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Integrative Approach of Mathematical Learning Disability

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I. Introduction

Many investigators have determined the prevalence of learning disabilities. Every year, approximately 5% of all children in public schools in the United States are diagnosed with learning disabilities(LD), and being served in programs. Recently the growth rate of LD has been increasing. However, a continuing problem is that prevalence rates do vary considerably from state to state, with a range from about 3% to close to 10% (Torgesen, 1998). These different rates are partly caused by the method of diagnosis of LD. One authority (Farnham-Diggory, 1992) suggested that the mislabeling of children as learning disabilities is rampant in the United States: "By recent estimates, 80% of the children who are classified as learning-disabled should not have been (pp. 5-6)." It is clear that the issue of idenfying learning disabilities is the core in research area of LD.

This problem gets more severe if we focus on mathