatim. It was as if the words themselves were what was important rather than the meaning of the words. I worked with both Kay and her mother encouraging them to read together and stop for Kay to tell in her own words what had happened in each paragraph. I modeled this practice with Kay during some of the tutoring sessions, and at least for a while, Kay's mother was able to work with her on it between sessions.

. In timed reading exercises Kay still doesn't finish. But then, thanks to her teacher's understanding and flexibility, Kay continues those papers at some later time. However, Kay's teacher believes that Kay's confidence and oral reading have improved since her mother and I have been pair-reading with Kay. Her teacher told me:

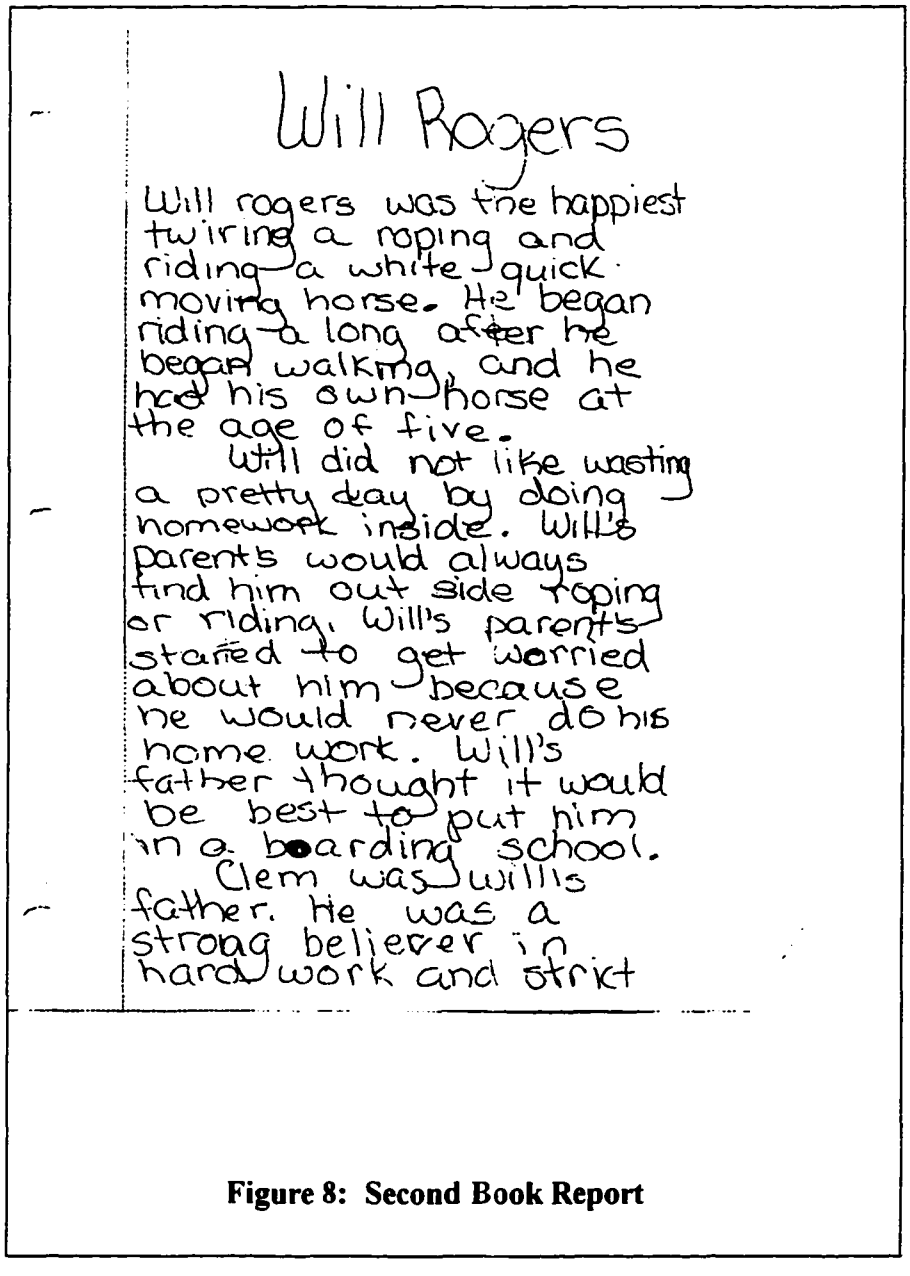
> I noticed at the first of the year when we would do oral reading in the classroom and everyone would have a turn to read, when I got to her, she was very self conscious. She wouldn't just dive in, she would . . . was real hesitant and rubbed her head a lot and looked down, hid her face, and she'd get real red. She couldn't hardly get through a paragraph.
>
> Now, I give her sections to read like in science, when we do science. I can give her a section and she will read through it and she will wade through some of the big words and she's much more confident now than she used to be . . . . she attacked it in a much more confident way. She doesn't seem to be so easily embarrassed by her reading anymore. So I was glad to see that. [interview, 1/20/97, p. 10]

Kay's book reports have improved tremendously since the beginning of the year. There is evidence that she is really making sense out of the stories, now, as she reads. Her first book report was hardly intelligible and she was not able to answer any of my questions about the story.

Figure 7: First Book Report


The Black is the stallion that the book is about. The Black was a famous race horse; Alec and Henry travelled to Spain tosee the horse called EL Dorado and see if it was The Black's Sire. The two characters had an adventure mystery. They help an Arabic man find the Black real sire whose name is Ziyaddah.

But her next book report showed much better understanding of both writing about a book and about the story itself. It was three pages long. The following figure shows the first page of that book report.



Will Rogers

Will rogers was the happiest twiring a roping and riding a white quick moving horse. He began riding a long after he began walking, and he had his own horse at the age of five.

Will did not like wasting a pretty day by doing homework inside. Will's parents would always find him out side roping or riding. Will's parents stared to get worried about him because he would never do his home work. Will's father thought it would be best to put him in a boarding school.

Clem was Will's father. He was a strong believer in hard work and strict

Figure 8: Second Book Report

I was particularly pleased with a reading assignment in which Kay and I pair-read the story at home during our tutoring time and then a week later the teacher asked the students to write a summary of the story at school. Her summary was correct and detailed which indicated that she not only understood what she had read, but also that she was able to retain it without further review for an entire week [school papers, "Betsy's Grade"].

We really didn't achieve a similar transition in making sense of mathematics, probably because the process of meaning-making was much easier in stories than in the process of making sense of abstract relations. Kay could tell the motivation of a character from the story by drawing on her own life experience, but she was never spontaneously able to see any reason for equivalent forms of numbers such as ½ would equal 6/12, .5, or 50%. She accepted that these equivalents were true and eventually could even draw pictures to show the relations. But she was never able to explain why anyone would want to have so many names for the same thing. Human motivations and real life situations made sense to her and she could describe them in depth. But abstractions, especially multiple meanings or multiple representations seemed to baffle her.[11]

QUESTION 3: APPLICABLE LEARNING THEORIES

How can existing learning theory perspectives inform or explain Kay's learning experiences? What alternative strategies or experiences do these theories suggest? What might be expected, according to these theories, to assist Kay in coping with or overcoming these difficulties?

On-Going Literature Review

Part of the emergent quality of this study design is that the literature review continued throughout the study. As difficulties became apparent in tutoring sessions, the first step was to look in the existing literature for ideas of strategies which might be helpful. The four learning theories which predominated in the study were developmental, constructivist, cognitive, and language-oriented. Additional information was gathered

---

[11] See also Chapter V. "Concrete and Abstract Cultures: A Hypothesis"

from the area of special education. Most of the background material from these perspectives is written up in Chapter III: Review of the Literature. This section only summarizes how various strategies and insights emerged from each of the learning theory perspectives.

Developmental Perspective

The developmental perspective offers several separate insights into Kay's learning difficulties. First of all, since Kay's birthday falls in August, she would have been a very young five-year-old when she entered kindergarten. Despite the retention in Transition (between kindergarten and first grade), she is really only a few months older than most of her classmates now. There is also evidence that Kay lagged behind physically and emotionally early in her development. The diagnostic referral [diagnostic 4/8/93] states that in second grade (after one retention already) Kay was immature for her age and still occasionally had trouble with bedwetting. There is some evidence that this developmental delay may be a family trait, since Kay's older brother Matt seemed to have "grown out of" his learning difficulties sometime around 9th grade when reading and studying suddenly began to make sense to him. Kay's younger brother seems extremely immature for his age and was recently diagnosed as ADHD [mother and fathers interviews].

Kay certainly operates at a concrete level rather than an abstract level. An unpublished developmental mathematics task interview by Grayson Wheatley was used to assess her level of mathematics understanding. The results indicated that she was operating between 2nd and 3rd grade levels [tutoring 11/96] but that may very well be low due to her language deficits compounding her difficulty in understanding and answering

the tasks. Those items she could do she viewed as "silly" while those which she could not do seemed to be beyond her grasp of even understanding what was wanted.

Constructivist Perspective

The previous section on research question #2 addresses most of how the constructivist perspective was applied in this study. The basic premise is that Kay lives in a very different world than most students – a world distinguished by fuzzy perceptions which affect how she constructs her understandings of the world and her coping strategies.

In terms of constructivist ideas, it may be that she has never had the kinds of experiences which would lead her to make sense of number equivalence. For instance, being so concrete in her approach to life, measure may not need to be converted. She simply measures it the way she needs it to be in the first place. Why would she do anything else? Again, note that the problem of multiple meanings or methods is very difficult for Kay.

On the other hand, the math curriculum which is used by the school does not emphasize consistent meaning at all. When explaining the idea of "square units" in the measure of area, the text is satisfied with a diagram that instead portrays the "square units" as rectangles.

In other places in her text there are inconsistencies when dealing with fractions, decimals and percents. In one lesson 2/3 is given as .66. In another it is .67. Sometimes in percents it is 66%, sometimes 67%, and sometimes 66.6%. None of these approximations are explicitly labeled as such. When grading papers, the answer must match the answer book exactly, and these inconsistencies caused numerous correct

approaches to the problems to be marked wrong. Kay is not certain enough of herself to question these inconsistencies, and instead, accepts them as "things I don't understand." This contributes to her perception of mathematics as fuzzy and elusive.

Cognitive Perspective

Cognitive learning theory contributes explanations to this case in terms of memory, processing speed, and recall strategies. In particular, the procedures designed to reduce memory load for Kay were developed from this perspective. For Kay, understanding was not enough to be able to perform up to her school's requirements. She needed to be able to use her organizational strengths to make up for her memory weaknesses. This resulted in the creation of procedures based on reducing memory load . This helped her to be able to perform multiple step procedures and problems without getting lost in remembering where she was in the process.[12]

This was not used as a substitute for understanding the underlying meanings. In fact, until she understood underlying meanings, the memory techniques were not especially effective. The memory techniques simply cued Kay when to apply the operations she had come to understand through the use of other hands-on techniques.

Another cognitive aspect of Kay's learning difficulties was that she often did not have the prerequisite knowledge to do the tasks assigned to her. For instance, in working with scale drawings, no one at school or at home had noticed that she didn't know how to read a ruler accurately [tutoring, 1/27/97] or that her ruler was broken and missing the first 1/8 of an inch. This neglect of prerequisite knowledge also occurred in both reading

---

[12] See Chapter IV, Question 4, "The Clinical Interview" and Chapter III, "Sample"

and mathematics when critical new vocabulary was not explicitly discussed in the lesson [tutoring 2/3/97].

This was not just a problem for Kay, but for her entire class, as they began using protractors to measure angles. No explicit instruction on the use of the protractors was made before having students use them to measure angles [classroom observations 3/97]. At the end of the unit, even some of the better students in the class had still not figured out how to use their protractors correctly.

Another related difficulty was that right/wrong feedback was given regularly, albeit not always accurately. But feedback on how to correct work or how to approach a problem correctly was not given in class. It was the student's responsibility to go home and fix the errors. In Kay's case, this was not very effective because frequently her parents also did not know how to do the school work correctly.

One area in which cognitive theory was especially helpful was in tackling Kay's difficulty differentiating between similar words or ideas. It became apparent early in the project that Kay lumped many dissimilar ideas or concepts into the same categories. This was probably a result of the fuzzy perception discussed earlier. The strategy of making differentiations explicit came from cognitive theory and was a successful intervention in both the area/perimeter intervention and the naming equivalent fractions intervention.[13] In both cases, progress hinged on getting Kay to correctly identify which items were of the same type and which were of different types. In particular, the creation of a separate

---

[13] See also Chapter IV, Question 4, "Visual Aids" and "Manipulatives"

concrete model to show which part of a figure was perimeter distinct from which part of the figure was area was pivotal in Kay's mastery of the concepts as used in her book.

Language and Culture Perspective

In many ways working with Kay was like working with a 2nd language learner or student from another culture. I found Feuerstein's work on IQ assessment for 2nd language learners and children from other cultures helpful in this respect and patterned many of the tutoring sessions after his Learning Potential Assessment Device, or LPAD, which he used to assess individuals who have had an intellectually deprived background. The method attempts to assess the individual's ability to respond to intensive instruction and is designed to increase intelligence (Brody, 1985).

From a language perspective, children learn language skills from being in language rich environments. In Kay's case, her mother is fairly verbal, but her father has great difficulty expressing himself. While he is successful in that he owns his own construction company, in his interview he was quite candid about his own difficulties both with learning and expressing himself.

Dad: I didn't have a mother and I didn't have a dad that would sit down . . . I lived with my grandparents, you know it's like I'd go to school if I wanted to and I had no one to oversee homework or my school . . . I didn't have anyone that took interest in me at all.

So, and I tried and tried to learn and grasp but couldn't. It was an extremely hard struggle and (I did) not make any good grades at all . . . so, and I went on to college with just a . . . but I didn't stay. I didn't actually grow up . . . I loved high school, because actually I lived on the streets . . . I didn't know . . . I didn't have a home . . . but a . . . I was trying to go to high school . . . that was a joke because I had nobody . . . nobody to take care of me. I joined the service, and after I got out of the

service, took my GED.

I've learned the hard way . . . trial and error. (pp 2-3)

K: Do you see the same kinds of difficulties in Kay?

Dad: Yeah, I do and I, you know, like look at Kay and I even look at Jake and I see myself . . . and it is frustrating because I feel like . . . uh, this is like sixth grade level math and you should be able to comprehend but . . . and I think a lot of it is . . . when I read things and it's hard for me to comprehend the language of it? . . . even though it's simple, when I read I get a different meaning to it . . . so and it is hard for me to comprehend . . . I think, 'am I that dumb that I can't comprehend even sixth grade math?'(p. 4)

Well, um, and it very well could be that's where she's (Kay) getting it is from me. I don't know, it's just uh . . . it's like um expressing . . . I can't express myself . . . I have the knowledge up here, but to get it out here, you know, express it I can't do it! And sometimes it's not very well. .... (p. 15)

I mean, Kay talks, but she uh she's probably basically quiet like I am [father's interview, 4/8/97, p. 16].

QUESTION 4: INTERVENTIONS AND RESULTS

When alternative strategies and experiences are used, how does Kay respond? Are there patterns to the types of new strategies or experiences she adopts and applies? Are any of them effective for her?

Corrective Feedback

The first intervention I tried in July, when there were only two weeks before the test Kay had to pass, was basic corrective feedback. I would have Kay work problems like what were going to be on the test and then we would go over the problems together and work on the corrections that needed to be made. This would be a good cognitive intervention if it were actually a case of lack of procedural knowledge and/or lack of

practice which was at the root of Kay's difficulties. It became apparent, however, that Kay's problem was not just "not knowing how."

There was a large amount of inconsistency in her performance. She would get a problem right and then miss a similar problem, or copy the problem incorrectly, or mysteriously change a digit in the middle of a problem causing an error unrelated to either faulty procedure or deficits in basic facts. As noted previously, I at first interpreted this as a visual, perhaps dyslexic sort of difficulty. But as time went on, it seemed to be more of a combination of figure-ground and short term memory difficulties.

To help her focus in on just the problem, I tried to get her to copy it out on scratch paper and work it where she had plenty of room. But her aversion to using scratch paper[14] was quite strong. Working on the short term memory difficulty became a separate intervention, which is discussed later in this section[15].

The Clinical Interview

Tutoring sessions simultaneously became clinical interviews in which I was trying to find out how Kay was thinking about the problems and how she was getting the kinds of answers she did. I felt that this was necessary because without an understanding of how Kay was perceiving the tasks and processes, it was difficult to know how to help her.

Meanwhile, the fuzziness of Kay's auditory perceptions was becoming apparent as Kay often confused similar sounding number-words such as five, fifteen, fifty, and fifths [tutoring; 10/1/96; 1/28/97]. This became a strategic area of concern when we began to

---

[14] See also Chapter IV, Question 2, "Problems Related to Coping Too Well"
[15] See also Chapter IV, Question 4, "Memory Load Reduction"

work with fractions and she seemed to be unable to correctly name fractional parts. Repeatedly she would tell me "four" instead of "fourths" in naming fractions [tutoring 11/4/96]. It happened again later in the session with "eight" and "eighth." In this session it appears that she could count the selected parts (numerator) or the number of parts in the whole (denominator), but had never before grasped the language which would allow her to put the ideas together as a parts-to-whole form of verbalization.

She had the concept of fraction related to the written symbols and could fill in the blanks for

 $= \frac{\square}{4}$ or  $= \frac{4}{\square}$

but she had not yet grasped the verbalization of the denominator as ending with "th." So for the first picture, the "answer" for Kay was "three" not "three-fourths" and the answer to the second picture was "eight" not "four-eighths." This led to her consistently naming the number of pieces of either the part or the whole, but not the standard fraction form which included both.

It makes sense then, that the naming "equivalent fractions," which looks at the overall relationship between parts and whole, would be difficult for her to grasp. She could fill in blanks for the types of problems above, but in reality she did not yet grasp the underlying concept of the standard fraction naming scheme. Because she could work some types of fraction equivalence problems, I had difficulty realizing what it was that she really didn't understand.

Not until towards the end of a session using Cuisinaire Rods did I finally comprehend that Kay was not using the standard fraction naming scheme of "numerator-denominator-ths." I had not realized the significance of Kay calling $\frac{8}{8}$ "eight over eight." This, combined with her confusion between the terms "eight" and "eighths" had led her to construct the fraction as "eight pieces shaded" over "eight pieces total" with the numerator and the denominator being separate entities with no connecting relationship. It was only when she began naming fractions with both numerator and denominator together, using the "th" verbalization that she was able to successfully integrate what she already knew about fractions and apply it to the concept of "equivalent fractions." It was a very fluid, almost magical transition in which gaining the language seemed to facilitate the idea of there being an additional relationship between the two numbers. Having initially missed the language cue, Kay had also missed the connecting relationship.

Once the language was in place, Kay became able to operate effectively with fractions. Notice, however, that the problem wasn't exactly the concept of 'fractional parts' or 'equivalent fractions', but was rather in the basic idea of how to name a fraction by saying both the numerator and denominator – the idea that the fraction involved both the numerator and the denominator in relationship to one another.

Once Kay constructed the standard fraction naming procedure, equivalent fractions became easy for her. She was immediately able to correctly apply the procedure for finding equivalent fractions which had been taught at school, when previously she had been applying it in a haphazard and often incorrect fashion. Similarly, mixed numbers and their equivalent improper fractions suddenly made sense to Kay. She no longer hesitated

when faced with problems in which she had to convert from one to the other. This indicates once again that Kay's particular difficulty (as demonstrated by her hesitations) did not stem from the concrete fractional concepts themselves, but from the language – the verbal concept formation of how we standardly talk about and write fractions.

This should not to be confused with the notion that simply knowing the language involved automatically brings about understanding of the underlying concepts. In the history of education, the belief that simply naming a concept implies understanding of that concept has been a recurrent error in pedagogical thinking. Bloom's taxonomy is one educator's attempt to correct this misconception by pointing out that naming is merely the lowest of the different levels of understanding and application which are possible. The current emphasis of the educational process as students "constructing" knowledge rather than teachers "transmitting" knowledge goes one step further and claims that the understanding must be constructed first, before the naming is even useful.

My claim in this instance is that Kay had some experiential knowledge which she was not able to coordinate with the collective, procedural knowledge to which she had been exposed, until the confusion in the mediating language was cleared up. So "languaging" was neither the first nor the last step in the development of the concept, but rather was an intermediate step which had to be developed in order to allow Kay's individual experiences and concept construction to connect to the larger pool of collective knowledge and experience, which includes generalization and abstraction.

In this way I see learning as a process which weaves in and out of individual experience and connects to collective knowledge through the mediation of language. This is why the goal in the NCTM standards about communicating is so important. It is this

process of connecting one's own meaning-making with the meaning-making of others and with the cumulative knowledge in the field which is the basis of learning.[16]

Visual Aids

Another type of intervention involved using diagrams, charts, or graphs. These were all excellent interventions for Kay. Once she had a diagram, chart, or graph, she was able to answer questions regarding the represented information. This fits with her strong visual preference and visual organization skills.

She was also able to draw diagrams, charts, and graphs quite well when given information to represent. In fact, her performance on work from the chapter on charts and graphs was one of her best overall grades for the year The difficulty came when she was not specifically told to draw such a visual aid. Unless told to draw such an aid, the idea to do so on her own simply never occurred to her. Even with conversion factors, which are repeatedly stressed in her math text, I was never able to get her to spontaneously draw the relationship of the conversion factor. When I drew 3 ft = 1 yd she was able to extend the diagram to fit "7 ft. = ____ yds" as shown in Figure 9 below.

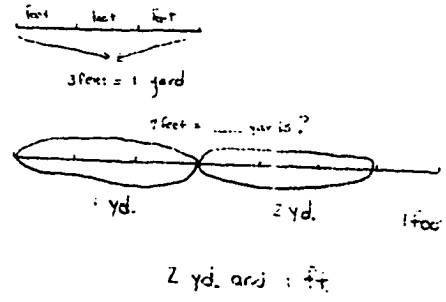


Figure 9: Conversion Diagram

[16] See also Chapter V. "Concrete and Abstract Cultures: A Hypothesis"

But for her to read the information and formulate the relationships into a diagram on her own was difficult for her. Her father reported a similar kind of ability in himself:

> . . . that's the way I've always been . . . and it's kind of like directions . . . instructions on how to put something together . . . just show me the box, just show me the finished product and I'll put it together piece by piece the way it supposed to be to get that finished product. I don't analyze it, I just do it, but to read all that . . . I can't comprehend that A has to line up with B, and get Z and all that crap . . . I can't do it . . . that's all there is to it [interview 4/8/97, p. 19].

Manipulatives

We used many types of manipulatives over the course of the year. Some were hand made in the moment like cutting up index cards to model the relationship between 3/2 and 1 1/2. Others were commercially made like the Cuisinaire Rods which became the vehicle for discovering the underlying difficulty Kay was having with equivalent fractions.[17] I was repeatedly surprised that the relation between manipulatives and problems was never readily apparent to Kay, nor did she ever make any attempt to create her own manipulatives to model situations concretely. It was necessary to make the suggestion or even describe the relationship, before Kay would see the connection between the objects and the questions she was trying to answer. She did not seem to be able to spontaneously apply this kind of approach to problem solving although she was able to use them once the representation was explained. So manipulatives were not at all "transparent" to Kay, but once the relationships were established, she did find the physical representations to be helpful.

---

[17] See also Chapter IV, Question 4, "Clinical Interview"

One intervention which exemplified this process was the use of color tiles and sticks when Kay was having difficulty differentiating between perimeter and area. At first, Kay was doing perimeter just fine. When area was introduced, though, the area formula seemed to take over in her mind, and whether asked for perimeter or area, she gave the area. The session continued as follows [tutoring, 2/11/97, pp. 15-19 – some sections omitted]:

M: I brought these tiles. What shape are they?

K: Square

M: Yeah, they're squares, so do you think you measure perimeter or area with them?

K: Perimeter . . . or area.

M: Okay.

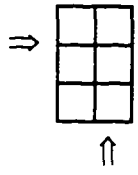
K: . . . and you can do both.

M: Well you could do both, yeah, you're right. But which one is actually measured in squares?

K: Area

M: Area. If I put this together like this . . . okay, now, it happens that each side of these little squares is one inch. so you don't have to measure it, you just know that each square is one inch on every side. Can you tell me or you can . . . if you need to write there's paper. Okay? Um, how long is this side?

K: Three inches.



M: Three inches. How long is this side?

K: Two inches.

M: Two inches. What's the perimeter of this rectangle?

K: Uh, six inches.

M: Show me how you got six.

K: Three times two.

M: Okay. (hesitant)

K: or . . .

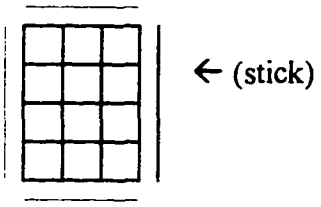
M: Now which one is perimeter?

K: Oh. . . . It would be nine?

M: I don't think so.

K: Maybe ten.

We worked for a while more, but I couldn't get her to shift from area to perimeter on request. Finally, when I kept saying I wish I had brought some straws, Kay went to look to the nearby cabinet to look for straws. There were no straws but she turned around and announced, "I have a stick. Will that help?" So we took some wooden shish-k-bob skewers she had found and cut them into the lengths of the sides of the tile figure. (Later we replaced then with coffee stirrers which cut more easily.) Then we used them as follows:



M: All right, so we're talking about the perimeter here. The distance around. . . and I'm just using these to make it real obvious where we're measuring. We're not measuring in squares now, we're measuring distances. (Placing the sticks around the outside of the tile design).. . .

. . . So these, the skewer sticks represent the .. . perimeter. All right, that's the perimeter along that side. How long is this piece? (indicating one of the longer sticks)

K: Four inches

M: Okay, so we have four inches. How long is this piece?

K: Four inches.

M: Okay, that makes a total of . . .

K: Um. ..

M: Well?

K: Eight inches!

M: Eight inches. How long is this piece?

K: Three inches.

M: Okay, how long is this piece?

K: Three inches.

M: . . . and that's what your book has been having you do. . . is group them together . . . first . . . you got eight inches here and . . .

K: Six inches here.

M: So you've got a total of . . .

K: Um . . . ten

M: Four, eight . . .

K: Eight . . .

M: You can write it down.

K: It's fourteen.

M: Fourteen, okay. Okay, you have counted it along the edges . . . one, two, three, four, five, six, seven, eight, nine, ten, eleven, twelve, thirteen,

fourteen . . . all right? You've just got to remember where you started when you do that. All right, now, so you had a perimeter of fourteen, but had an area of how much?

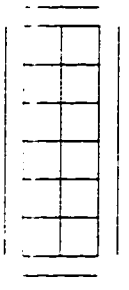
K: Area . . . ? Twelve.

M: Twelve. Okay, so the area is . . . ? The space inside, the perimeter is the distance. . .

K: Around.

M: Around the edges. Okay, let's look at this one. This one also had an area of twelve, that's how we built it. . . . There is a two.

How long is this piece going to be? →



K: Um. Six inches.

M: uh huh. Okay, we ran out of skewers, but you're just going to have to imagine . . . or do you want one more? (she nodded) Go get one more.

K: Okay.

M: We'll use one more. Okay. Oops, don't lose it. ... Okay . . . the perimeter is like the fence line, which we're doing with the . . . skewer stick. How long is this stick?

K: It's six inches.

M: Okay, how long is this stick?

K: It's six inches

M: Okay, so those two sides together make . . . ?

K: Twelve.

M: Okay, how long is this one?

K: Two.

M: How long is this one?

K: Two

M: Okay, so these two together make . . . ?

K: Four.

M: Okay, so that twelve here and four more make . . .?

K: Sixteen

M: Sixteen .. . and that's sixteen of those squares or are those regular length inches?

K: Length.

M: Yeah! They're just length, see. That's what I'm trying to get you to see – the difference between the squares which are area, and the sticks which are . . . Length.

K: Length.

M: Okay, so the sticks are perimeter, okay, it's like a big tooth pick . . . "p" for pick and "p" for perimeter. The toothpicks are on the perimeter. Okay, but the squares are . . . ?

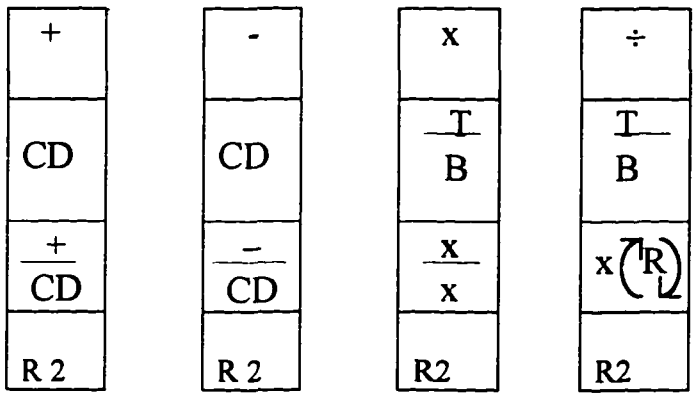
K: Area.

As we continued to model area with color tiles and perimeter with the sticks, Kay became more and more proficient with separating the two and by the end of the session could do both perimeter and area from just a diagram in her book. In later sessions she mostly maintained this ability to keep the concepts of perimeter and area separate. When

she did slip, all I had to ask her was "Is that squares or is it stick-distance?" and then she would readily distinguish between the two.

Memory Load Reduction

The memory load reduction intervention was one of the most successful of the interventions used in this study. It consisted of breaking down the procedures for doing fraction arithmetic into four "capsules" summarizing the procedures:



This was the first intervention created using the case study intervention protocol and was reported in detail as the example used to describe the intervention protocol in Chapter III.

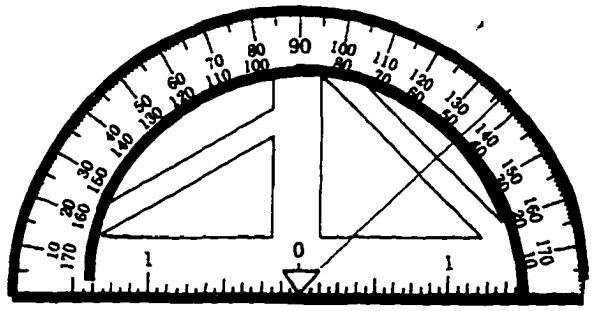
Proactive Teaching

Proactive teaching was the intervention which involved preparing Kay for the lessons she would do at school ahead of time, rather than trying to correct and remediate after she had done the lesson at school. Because her lessons were so regimented,

following the worktext one page a day, it was easy to begin working one page ahead rather than one or more pages behind where the class was currently working.

In this intervention I color coded the two scales and the two corresponding "baselines" for measuring angles on her protractor. See Figure 10.

Figure 10: Protractor Color Coding



Kay and I investigated how an angle could be measured using either scale depending on how you put the protractor over the angle and then practiced reading the measure of the same angle with each of the scales. We did all of this before the protractor lesson was done at school. There was no specific instruction given during class time on how to read the protractors. The teacher helped students individually at their desks if they had questions.

Many of the other students in her class never really figured out how to correctly use the dual scale on the protractor so that Kay's class as a whole did not do well on this section. On the chapter test, the class average of 73% was the lowest class average on any test during the three quarters for which I have the class grades.

In comparison to the other students in her class, Kay performed significantly better than usual on the chapter test for this unit. On the other tests during the year she scored an average of 11.6 points below the class's percent average, so in comparison, she did much better on this chapter with her score of 78% in comparison to the class average of 73%.

Metacognition

Metacognitive strategies were difficult for Kay to pinpoint because she was not inclined to be self-reflective. Also, her difficulty putting her thoughts into words hampered the process of determining metacognitive strategies. She was able, however, to identify from a number of choices which one was closest to what she was experiencing. For instance, in one session [tutoring, 9/23/96] we had the following conversation:

M: I want you to think again. How much is 5 plus 6?

K: 13. Oh no, 11.

M: How did you decide it was 11?

K: Cause I always do that on that first one . . . 13 cause in 5th grade I called this 13 so . . . cause I memorized it as 13.

M: So you mis-memorized and it still crops up.

K: Yeah.

M: Um. You need a little red light to go on in your head that when you see 5 plus 6, "oh that's the wrong number . . . I need the new number." Can you . . . When you do try to remember it, do you see it? Do you hear it? Where does that 13 come from? How does it pop up into your mind?

K: 7 plus 6 . . . it just does.

M: So 7 plus 6 instead of 5 plus 6? . . . What I am trying to get at is are you hearing it or seeing it or . . . do you remember?

K: Hearing it.

M: Hearing it?

K: yeah, unconsciously [my note: does she mean subvocally?]

M: So you actually, when you are remember things, you are actually hearing yourself say it or something?

K: (nods)

This would fit with another episode I observed in that same session. Kay was working on writing her spelling words in cursive handwriting. We were investigating her statement that she had trouble in spelling last year because she was required to write in cursive but this year she was allowed to print and was doing much better. She had written the words "dictionary," "suboceanic," "subpoena," and "diaphragm" and then while she was still writing "subconscious" the telephone started to ring. She sighed and said, "wait, wait," erased part of the word and rewrote it. It seemed that the auditory distraction was linked to her making the error and that she was at least aware that the interruption was interfering with her ability to write the word correctly.

This is congruent with how, when I first started working with her, Kay used to press so hard on her pencil that she would often break the pencil lead. She drew her numbers meticulously and it appeared that writing was an intense effort for her. According to Bley and Thornton (1989) writing is memory-intense for some students because their fine motor skills are poorly developed. That causes them to have to concentrate to remember how to make each stroke with their pencil. When they then

switch to cursive handwriting it forces them to learn a whole new system and it takes so much concentration that often parts of the words or even whole words are missing when they write.

It appeared from Kay's successful spelling of the words in cursive that she was in the process of mastering cursive writing. At the same time it still required an extreme level of concentration and memory load for both the spelling and the actually physical process of writing. The ringing of the telephone was a significant interference in this process.

Kay was also aware of how, when a page became too crowded or there were too many numbers in an addition problem, she then had difficulty "keeping them all in her head." When I tried to get her to add a long column of numbers by grouping in 10's, she simply couldn't keep one value in her head and regroup the next one at the same time [tutoring, 9/23/96]. She actually stated in this situation that there were "too many numbers to keep straight."

Calculator and Reference Chart Use

Two metacognitive strategies which Kay used well and spontaneously were aids such as reference charts in the back of her text and her calculator. When faced with conversions, she knew exactly where to look to find the conversions factors both for metric and standard units. She also knew exactly where the table was that showed the decimal-fraction equivalents. Early in the year she was hesitant to use a calculator because "it wasn't permitted," but later when the teacher permitted calculator use, Kay became quite proficient with it. She even learned how to compute sale price with percentage discount and do it all in one step on the calculator.

Like the manipulatives, though, the use of the calculator was not automatically transparent for Kay. At first she got more wrong answers with her calculator than she did by hand. This seemed to be due to the fact that using the calculator required remembering a series of sequential procedures with which she was not yet familiar. With practice, though, she became quick and accurate with her calculator. In real life, her ability to use the calculator proficiently will go a long way towards compensating for her slow, arduous performance in computation.

Study Skills

I was surprised to find out that neither Kay nor her mother had any idea how to study for a math test. Her mother even commented that she knew how to help Kay study for spelling or vocabulary tests but not how to study for a math test. As we moved into proactive interventions I questioned Kay about how she studied.

M: Okay, when you, say, study for a math test, what kinds of things do you do?

K: Just study . . . just one of these.

M: A worksheet?

K: Yeah.

M: And what do you do with it?

K: Just review it . . . just . . .

M: When you say review it, what do you mean?

K: Like . . . just redo the problems and just redo it.

M Okay. So you just work the whole thing over again?

K: . . . just know what it is.

M: Okay. When you say, "know what it is" how do you know when you know? How do you know when you're done reviewing? Remember this is just your opinion, there's no right or wrong.

K: I don't know.

M: You don't know? Okay. Ummm, if you were helping somebody else study, what kinds of advice would you give them?

K: Ummm, I guess I would ask them what they need help on . . . like what they don't know . . .

M: Uh huh.

K: . . . and then I would help them on it.

M: Okay, and when you're helping, what would you be trying to do?

K: Help them learn . . . like if they didn't know their fractions, I'd help them . . . I'd go over fractions with them [tutoring 2/3/97].

As you can see, Kay did not have any well defined strategies for studying other than redoing the problems and "just know what it is." I worked with her on developing a study sheet for her next test with the guidelines of keeping it to one page front and back, with the vocabulary, procedures, and cautions she wanted to remember clearly written out.

Then I talked to her about how to use the study sheet . . . that she needed to go over it before she went to bed that night and again in the morning before she went to school. This was another successful intervention in terms of her school grades. She made an 87% on her test even though it had both geometry vocabulary and fraction computation on it. The only things she missed were the conversions, which continued to be a problem for her whenever she didn't have the table or a diagram to work with. I haven't pressed

the conversions because in real life she will either use them so often that they will become natural to her or she will have access to the table.

At the end of the following week I had her organize her own study sheet for the test, made some suggestions on it, and reminded her to read through it that night and the next morning. Again she did very well on her test. I think this intervention fit with her natural strength in organization and crystallized for her what she most needed to remember.

SUMMARY OF RESULTS

This study identified and described the impact of learning difficulties on the life-experiences of a 12 year old student named Kay. The study proceeded with an analysis of how Kay makes sense of her world and copes with her learning difficulties, particularly in the areas of mathematics and reading. Then an intervention protocol was used to match elements of constructivist, developmental, cognitive, and language/cultural learning theories with the specific difficulties observed during the tutoring sessions. These elements were implemented in an action research design during tutoring sessions over the 1996-97 school year.

The results of this study centered around the ten types of interventions which were tried:

1. Corrective Feedback
2. The Clinical Interview
3. Use of Visual Aids
4. Pair-Reading with Discussion after Each Paragraph
5. Use of Manipulatives

6. Memory Load Reduction

7. Proactive Teaching

8. Metacognitive Strategies

9. Calculator and Reference Charts

10. Explicit Instruction in Study Skills

Once again, the three types of evidence of learning considered in this study were:

1. school defined achievement as measured or described by school grades and report card, teacher perceptions, and standardized testing.

2. sense-making as assessed through the tutoring interviews, constructivist problem solving tasks and inferences from the student's written work.

3. coping strategies as assessed through (a) professional educational evaluation, (b) observations of student in the classroom, during tutoring sessions, and in other real-life but non-academic settings, (c) interviews with student, parents, teachers, and (d) other psychological measures where available and appropriate.

As discussed in the preceding sections, observations and other evidence from the data log indicated that each of these interventions had some positive impact on Kay's learning. Since some of the interventions overlap (for instance, visual aids and proactive teaching) it is difficult to show conclusively which interventions were most effective. However, several general trends are be identified and discussed below.

In terms of school grades the four most dramatic observed changes were associated with (1) Explicit Instruction in Study Skills,[18] (2) Memory Load Reduction,[19]

[18] See Chapter IV. "Explicit Instruction in Study Skills"
[19] See Chapter IV. "Memory Load Reduction"

(3) Proactive Teaching, [20] and (4) Pair-Reading with Discussion.[21] The Clinical Interview was the most helpful in terms of helping me understand Kay's thought processes and then create appropriate interventions. It resulted in positive change both in meaning-making and school defined achievement as seen in the fraction episode[22]. The Clinical Interview also overlapped the Pair-Reading with Discussion intervention, which showed evidence of learning in school defined achievement and meaning-making. Significant gains in reading, study skills, listening, and spelling were also demonstrated on the standardized testing[23] and the 7-8 point increase in Kay's IQ (see Chapter V, Table 5) indicates some improvement in coping with IQ test sorts of tasks.

The results substantiated the usefulness of the aspects of the learning theories which were applied. It was observed, however, that classroom instruction was in many instances not consistent with such theories and in these cases Kay's learning difficulties were acerbated.

The following chapter discusses some of the implications of these findings, relates them back to existing theory, and identifies needs for further research.

---

[20] See Chapter IV, "Proactive Teaching"
[21] See Chapter IV, "Coping Strategies in Reading"
[22] See Chapter IV, "Clinical Interview"
[23] See Chapter V, Table 5.

CHAPTER V: MAKING SENSE OF IT ALL

INTRODUCTION

This study set out to explore and analyze why reading and mathematics are so problematic for a 12 year old student named Kay. The previous chapter analyzed and discussed the collected data as it related to the first four guiding questions of this study. This chapter will cover the fifth guiding question by relating the discussions from the previous chapter back to existing theory. This chapter will also identify areas for further research.

QUESTION 5: GROUNDED THEORY

In what ways is Kay's case congruent or incongruent with existing theories of learning? What need for elaboration or modification of existing learning theory is indicated by this case? What grounded learning theory or perspective emerges from this case as interpreted in this study?

Overview

Answering this question requires discussing the significance and interrelations among results which have already been presented in other sections. I have tried to footnote the locations of those previous discussions rather than repeat them here.

Everything in my experiences with Kay corresponds to an already existing theory of some kind. What her case highlights is that no one theory or approach is able to respond to all the individual strengths and weaknesses which are so prominent in Kay's case. This is the power of the in-depth case study: we can see how all the threads of experience and personality come together and become a rich, interwoven tapestry underlying the individual's learning processes.

The IQ Debate Revisited

Looking only at Kay's IQ, one would expect characteristics of a fragile learner at risk for school failure, social torment by peers, emotional and social difficulties and long term problems managing even the most basic of life skills. With a full scale score IQ of 84 on the WISC-III in 1993 supported by a similar score of 83 in 1996 , her difficulties in learning can easily be explained away as resulting from lack of innate intellectual ability. These scores place her in the bottom eighteen percent of the population in terms of what is usually interpreted as "ability." The scores are not quite low enough to qualify as "mentally handicapped"; but they are just as close to that range as they are to a mid-range normal IQ.

This case demonstrates, however, that whatever IQ measures, in this case it is not by itself an adequate measure of ability. It may be as Boehm (1985) and Bloom (cited in Brody, 1985) suggest that IQ is more a measure of the speed and efficiency with which a person is able to learn rather than a measure of the ultimate capacity to learn. In Kay's case, she has maintained a slow but steady progress, and is actually beginning to approach on-grade level scores in some subjects where earlier in school she was seriously below grade level.

Table 5 shows a comparison of WISC IQ and Stanford Achievement test scores for Kay over time. The 1997 set were the result of testing done at the parents' request at the end of the school year (which coincided with the end of this study) because they felt that, due to economic reasons, they were going to have to move their children back into the public schools. They wanted to see what kind of educational support services would be available to them.

This testing information cannot be used as a pre-post test assessment of this study since this study was not of a controlled, experimental design. It is included only to show two general trends in Kay's educational history. This first is that Kay is not a very consistent test taker and scores on any one test need to be considered within the context of other scores and her ability to cope outside of testing situations. For example, the 7-8 point difference between her 1997 IQ score of 91 and the previous scores of 83 and 84 is more than twice the ±3 point standard error of measurement for the test (Searles, 1984; Weschler, 1974). Also, Kay now qualifies for special education services in the public schools because she has a "normal IQ" whereas she did not previously qualify because here scores were in the "slow learner" range.

The second trend which these scores show is that Kay is continuing to make educational progress, and is not following the general slow learner pattern of falling further and further behind her peers across all areas of study.

As noted previously, many experts question whether IQ and achievement tests can adequately assess students with learning disabilities – especially language disabilities such as Kay has (Berninger et al.,1992; Reynolds and Kaufman, 1985; Silver and Hagin, 1990). Kay's case appears to support the position that a language learning disability can significantly affect and perhaps invalidate such test procedures and scores. A better way to assess such students is needed.

Table 5: Comparison of Test Results

WISC III Scores

	1993 Diagnostic Evaluation	1996 Diagnostic Evaluation	1997 Diagnostic Evaluation
Full Scale IQ	**84**	**83**	**91**
Percentile		**13**	**27**
Performance IQ	**96**	**89**	**95**
Verbal IQ	**76**	**80**	**89**

Stanford Achievement Test Scores
(National Percentile Ranks)

Subtests	1996 NPR	1997 NPR	Change +	Change −
Total Reading	19	34	+15	
Vocabulary	28	43	+15	
Reading Comprehension	18	32	+14	
Total Mathematics	42	36		-6
Problem Solving	48	39		-9
Procedures	36	36		-0
Language	53	32		-21
Language Mechanics	44	30		-14
Language Expression	60	36		-24
Spelling	35	58	+23	
Study Skills	16	30	+14	
Science	5	9	+4	
Social Studies	9	11	+2	
Listening	12	43	+31	
Using Information	11	20	+9	
Thinking Skills	20	30	+10	
Basic Battery	29	39	+10	
Complete Battery	23	32	+10	

Attributions, Belief Systems, and Expectations

The apparent impact of attributions and belief systems was much as would be expected from current motivation theory. This was discussed in depth in the section on motivation.[24]

The one observation which did not fit with current educational wisdom was that Kay, with a low-normal IQ was placed by her parents. not in a special education or remedial classroom, but in an elite private school with extraordinarily high expectations. It should be noted that, while the expectations were high at the school, students were treated well and not shamed or humiliated in class, nor permitted to harass or make fun of each other. Kindness, gentleness, humility, and self-control (Gifts of the Spirit, Galations 5:22-26, The Bible) were the basis for the overall rule of mutual respect [classroom rules, classroom observations, mother's interview] and were considered very important.

It was not a competitive environment in the regular sense that some students in the class were winners and others were losers. It was competitive in the sense that everyone was expected to put in the effort to do well and was valued for his/her own accomplishments.

I believe it was in part due to this environment of high expectations and caring atmosphere that Kay has progressed as far as she has. She is still expected to learn and achieve, although it is generally acknowledged that it may take her more effort and more time to do so. This combination of high expectations and adaptable time frame seems to

---

[24] See Chapter IV. Question 2. "Motivation"

have been pivotal in Kay's construction of "I don't understand now, but I can learn" which seems to have promoted her high self-esteem, positive motivation, and persistence.

The issue allowing inadequate time in classrooms for most students to "get" the concepts has been noted by researchers such as Boehm (1985), Brody (1985), Romberg and Carpenter (1983), Nunes (1992). Therefore one area in need of research and probably substantial revision in our educational system is the assumption that "covering the curriculum" on a rigid schedule is the best way for students to learn (Ramsden, 1988). In Kay's case, extra time was needed even to work at what Ramsden calls the "surface approach." For most students, what he calls the "deep approach" requires flexibility in both approach and time spent in order for students to focus on deeper meanings: "to understand what is signified rather than just memorize" and "to relate to other practical and theoretical knowledge rather than to focus on tests, grades, and 'getting through'."

Phonological Hypothesis

Phonological processing refers to the brain's processing of speech sounds.[25] In studying children with language disorders, Tallal (in Blakeslee, 1995, 1996) has developed a hypothesis that phonemes with relatively rapid transition time (40 milliseconds) like ba, da, ga, pa, ta, and ka may easily be confused or missed entirely. Children suffering from such slow processing are hypothesized to either compensate by pulling meaning from context or to struggle through life "living in a language fog."

---

[25] See also Chapter IV, Question 5, "Phonological Hypothesis"

Certainly the amount of evidence collected for Kay's fuzzy perception, language deficits, and reading context cues, fit with this hypothesis.[26] I find the "th" episode for fractional naming particularly indicative of this kind of difficulty.[27] Where Tallal has experimented with special computer programs to slow down the speech sound for such children, we simply kept at it until Kay finally heard the difference and made the associations.

Cognition and Memory

My experiences with Kay were congruent with current theories of information processing and memory. The incongruence I experienced in this study was that the educational processes as commonly practiced in the classroom were not congruent with what we know about cognition and memory. Neglecting to give adequate feedback, assuming that a student has the necessary prerequisite skills, assuming that explanation-communication or class discussion has been effectively received without adequately assessing or adjusting, jumping levels of difficulty without additional instruction -- all of these practices were common in the classroom and yet are not congruent with what we know about how people learn.

It is not just "bad" or "old-fashioned" or "lecture-style" teachers who do not apply what is known about learning. I even found myself, despite all my education and experience, stumbling through tutoring sessions with Kay. I found that being successful in the role of "teacher as facilitator" actually involved much more expertise and

---

[26] See Chapter IV, Question 2, "Fuzzy Perception" and "Reading Cues ..."
[27] See Chapter IV, Question 4, "The Clinical Interview"

sophistication in applying learning theory than "direct instruction."[28] A facilitator can't be just a lifeguard or baby-sitter, who stands by watching to be sure no one gets into serious trouble. A facilitator plans, watches, reflects, adjusts. and provides input. A facilitator makes things "facile" or "easy" by smoothing the way. This involves a much more complex combination of the elements of instructional design than does creating programmed instruction, lecture, or worksheet.

To design an effective problem solving situation, class discussion, or educational intervention requires careful attention to everything we know about instructional design. "Teacher as Facilitator" does not imply that the teacher is no longer designing instruction and is simply present as a resource like a book on a bookshelf. "Teacher as Facilitator" means that the teacher is actively involved in the problem-solving process of teaching and learning.[29]

Cognitive Plateaus and Leaps

In working with Kay it became apparent that she often moved along cognitive plateaus, not making much progress, until there was some kind of "ah-ha" experience which pushed her up to a new level of functioning. Kay seemed to make these leaps, not due to the passing of chronological time, but due to the culmination of experiences which reached a critical point and suddenly reorganized into a new understanding. This is congruent with Piaget's stages of cognitive development as described in his later work (Piaget, 1985). Often Kay was unaware of the transition to the new understanding, as in

---

[28] See also Chapter V, "Hope for the Future"

the case of learning how to use standard "th" names for fractions. Once that transition had been made, all of her other learning shifted to accommodate it and it seemed to her as if she had always had that understanding.

This same process of making cognitive leaps may be one of the reasons why teachers "forget" that students don't have the same conceptualizations and previous knowledge as the teacher. We need to become acutely aware of these shifts and their significance. If we don't, then we keep teaching from our experienced perspective to those who haven't had the necessary experiences to understand what we are asking them to conceptualize.

Disparity between Theory and Practice in the Classroom

Many researchers have noted that in general, educational practice in the classroom has not kept step with the results of current research and contemporary models of learning and instruction (Bishop, 1983; Gregg, 1995; Romberg and Carpenter, 1983; Secada, 1992). Looking at Kay's learning compared to other students in her class [teacher's grade book, 9/96 through 3/97; tutoring; school observations] there are many instances in which other students were able to overcome the effects of poor educational practices while Kay was not able to effectively cope with them by herself.

For example, many instances of inaccurate right/wrong feedback occurred while I was present in the classroom, both on written work and in class discussion. While other students could adapt and conform by realizing .75 was the same thing as ¾ but the book wanted the fraction, Kay was unable to make such associations on her own. Similarly,

---

[29] See also Chapter V, "Disparity between Theory and Practice . . ."

more able students would challenge the teacher or the book when feedback didn't make sense to them, while Kay simply accepted such feedback as her error. When some important piece of information was missing from the lesson, the other students would ask. Kay simply assumed that she didn't understand.

It was obvious that some students got their lessons done at home and came to class with them already completed [classroom observations]. This indicates that they had resources for instruction and learning at home which were not available to Kay. The cumulative effect was that poor educational practices were much more devastating for Kay than they were for her more able classmates, who had other means to compensate.

So if we are to have "mathematics for all" we need to examine how and why teachers come out of their training with such a limited repertoire of instructional approaches. Effective teacher preparation needs to be developed in which prospective teachers become much more aware and comfortable with a wide variety of learning theories and instructional strategies. Such preparation must also include methods for identifying the nature of student difficulties and deciding on appropriate interventions. Further research is needed in design of instruction which is not so verbally oriented as well as how teachers can become sufficiently comfortable with these other modalities to actually use them.

It is understandable that teachers have comfort zones which encompass a few often used approaches. But when teachers fixate on one or two facets of a particular theory or approach and fail to adapt readily to their students' varying needs, it is an indication that the comfort zone needs to be expanded.

As noted in the initial assumptions of this study, and supported by the experiences in this study, learning is multi-faceted with many different factors influencing both a student's difficulties and successes. Viewing the instructional situation from several differing learning theory perspectives may provide insights and instructional options which would not be considered, otherwise. So it is important to be able to keep in mind what options are available and have a method for deciding which is appropriate. Research into ways that the intervention protocol idea used in this study could be applied in a classroom situation may be helpful in this area.

GENERALIZABILITY OF THE INTERVENTION PROTOCOL

The usual methodological answer to the question, "How much generalization can you make from a single case?" is that it can only be generalized to other cases which are sufficiently similar (Yin, 1994). Another approach that is often taken is that a case study doesn't generalize to a predetermined population the way a controlled experiment is designed to do. Instead, replication logic comes into play as many case studies are done and the patterns among them are teased out. One of those patterns is a characterization of the population in which the patterns are occurring.

In this case study there is a basis for generalization to any instructional situation. Since all students are unique in their strengths, weaknesses, interests, resources, etc., the principles developed in this study for assessing and making informed decisions about instructional interventions based on that uniqueness should be valid across learning situations. I believe one of biggest potential contributions of this study to be the demonstration of how such an approach can be used with a student and how the approach benefits both the student and teacher alike.

CONCRETE AND ABSTRACT CULTURES – A HYPOTHESIS

Introduction

The relation of a society's predominate culture to its formal educational system has often been examined from philosophical, social, economic, and political perspectives. Each perspective has its own flavor and insights. For instance, the critical theorist perspective looks at formal education in terms of its functions in maintaining the existing political and economic power structures in society (Grundy, 1987). Reformers such as Paulo Freire have looked at how the educational system can promote political oppression (Freire, 1982) as well as the role education can play in liberation (Freire, 1985). Feuerstein (1979) studied how the definition of knowledge and intellectual ability is shaped by our cultural experiences.

Hypothesis of a Concrete-Abstract Cultural Gulf

Reflection on this case study has prompted me to hypothesize a cultural effect which, although often related to ethnic and socio-economic situations, is not entirely defined by those variables. This cultural effect has to do with the difference between knowledge as it is acquired and used in everyday life and knowledge as it is used in abstract, intellectual culture (including, but not limited to school mathematics culture).

Review of Literature

Numerous educators have touched on this aspect in the past. Bishop (1983) speaks of colloquial speech and colloquial learning which are part of the everyday, lived-in experience. Hiebert and Carpenter (1992) have made conjectures about the knowledge

which informs the procedures which students use to solve problems and point to the cultural and experiential sources of that knowledge.

In mathematics, specifically, Nunes (1992) discusses extensively how cultural orientation affects the process of mathematizing reality and recognizing what constitutes the structure of mathematics. Secada (1992) notes that mathematics is a human activity and as such is a cultural artifact. He further notes that the psychological study of people is predicated on specific Western norms which have deeply influenced our beliefs about how people learn mathematics. Erickson (1986) emphasizes that in the process of teaching and learning, the dimension of social organization and the dimension of subject matter organization "are always reflexively intertwined in the enactment of the lesson (p. 136)."

Each of these points-of-view touches on, but does not make explicit, how the student's lived-in culture directly impacts how a student is able to make sense of his/her educational experiences – that is to say, how the student actually learns. Borrowing from developmental learning theory, we could call most students' lived-in cultures "concrete cultures" because they are based on concrete operations rather than abstract operations. These cultures deal with concrete objects and specific situations rather than generalized ideas and abstractions.

A classic example would be the arithmetic capabilities of the Brazilian street children studied by Carraher et al. (1985, cited in Dockrell). The study reported a dramatic difference between the ability to compute prices of items in the marketplace and the ability to compute formal versions of those same problems. The success rate was nearly 100% in the marketplace context, 74% in formal presentation of verbal problems,

and only 37% when the problem was presented in the written symbol form such as 105 + 105.

Similarly, formal education represents "abstract culture" and deals in ideas and generalizations which are manipulated using abstract means such as reason and logic. The difference in how we operate in these two cultures is hinted at by Stephanie Thornton (1995, p. 25) in her work in children's problem solving. She writes:

> Overall, logic is far less relevant even to adult problem-solving than we thought. Forced to think logically, we make mistakes and find the problem hard. In tasks that ought to involve logical inferences, the evidence suggests that we do not in fact use logical processes even though we can draw the inferences. Even professional logicians do not generally use logic in the everyday contexts where that would be the most obvious and appropriate thing to do. Just like children, we adults are more likely to draw on factual knowledge than on logic and our success is more influenced by factors particular to the task in hand than by any consistent general skill.

This same tension is identified by Hilbert (1983) in relation to mathematics when he writes:

> In mathematics . . . we find two tendencies present. On the one hand, the tendency toward abstraction seeks to crystallize the logical relations inherent in the maze of material that is being studied, and to correlate the material in a systematic and orderly manner. On the other hand, the tendency toward intuitive understanding fosters a more immediate grasp of the objects one studies, a live rapport with them, so to speak, which stresses the concrete meaning of their relations.

I believe this case study supports the hypothesis of a serious gap between the lived-in everyday culture and the intellectual/academic culture in which formal, school mathematics operates. But schools must necessarily endeavor to bring students to

operate in that intellectual/academic culture. Otherwise, there is no reason for formal education.

Abstract and Concrete Culture as They Relate to School Experiences

The problem arises because the vast majority of our students come from a concrete culture which exists across lines of gender, ethnicity, and socio-economic status. Also, many of our teachers are also rooted in concrete culture and are not adequately prepared to guide students around in the unfamiliar abstract intellectual culture. Other teachers, who have made the transition to the abstract, find it very difficult to understand how those who have not made the transition are thinking.

When people like Kay come through the schools from a completely different culture (in this case not a particular ethnic culture, but a "concrete" culture) and we do not make the necessary allowances for the transition from the concrete everyday culture to the abstract intellectual culture, we are setting both ourselves and our students up for failure. When we assume that students can go home and talk to their parents about finding mileage or conversions of units we are assuming that the parents are in contact with a reflective, intellectual way of life which operates at the abstract level. The problem is that most people do not actually operate that way. Instead of computing "miles per gallon," most people make a mental note of how many times they have had to fill their gas tank this week, or how much money they have had to spend on gas this month. It is a concrete operation comparing concrete experiences rather than an abstract one involving numerical ratios. Likewise, Kay's comment on conversions was very illuminating: "Why would you

measure in centimeters if you wanted to know how many inches?" The concrete solution is to measure in inches in the first place.

Likewise reading and books are viewed very differently in concrete culture vs. intellectual culture. In concrete culture, reading is a method of getting a job done, like ordering from a menu, using a cookbook, an auto repair manual, telephone directory, or perhaps preparing for a test. In this instrumental culture, reading to children, reading with children, reading for fun or just to learn something are "foreign" ideas.

This "operating in the immediate and the concrete" is part of the daily culture for most people. My hypothesis is that as a cultural effect in education, it is much more pervasive than racial, second language, or SES effects because it would include all of those and more. Understanding the impact of this concrete culture would include understanding those, as well as other cultural parameters, such as handicaps and disabilities.

We who have been enculturated in the intellectual world simply assume that children have books in their home and parents who will read to them, with them, and in front of them. We forget that we come from a different culture and that not everywhere are such activities the usual practice.

Likewise, math teachers assume every student has a ruler at home and is frequently involved in tasks involving measuring with it. Nothing could be farther from the truth. Measuring in homes is most often done by matching up and marking or cutting to size. People even move heavy furniture around and back to where it was before, rather than measuring first to see if it fits in the new location.

If we want schools to provide an introduction into abstract intellectual culture, we need to remember that we are then talking about helping students construct a bridge from one culture to another. Then classroom experiences need to start in their culture and move into the abstract culture, not just once or twice, but as an on-going process like the process of translating back and forth from a familiar language to the one you are just beginning to learn[30].

When Gregg (1995) talks about a "school mathematics culture," I believe he is describing what has been the traditional attempt to bridge between the concrete and abstract cultures. The traditional approach has been reductionistic, based on algorithms and form rather than on meaning. It was also firmly grounded in the belief that the mind must be exercised and that students learn by repetitive practice of procedures. This was further reinforced by the preeminence of Skinnerian behaviorist theory in the United States. In that mindset, teaching and learning were based on breaking down procedures to their smallest components and reinforcing correct performance of those components.

This approach assumed that the whole was simply the sum of its parts and that thinking and problem solving automatically occur with the acquisition of performance skills. What has been missing in such instruction is the interaction between the concrete performance skills and the abstraction of thinking and theoretical problem solving.

To engage students in this interaction we need to develop a better bridge between the concrete and the abstract. In its best possible existence – this bridge-building

---

[30] See also the next section "Language as Mediator".

approach would be sensitive to and proficient in both the concrete and the abstract cultures.

Unfortunately school mathematics in the past has often been an attempt to get from the concrete to the abstract without acknowledging there is a gulf which must be crossed. This is not surprising since, similar to how children move from one stage to another in Piagetian tasks, those who have made the cognitive "leap" to abstract mathematical thinking seem not to realize they have changed their world-view or that they ever thought a different way. This causes a problem when we as educators do not recognize that there is a critical transition which must be developed between the two types of experiences. Too often we teach, not towards building this bridge, but as if the student were already firmly settled on the abstract ground on which we wish the student to operate.

Implications for Teacher Preparation

The implication is that a teacher must be aware of and proficient in the style of operations on both sides of the bridge – in both the concrete and the abstract forms. Curriculum needs to be developed which weaves back and forth between the two cultures, giving students a wide variety of experiences from which to accumulate and organize the patterns and generalizations which would form such a cognitive bridge .

LANGUAGE AS MEDIATOR

One of the major foundations of that bridge is the use of language. Our culture and school system are based on verbal instruction (Cazden, 1986, Romberg & Carpenter, 1986). Lesh, Landau, and Hamilton (1983) have noted that the way language is used in

the classroom can either assist or deter students from understanding and successfully solving problems.

Nunes (1992, p.570) points out that language use in mathematics is particularly tenuous since the "meaning of a mathematical concept is always abstract and its acquisition is represented by the understanding of relations and invariates, not by the recognition of physical objects." Bishop (1983) gives the example of geometry vocabulary which when translated into the native Manus language became understandably ambiguous when "above," "surface," "top," "over," and "up" were all translated into the same, single Manus term.

Erickson (1992) states that these ambiguities are not just a problem for a second-language learner. He notes, "subtle subcultural differences between community and school led to interactional difficulties, misunderstandings, and negative attributions" (p. 135). These include assumptions about (1) appropriate conduct for face-to-face interaction, (2) means of showing attention and understanding by use of non-verbal behaviors, (3) the organization of turn taking in conversation, (4) the uses and meanings of silence, (5) appropriate adult and child roles, (6) appropriate levels of directness and indirectness in communication, and (7) appropriateness of competitiveness, humor, and mock aggression during interactions. These are subtle cultural assumptions which are learned outside the conscious awareness and are therefore especially prone to cause misunderstandings since each person assumes his/her understanding is "just the way it is."

These researchers and theorists have focused on the difficulties experienced by ethnic and second language students. But Kay demonstrates the same difficulties due to her learning disability, and because that type of disability characterizes her home, those

deficits and coping strategies form part of her most basic, concrete cultural experience. The way Kay went about dealing with language and using language in exploration and problem solving indicates that "concrete culture" includes "concrete language" characterized by relative inflexibility in word usage, focus on the immediate present, and focus on the situation rather than the concepts involved.

This type of focus limits concepts to use as "tools" as opposed to fully functional, abstract concepts. Nunes (1992) explains that concepts used in such concrete situations remain "transparent" and endowed with a concrete understanding. A person working in this concrete situation thinks about the situation, not about the mathematical concept. And so Nunes concludes that "everyday mathematics and mathematics education are clearly distinct. Mathematics concepts are tools in everyday life and are objects of study in the classroom."

This transparency of concepts used as tools may be one way to form a bridge between the concrete and the abstract. But we need to be aware of how this transparency is not sufficient to span the entire gulf between the concrete and the abstract. Even with manipulatives and concrete problem situations, there is much that must be done to connect the two cultures meaningfully. There is a strategic need for continued reflection and research in this area if conceptual, abstract mathematics is to become accessible to all.

One related question which I believe needs to be asked and seriously considered is one which Nel Noddings (1996) recently asked in a review of books about equity issues in the mathematics. In that review Noddings wrote,

> Math educators, in their almost evangelical zeal to get "all children to learn mathematics" neglect to ask why mathematics is so valorized in Western culture. The underlying assumption, uncritically accepted, is that

> whatever has been important in the lives of white males must necessarily be important for everyone else. When we worry that girls or African American youngsters are not sufficiently interested in mathematics or mathematical occupations, we forget to ask the question, "What *are* they interested in?" (Noddings, 1994). Careful examination of the answer to this question might encourage us to place a higher value on, for example, the caring professions and the arts. We might even ask, Why are so few white males interested in the caring professions?

Restated in terms of this cultural hypothesis, the questions become: Is there also an artistic or nurturing culture? Are there other cultures or ways of thinking which need to be recognized other than the concrete and abstract? What balance between these competing cultures is desirable in today's world? What sorts of factors affect that decision?" The current assumption that everyone must be able and trained to function in the abstract culture may be faulty. In some ways, this sets us on the horns of a dilemma. If our dominant culture continues to 'valorize' the analytic culture, economic compensation will continue to be higher in those areas. Those of lower SES do not have the experiences, so can not get the higher paying jobs, and therefore continue in the lower SES, maintaining the cycle (Lubienski, 1997). Lubienski's concern is that students of lower SES achieve equity in the mathematics classroom. One solution is to try to make the abstract culture universal. But that is not the only possible solution. We also need to ask, "Does the dominant culture have to continue to be this way? Should it? Or has it been seriously skewed by the scientific/mechanistic age and Western belief systems. Are there other valid ways of knowing and being which should be equally valued and economically rewarded?"

Certainly all ethnic, gender, and socio-economic groups should have equal access to the education which is needed to improve their economic situations, so we must

continue to work on the problem of making mathematics accessible to all. We also need to remember that there may be other choices which should be made accessible and valued, as well.

MATHEMATICS FOR ALL

The initial impetus for this study was that if mathematics is to be for all students, it must be made accessible to students like Kay for whom the traditional classroom is not working well. This study provides evidence that it is possible for a student with "low normal IQ" who is a "slow learner" to achieve far more than such an IQ would lead us to believe.

The questions we need to research now are "how was this possible?" and "how can we do this with other students?" My own analysis of these questions involves looking at how constructivist and cognitive approaches can be complimentary in the instructional process. Briefly, my analysis is as follows.

In this study constructivist and cognitive learning theories informed the instructional process. Both constructivist and cognitive theorists recognize prior learning as a key component for the subsequent learning or meaning-making in which a student engages. Constructivism emphasizes the individual uniqueness of these previous constructions, whereas, cognitive theorists such as Gagne regard them as generally discernible preconditions which can be deduced by doing "task analyses."

In this study, the noted instances in which Kay's learning was hindered by lack of previous knowledge and experiences, were the situations which were <u>not</u> unique to Kay. Each one would have been included in a careful task analysis which did not make assumptions about what she would automatically "just know" from her ordinary,

everyday, lived-in culture. It was the assumption of this knowledge without any confirmation, not some bizarre or truly unique individual constructions on Kay's part, which blocked the new learning from occurring.

Still, there were unique constructions which affected the process, as well. In particular, Kay's construction of "I don't understand this now, but I will if I keep at it" is an attitude which was an individual and unusual construction given the situation. It may be that the construction part of learning has more to do with attitudes and beliefs than it does with actual development of knowledge. In some ways, we have a choice about our attitudes and beliefs, whereas the "body of knowledge" is assumed by most, at least from within the concrete culture, as immutable. But there is a fine line between what we "believe" and what we "know." Some would even say it is non-existent and that we only believe and never really know.

The significance of such a debate comes down to whether there is a body of knowledge which can be taught – for which task analyses may be done. In the everyday world of school, it is assumed that such a body of knowledge exists and can be taught. The need for both approaches becomes evident when we recognize, first, that making a task analysis is not nearly as easy or self-evident as it would be if we could assume that everyone has the same initial understandings, and second, that our belief systems about the world and about learning are at least as important as any facts and strategies which we may learn.

Therefore as teachers we need to attend to both the idiosyncratic constructions of the individual and the general body of knowledge which our culture values and how those

are interrelated in the process of teaching and learning. Careful thought, reflection, and research needs to continue in the examination of these issues.

HOPE FOR THE FUTURE

Another way of looking at this would be to frame teaching and learning as complimentary problem solving processes – a dance in which student and teacher move together, back and forth, between the concrete and the abstract cultures – between the familiar and the unfamiliar – and between the thoughts and perceptions of one another. The teacher and student are learning from each other. Both are engaged in the process of trying to understand the other. Both are using the skills they possess to solve this problem of communication and understanding. Both are making individual constructions about their experiences together. "Good" teachers are trying to solve the problem of how to teach effectively. "Good" students are trying to solve the problem of how to learn well and efficiently. When these two groups work together, amazing progress can be made, not only for the present situation, but as a growth experience which makes future situations easier and more successful for both of them.

I do not believe there is any one "good" teaching method. That has been the premise throughout this study. What makes good teaching is integrity: we do as much as we can. If we as teachers are not still learning and trying new approaches, then we really are not doing as much as we can. One advantage of the intervention protocol used in this study is that it helps the teacher figure out what to try next. This keeps us from falling into the "naming and blaming" method of dealing with unsuccessful students. If we name our difficult students "slow learners" or blame their difficulties on "laziness" and

consequently give up on them, we are at a dead-end and so are the students. As an alternative, looking at what we might try next, keeps the possibilities open.

This is not to say that teachers are responsible for solving all of their students' problems – even their learning problems. No one can deal with every individual problem of every student in a class all of the time. What I do believe is that it is important for the teacher to consider teaching as a problem solving process. The problems are just that – problems which may or may not be solved today – but they must be recognized as problems which need to be thought about and about which decisions must be made. Let us make this a thoughtful, conscious process and not just an assumption that some kids just can not or will not learn.

REFERENCES

Ackerman, P., Dykman, R., & Oglesby, DM. (1994). Visual event-related potentials of dyslexic children to rhyming and nonrhyming stimuli. ***Journal of Clinical and Experimental Neuropsychology, 16,*** pp. 103-118.

Babbitt, B., & Van Vactor, J. (1993). A case study of mathematics learning disability in a prospective teacher. ***Focus on Learning Problems in Mathematics 15,*** pp. 23-37.

Bishop, A. (1983). Chapter 6: Space and geometry. In Lesh, R. and Landau, M., (Eds.), ***Acquisition of mathematics concepts and processes***, pp. 175-203. Orlando: Academic Press.

Blakeslee, S. (Nov. 14,1995). Glasses for the ears: Easing children's language woes. ***New York Times, 145***, p. C1(L) col. 4.

Blakeslee, S. (Aug. 16, 1994). New clue to cause of dyslexia seen in mishearing of fast sounds. ***New York Times, 143,*** p. B7(N), p. C1(L) col. 1.

Bley N. and Thornton, C. (1989). ***Teaching mathematics to the learning disabled.*** Austin, Texas: Pro-Ed.

Boehm, A. (1985). Chapter 23: Educational applications of intelligence testing. In Wolman, B., (Ed.), ***Handbook of intelligence: Theories, measurements, and applications***. New York: John Wiley & Sons.

Brackacki, G., Fawcett, A., & Nicolson, R. (1994). Adults with dyslexia have a deficit in voice recognition. ***Perceptual and Motor Skills, 78***, pp. 304-306.

Brody, N. (1985). Chapter: The validity of tests of intelligence. In Wolman, B., (Ed.), ***Handbook of intelligence,*** pp.353-390. NY: John Wiley & Sons.

Castles, A. & Coltheart, M. (1996). Cognitive correlates of developmental surface dyslexia: A single case study. ***Cognitive Neuropsychology, 13***, pp. 25-50.

Cawley, J. (1985). ***Cognitive strategies and mathematics for the learning disabled.*** Rockville, Maryland: Appen Systems Corp.

Cazden, C. (1986). Chapter 15: Classroom discourse. In Wittrock, M., (Ed.), ***Handbook of research on teaching, third edition,*** pp. 432-463. New York: MacMillan Publishing Company.

Chard, D. & Kameenui, E. (1995). Mathematics instruction for students with diverse learning needs: Heeding the message of the cheshire cat. ***Focus on Learning Problems in Mathematics,17***, pp. 24-38.

Cobb, P. & Steffe, L. (1983). The constructivist researcher: Teacher & model builder. ***Journal for Research in Mathematics Education, 14***(2), pp.83-94.

Cumming, J & Elkins, J. (1994). Are any errors careless?. ***Focus on Learning Problems in Mathematics, 16,*** 21-29.

Davis, H., Bryson, S., & Hoy, C. (1992). Case study of language and numerical disability: A sequential processing deficit? ***Annals of Dyslexia, 42***, pp. 69-89.

deBettencourt, L., Putnam, R., & Leinhardt,G. (1993). Learning disabled students' understanding of derived fact strategies in addition and subtraction. ***Focus on Learning Probems in Mathematics, 15***, pp. 27-43.

Dockrell, J. & McShane, J. (1993). ***Children's learning difficulties: A cognitive approach***. Cambridge Massachusetts: Blackwell.

Erickson, F. (1986). Chapter 5: Qualitative methods in research on teaching. In Wittrock, M. (Ed.), ***Handbook of research on teaching, third edition***, pp. 119-161. New York: MacMillan Co.

Feuerstein, R. (1979). ***The dynamic assessment of retarded performers: The learning potential assessment device: Theory, instruments, and techniques***. Baltimore: University Press.

Fleischner, J. & Marzola, E. (1987). Chapter 6: Arithmetic. In Kavale, K., Forness, S., & Bender, M., (Eds.), ***Handbook of learning disabilities vol. II: Methods and interventions,*** pp. 89-110.

Fleischner, J. and Garne, K. (1987). Arithmetic difficulties . In Kavale, K., Forness, S., & Bender, M., (Eds.), ***Handbook of learning disabilities vol. I: Dimensions and diagnosis,*** 189-209.

Freire, P. (1982). ***Pedagogy of the oppressed***. New York: The Continuum Publishing Corporation.

Freire, P. (1985). ***The politics of education: Culture, power, and liberation.*** Massachusetts: Bergin and Garvey Publishers, Inc.

Gillis, J., DeFries, J., & Fulker, D. (1992). Confirmatory factor analysis of reading and mathematics performance: A twin study. (7th International Congress on Twin Studies). ***Acta genet med gememllol, 41,*** pp. 287-301.

Gillis-Light, J., & DeFries, J. (1995). Comorbidity of reading and mathematics disabilities: Genetic and environmental etiologies. ***Journal of Learning Disabilities*** 28, pp. 96-106.

Gregg, J. (1995). The tensions and contradictions of the school mathematics tradition. ***Journal of Research in Mathematics Education,*** 26, pp. 442-466.

Gross-Tsur, V., Manor, O., & Shalev, R. (1996). Developmental dyscalculia: Prevalence and demographic features. ***Developmental Medicine and Child Neurology*, 38,** pp. 25-33.

Gross-Tsur, V., Manor, O., & Shalev, R. (1993). Developmental dyscalculia, gender, and the brain. ***Archives of Disease in Childhood, 68***, pp. 510-512.

Grundy, S. (1987). ***Curriculum: Product or praxis***. London: The Falmer Press.

Hiebert, J. & Carpenter, T. (1992). Chapter 4: Learning and teaching with understanding. In Grouws, D., (Ed.), ***Handbook of research on mathematics teaching and learning,*** pp. 65-97. New York: MacMillan.

Hilbert, D. & Cohn-Vossen, S. (1983). ***Geometry and the imagination.*** Translated by P. Nemeyi. New York: Chelsea

Hittmair-Delazer, M.., Sailer, U., & Benke, T. (1995). Impaired arithmetic facts but intact conceptual knowledge -- A single-case study of dyscalculia. ***Cortex 31,*** pp. 137-147.

Hutchinson, N. (1993). Students with disabilities and mathematics education reform – let the dialogue begin. ***Remedial and Special Education (RASE), 14***, pp. 20-23.

Hynd, G. (1995). Dyslexia and corpus collasum morphology. ***Journal of the American Medical Association (JAMA), 16***, p. 1244.

Kennedy, L. & Tipps, S. (1991). ***Guiding children's learning of mathematics***. Belmont, California: Wadsworth Publishing.

Langenbach, M., Vaughn, C. & Aagaard, L. (1993). Chapter: A pedagogical model to enhance the conceptual understanding of educational research. In ***A broad introduction to educational research***. Allyn & Bacon Press.

Larsen, J., Hoien, T., & Odegaard, H. (1992). Magnetic resonance imagining of the corpus callosum in developmental dyslexia. ***Cogntive Neuropsychology 9,*** pp. 123-134.

Lewis, C., Hitch, G., & Walker, P. (1994). The prevalence of specific arithmetic difficulties and specific reading difficulties in 9- to 10- year-old boys and girls. ***Journal of Child Psychology and Psychiatry 35,*** pp.283-292.

Lubienski, S. (1997). Chapter 5: Class matters: A preliminary excursion. In ***NCTM 1997 yearbook: Multicultural and gender equity in the mathematics classroom: The gift of diversity***, pp. 46-59.

Martin, D. (1992). Maximizing intellectual potential in today's learner: Can we really improve students' thinking? ***Focus on Learning Problems in Mathematics 14,*** pp. 3-13.

Montague, M. (1995). Cognitive instruction and mathematics: Implications for students with learning disorders. ***Focus on Learning Problems in Mathematics 17.***

Morris, A. (1995). Meaningful instruction in fractions: Implementing a theory in a low-achieving mathematics classroom. ***Focus on Learning Problems in Mathematics 17.***

NCTM. (1953). ***The learning of mathematics: It's theory and practice. Twenty-first Yearbook.*** Washington, DC: NCTM, pp. 157-219.

NCTM. (1989). ***Curriculum and evaluation standards***. Reston, VA: NCTM.

NCTM. (1991). ***Professional standards for teaching mathematics***. Reston, VA:

NCTM.

Noddings, N. (1994). Does everybody count? ***Journal of Mathematical Behavior, 13,*** 89-104

Noddings, N. (1996). Equity and mathematics: Not a simple issue – A review of four new titles. ***Journal for Research in Mathematics Education, 27,*** 5, pp. 609-615.

Nunes, T. (1992). Chapter 22: Ethnomathematics and everyday cognition. In Grouws, D., Ed., ***Handbook of research on mathematics teaching and learning***, (pp. 557-574). New York: Macmillan.

O'Hare, A., Brown, J., & Aitken, K. (1991). Dyscalculia in children.. ***Developmental Medicine and Child Neurology, 33,*** pp. 356-361.

Peshkin, A. (1988). In search of subjectivity – One's own. ***Educational Researcher***, Oct. 1988, pp. 17-21.

Piaget, J. (1973). ***Psychology of intelligence***. Tokowa, NJ: Littlefield, Adams & Co.

Piaget, J. (1985). ***Equilibration of cognitive structures***. Chicago: University of Chicago.

Ramsden, P. (1988). ***Improving learning: New perspectives***. New York: Kogan Page, Nicholoas Publishing Co.

Reynolds, C. & Kaufman, A. (1985). Clinical assessment of children's intelligence with the WISC scales. In Wolman, B., (Ed.), ***Handbook of intelligence: Theories, measurements, and applications.*** NY: John Wiley & Sons, pp. 601-662.

Risey, J. & Briner, W. (1990). Dyscalculia in patients with vertigo. ***Journal of Vestibular Research,*** **1**, pp. 31-37.

Romberg, T. & Carpenter, T. (1986). Chapter 29: Research on teaching and learning mathematics: Two disciplines of scientific inquiry. In Wittrock, M., (Ed.), ***Handbook of research on teaching, third edition.*** New York: MacMillan. pp. 850-873.

Secada, W. (1992). Chapter 25: Race, ethnicity, social class, language and achievement in mathematics. In Grouws, D., Ed., ***Handbook on research on mathematics teaching and learning***, pp. 557-574. New York: MacMillan.

Shalev, R. & Gross-Tsur, V. (1993). Developmental dyscalculia and medical assessment. ***Journal of Learning Disabilities, 3***, pp. 134-137.

Shalev, R., Manor, O., Amir, N., Wertman-Elad, R., & Gross-Tsur, V. (1995). Developmental dyscalculia and brain laterality. ***Cortex 31,*** pp. 357-365.

Siegel, L., Share, D., & Geva, E. (1995). Evidence for superior orthographic skills in dyslexics. ***Psychological Science, 6***, pp. 250-254.

Silver, A. & Hagin, R. (1990). ***Disorders of learning in childhood***. New York: John Wiley and Sons.

Spafford, C., & Grosser, G. (1996). Chapter 8 : Math disabilities and remediation. In ***Dyslexia: Research and resource guide,*** pp. 196-238. Boston: Allyn & Bacon.

Stake, R. (1994). Chapter 14: Case studies. In Denizen, N. and Lincoln, Y. (Eds.), ***Handbook for qualitative research***, pp. 236-247.

Sutaria, S. (1985). ***Specific learning disabilities: Nature and needs***. Springfield, Illinois: Charles C. Thomas.

Thornton, S. (1995). ***Children solving problems***. Cambridge, Massachusetts: Harvard University Press.

Vocate, D. (1987). ***The theory of A. R. Luria: Functions of spoken language in the development of higher mental processes***. Hillsdale, NJ: LEA.

Weschler, D. (1974). ***Manual for WISC – Revised.*** New York: Psychological Corporation.

Yin, R. (1994). ***Case study research: Design and methods***, (2nd edition). Thousand Oaks:Sage Publications

APPENDICES

APPENDIX A – GLOSSARY

Acalculia.
(also called number blindness). A loss of ability in adults to calculate or perform mathematical functions as a result of brain injury.

ACID profile
Substantially lower scores on the arithmetic, coding, information and digit span subtests of the WISC or WISC-R which has been associated with the existence of learning disabilities.

Agnosia.
An inability to understand incoming stimuli.

Alexia.
A loss of ability to read in adults as a result of brain injury.

Anarithmetria.
Difficulties in performing arithmetic operations, associated with brain injury.

Aphasia
A disorder in language, either in understanding or in making use of it in self-expression, or both.

Apraxia
An inability to send out a comprehensible message, either motorically or verbally.

Bilateral
Involving both hemispheres or both sides

CAT-scan
Computerized Axial Tomography – a method of imaging internal organs using x-rays

Central Aphasia
An inability to integrate verbal learning, to think; disorder in inner language

Confused Laterality
Confusion about the two sides of the body; lack of a clear preference for one side resulting in switching back and forth between the two sides

Disorganization
: This is characterized by random, haphazard approach to task performance

Distractibility
: Easily distracted from tasks at hand by extraneous stimuli

Dyscalculia
: A disorder in dealing with quantitative concepts and computational processes

Dysgraphia
: Inability to coordinate visual-motor patterns to produce legible handwriting

Dyslexia
: Severe disability in the process of decoding due to neurological dysfunction

Dysnomia
: Inability to recall words to use in spontaneous speech

Echolalia
: Repeating parrot fashion without any understanding

EEG
: Electroencephalogram – recording the electrical activity of the brain

Finger agnosia
: An inability to recognize or identify own individual fingers by touch

Finger-gnosis
: Being able to recognize or identify own individual fingers by touch

Figure-ground disturbance
: Inability to pick out form from its surrounding background

Gerstmann syndrome
: A cluster of symptoms consisting of disorders in left-right discrimination, finger discrimination, handwriting and mathematics.

Gyrus
: A fold in the cerebral cortex; a convolution

"Hard" signs
: Readily diagnosable, generally associated with brain trauma as in epilepsy, cerebral palsy, mental retardation

Inversions
: Upside down forms such as n for u or m for w

IQ
: "Intelligence Quotient". Computed from an Intelligence test, it is the ratio of the mental age to the chronological age of the person

Kinesthesia
: The sense of movement of muscles and the perception of weight, resistance, and position

Kinetic
: Involving motion

LD
: Common abbreviation for learning disability.

Learning Disability
: a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, which may manifest as imperfect ability to listen, speak, read, write, spell, or do mathematical calculations.

Left-right disorientation
: An inability to distinguish left from right, causing confusions about directions in space

Lesion
: Any change in tissue due to disease or injury

Lobe
: General parts of the brain. Each cerebral hemisphere has a frontal, temporal, parietal, and occipital lobe

Minimal Brain Damage
: A presumption of an injury in the central nervous system, made on a basis of its consequence which is a cluster of behavioral characteristics called "soft" signs

Morphology
: structure and form of a body

MRI
: Magnetic Resonance Imaging is a non-intrusive, non-radioactive method of recording images of internal organs

Neurolinguistic

Used by Luria to refer to a field of study that investigates the neurodynamics underlying linguistic structures

Neuropsychology

Used by Luria to refer to the field of study that correlates human behavior with brain anatomy/neurology

Nonverbal apraxia

Inability to perform self-help skills

Orthographic Configurations

The written shape or spelling of a word as opposed to its sound.

Overloading

Overtaxing the input, output systems causing hindrance in making associations and transformations

Paradigmatic

Hierarchical, vertical dimension of language or its scheme for storage. Based on associative connections which may be phonetic, morphological, or semantic in nature

Paragraphia

Writing a word which was not intended

Paralexia

Substituting a synonym for a word which may be difficult to read

Perseveration

A tendency to persist in a task or an idea once begun, beyond its appropriateness; inability to make a mental or motor shift

Phonemes

The smallest units of speech which serve to distinguish one utterance from another in a language or dialect. In English, speech sounds like ba, da, ka are phonemes.

Phonological Processing

Refers to the brain's processing of speech sounds

P.L. 91-230

U.S. federal law passed in 1969 which defined specific learning disability. The current discrepancy definition is derived from this law

P.L. 94-142

U.S. federal law passed in 1977 which mandated public education for all handicapped children in the least restrictive environment possible

Poor body concept (body image)

Poor knowledge of one's body and its position in space

Praxis

In neurology refers to the ability to carry out purposeful movements by an individual with normal motor strength, reflexes, and coordination, and who had a normal comprehension of the act to be carried out.

Receptive aphasia

Inability to understand spoken words

Reticular formation

central core of the brain stem, comprises much of the central portion of the medulla oblongata, diffuse mixture of gray and white matter which contains many types of neurons. Has an important role in conscious states and attention

Reversals

Mirror image of forms such as b for d

Rotations

Turned-around forms such as b for p or q

Sagittal

The sagittal plane divides the body into right and left halves.

Semantic Aphasia

Speech defects manifested in inability to simultaneously handle the relational synthesis of concepts formed by language. Generally results from lesions to the tertiary zones of the temporal-parieto-occipital areas

Semantic conditioning

Establishing a conditional reflex to a particular word

Social imperception

Inability to recognize and conform to socially acceptable behaviors

"Soft" signs

Signs which are not readily detectable, suggesting a possible minimal brain dysfunction, such as problems in motor coordination or confusion in directionality.

Stimulus-bound (also called concrete behavior)
: Attracted to the immediate, physical or functional properties

Strephosymbolia
: Confusion in the order in which letters are recognized, resulting in word reversals

Unilateral
: Involving any one of the cerebral hemispheres

Vestibular
: Having to do with the central cavity of the bony labyrinth of the ear or parts of the membranous labyrinth that it contains.

WISC and WISC-R
: Wechsler Intelligence Scale for Children – an IQ test commonly used as part of a learning disability analysis

Word calling
: Decoding words without understanding their meanings.

APPENDIX B – LITERATURE SEARCH PROCEDURES

Topic: The general topic was research on dyscalculia, dyslexia, and/or mathematics learning disabilities. I was looking for information that links these topics or discusses possible interventions. I was particularly interested in any material on brain function in regard to either dyslexia or dyscalculia (especially if it was specifically related to learning).

Some reading has indicated that dyslexia is being looked at now as both an auditory and visual deficit. I wanted to know more about that, as well.

I particularly wanted to identify articles written in English, published since 1990.

Since this database search was for my dissertation, I needed a comprehensive review of material from scholarly journals, dissertations, etc. I was interested in the relative numbers of hits in the separate areas so I could defend my topic in terms of a unique contribution to the field. For instance, a low overall count in the intersection of all four terms would actually be helpful because it would show that not much has been done, looking at all those perspectives at once.

Since I was trying to understand the student I was studying from multiple perspectives, it was not necessary for a hit to include all four main ideas to be useful.

Articles which did not mention mathematics at all might be valuable for information which would lead to general instructional strategies or explanation of learning difficulties in general.

Databases: This describes the search done on PsychInfo. Similar searches were also done on ERIC and MEDLINE using their specific controlled vocabulary.

Breakdown of search topic into concepts.

Concept 1	Concept 2	Concept 3	Concept 4
dyslexia	dyscalculia	learning	brain

Possible search terms for each concept. ? is the wildcard symbol in PsychInfo.

dyslex?	dyscal?	learn?	brain?
reading	acalcul?	teach?	lateral dominance
reading difficulties	dysmath?	math? education	left brain
alexia	mathematical ability	educ? diagnos?	right brain
remedial education	visual?	elem? school stud?	brain map
visual	auditor?	disabil?	MRI

Other promising descriptors found in the first few hits:

minimally brain damaged & dyslexic children	auditory perception
therapeutic intervention	dichotic stimulation
treatment and intervention	neurolinguistic?
interhemispheric interaction	neurophysiology
learning disorders and mental retardation	short term memory

Search Strategy:

Since part of the purpose is to show relative amounts of current literature existing in these areas, I set up the strategy to create seven separate concept clusters so I could get separate counts on the topics. These cluster sets were:

DYS = dyslex? or dyscal? or dysmath?

LD = learning disorder? or special education or educational diagnos? or remedial education

NEURO = neurophysiolog? or neuropathology?

INTERV =(therapeutic or treatment) ( ) intervention?

AV = (auditor? or visual?) and (memory? or learn? or perce?) I ended up putting the "and" clause in this one because the recall was so huge on just the first part.

BRAIN = brain and (map? or MRI or lateral dominance)

MATHED = mathematics education

Then I put the clusters together into one set which I called my "basic set." The strategy for the basic set was:

BASIC = **(DYS** or **LD)** and **(NEURO** or **AV** or **BRAIN)**

I limited that set by age, language of article, and date. I did this after putting the clusters together so I only had to do it once. Also, it means I have the seven separate searches on my disk going back as far as the database does, if I need them. Age had been a concern in the recall of an early strategy, because I got geriatric neuropathology which didn't address my topic at all.

Then I removed duplicates. There were 1,442 removed. Again I had waited until this step so I would only have to do it once.

I saved the strategy both at Dialog and on disk.

Then I created my target sets by breaking out the 176 articles of the basic set into four sets and sorted each by author, publication year, and date.

The four target sets when I was finished were:

BASIC = all of the basic set

LEARN = basic and learn?

MATH = basic and math?

TREAT = basic and (treatment? or intervention?)

I printed out the bibliographic data and abstracts for each of these four target sets. From the descriptions given in the abstracts, I selected 67 items which looked most promising and located them either in our library or through library loan. These were the basis of my periodical literature review.

Summary and Evaluation of Results

Table of Initial Hits in CLUSTER SETS

DYS	LD	NEURO	INTERV	AV	BRAIN	MATHED	BASIC (raw)
2,070	13,808	7,221	945	45,703	2,538	2,585	1,143

Results of Limiting Strategies on BASIC Set

Raw Basic Set	Remove Duplicates	Not Elderly	/Eng	and PY=1990:1996
2,585	1,143	1,137	1,017	174

Results of Creating the Target Sets

	BASIC (=overall)	MATH	LEARN	INTERV
Total Records	174	10	63	13
Usable	163	9	63	10
Precision	93.6%	90%	100%	76.9%

I have significantly reduced the number of false drops (off-topic records returned) since my first attempt. In my basic set of 174 articles, I have 93.6% precision. It looks like the false hits either have to do with gifted education being within special education or intervention in diseases like alcoholism which cause brain damage. I didn't exclude "gifted" because some of the studies are looking at exceptionally good functioning of the

brain in the same areas where I am looking for deficits. But then some are just about gifted learning and don't apply at all.

I could have pulled out alcoholism, but some studies of fetal alcohol syndrome include brain studies that might be of interest. FAS is an area of interest of mine, anyway, so I left them in just to have them. However they are not really legitimate "hits" for the expressed purpose of this project. Also, very few of them made the final cut to the target sets.

The strategy in this paper represents the best of my many efforts to do this search. All of the "hits" from earlier attempts are present in at least one of the target sets. That makes the estimate of pertinent item recall 100% from these data bases.

APPENDIX C– ANTICIPATED ETHNOGRAPHIC VARIABLES

Physical -- Genetics, Health, and physical development

Family Environment
- expectations
- structure and support
- level of encouragement
- level of acceptance
- beliefs about learning and about education
- level of other family members' educational achievement
- SES
- religious/moral beliefs

School Environment
- expectations
- structure and support
- beliefs about learning
- types of instruction and instructional activities
- level of individualized instruction
- level of accommodation to special needs
- level and type of feedback provided
- social acceptance by other students
- teacher's perceptions of both ability and performance
- communication between school and home
- school's involvement of parents and home in learning process

Internal to Kay
- expectations
- self-efficacy
- level of motivation
- motivating factors (learning goal, performance goal . . .)
- beliefs about learning
- interests and hobbies
- attention span
- memory
- patterns of perception (visual, auditory . . .)
- identifiable disabilities or deficits
- "achievement"
- level of mathematics understanding /construction of mathematical ideas
- cognitive and metacognitive strategies
- level of satisfaction with current functioning (strategies being used)
- ability and willingness to verbalize
- ability and willingness to reflect on activities or strategies

Tutoring Environment

- types of activities – methods employed
  - underlying learning theory
  - level of tutor directive or non-directiveness
  - level of communication
  - purposes for the activities
    - passing at school
    - understanding material
- affective tone of sessions
- time of day/length of session
- performance and retention

Tutoring Environment

- types of activities – methods employed
  - underlying learning theory
  - level of tutor directive or non-directiveness
  - level of communication
  - purposes for the activities
    - passing at school
    - understanding material
- affective tone of sessions
- time of day/length of session
- performance and retention

antecedent and consequent events
Piagetian Developmental theory:
developmental experiences and growth
Special Education / Learning Disability research and theory:
controlled environment, methods of compensation
Cognitive and Metacognitive theory:
input, processing, strategy, metacognitive awareness
Psycholinguistic theory:
Constructivist theory:
careful attention to individually constructed meanings,
challenging inadequate constructions
explaining and "proving" ones one thinking

Action question

4. When alternative strategies and experiences are used, how does Kay respond? Are there patterns to the types of new strategies or experiences she adopts and applies? Are any of them effective for her?

strategy used
how used
response
effectiveness

APPENDIX E – RESEARCHER'S PHILOSOPHY AND SUBJECTIVITY

PERSONAL RESEARCH PHILOSOPHY

At the beginning of my graduate program, if I had been asked (and had answered candidly), I would have said that I didn't believe in "research" at all. In my experience research was a rule of conversation which said that when the person in power quoted research, that person became unquestionably infallible. I suppose it is a good example of how one constructs reality out of experience. Whenever someone quoted research to me, it was in the context of "I'm right and you're wrong" or "this is how we are going to do it . . . you've been told your opinion: now stick to it!" It seemed like a consistent pattern: at home, at school as a student, at school as a teacher and counselor, and even at the university as a graduate student.

I find, now, that with a more balanced appreciation of what research theory itself claims it can and can not do, the old "unquestionably infallible" definition of research is without any basis. It is a distorted carry-over from the culture of hard science, or, perhaps sometimes simply a power-play used in service of personal or political agendas. Along with the critical theorist understanding of research, I believe that social science research is often used as a method of control and manipulation by those in power. It is the preferred bludgeon of the intellectual elite . . . an academic parallel to the fundamentalist claim "God says. . ."

So when I (very quietly in my heart-of-hearts) said to myself that I didn't believe in research, I meant I didn't believe in using research the way I had seen it used – as an infallible absolute – or as a bludgeon in service of a particular agenda.

In terms of the conceptual scaffold of research types by Langenbach, Vaughn, & Aagaard (1993), research philosophy can be conceptualized as the intersection of positions along three orthogonal axes which represent three dimensional continuums: the philosophical dimension, the methodological dimension, and the ideological dimension. The first dimension represents the philosophical continuum from Naturalism ,which is concerned with constructing reality and seeking perspective, to Rationalism, which appeals to logic and sense-data in seeking ultimate truths. The second dimension represents the methodological continuum from completely quantitative (reduced to numerical summarization and statistical analysis, "objective") to completely qualitative (narrative ,descriptive, and subjective) methodology. The third dimension represents the ideological continuum from status quo, which is neutral in regard to seeking change, to radical, which seeks to use research to effect solutions to existing problems.

In this model I am probably on the naturalism end of the naturalism - rationalism continuum, because I am seeking perspective, seeking to understand, and being aware that ultimately I see and understand from my own unique set of values and experiences.

On the status-quo to radical change continuum I am somewhere in the middle. I think both sides ought to be considered and weighed. Most issues which involve any complexity at all, are not a matter of which method is best . . . but of when and where and how a particular method might be better than another Any time research is used simply to support a "program," whether the "status quo" program or a "radical change" program, it is being used once again as a bludgeon.

On the qualitative-quantitative continuum I still have mixed feelings. I think my own strength lies in the qualitative method of data analysis. I've been reading cues and

making inferences all my life. I have used that kind of data analysis much more often and more effectively than I have quantitative analysis in day to day life. So on a personal level, despite being a math person, I value and trust qualitative analysis more – or at least feel it should always be included. It seems to me it is like the Mr. Spock/Data dilemma from StarTrek – without the qualitative dimension, something significant is missing – particularly if you are dealing with human beings.

That valuing doesn't extend universally to trusting just anyone's qualitative analysis. Knowing the context of "who did the research, out of what background, and for what purpose" is every bit as important to evaluating the meaning and usefulness of qualitative research as carefully knowing the sampling technique and experimental methodology is to evaluating quantitative analysis.

SUBJECTIVE I'S --Reflections on my own subjectivity in this case study

The first awareness I came to was that I was following a life-long pattern of trying to "save" somebody. I have always been drawn to people who were "wounded" in some way. It is a classic symptom of being the oldest child of an alcoholic. But knowing that, and years of reflecting on it in therapy, did not stop the pattern. It did, however, come to my awareness, early on, in this situation, and allowed me to make a conscious decision about whether I wished to be involved in another one of "those" situations. Along with that were thoughts about how teaching has been that same kind of cathartic activity for me. My passion for "good teaching" which does not injure the student (emotionally, intellectually, or physically) and which makes the process as painless as possible is all part of that same personality trait. That orientation keeps coming up in my research interests . . . not just to help this particular student, but to improve theory and practice to benefit

students at the level of understanding the individual. In Peshkin's (1988) style of analysis, this is strong source of motivation, understanding, and sensitivity to bring to a study of this kind. At the same time it continues to loom as a fog bank which can blur the distinction between Kay's experiences and my own.

As an example, it showed up in my reaction to Kay's IQ test scores. They are very different from my own, which fit more of a "gifted, maybe mildly learning disabled" profile. My first reaction was, "Oh no! That means I have nothing to offer her!" which shows how much I was working from out of my own experiences.

Another example would be how I interpret Kay's silences. I once wrote an entire paper on the possible meanings of a client's silence in counseling sessions. I equate certain types of silence with my inability to put ideas immediately into words. For me, that is not at all a fluid transition. I have in therapy described myself as feeling similar to the autistic character played by Dustin Hoffman in Rainman. I have profound difficulty spontaneously putting my thoughts into words. (Writing turned out to be my salvation – with writing I can take my time, rewrite, adjust expression to fit my intended meanings, and go back to pick up thoughts from what is already written when my mind suddenly "goes blank.") That is how I broke the vicious cycle of silence for myself.

Part of my silence was related to the "don't talk about it" and "don't feel" rules of the alcoholic family. I've wondered if part of it is something like a petit-mal seizure . . . or maybe simple lack of practice speaking spontaneously resulting from the social isolation I grew up in.

Anyway, in terms of what it might contribute positively to the study, it is an intimate understanding of living in a world that is painfully not-quite-like everyone else's –

of not being able to totally trust one's perceptions or abilities – of being able to cover-up for the "defect" but always having to be on-guard against it being uncovered or ridiculed.

Negatively, it could again cause a blurring between my experience and hers. I must always keep in focus that she and I have very different anchors of strength and compensation: hers are her family, organizational, and social skills, while mine are "intelligence" and educational opportunity.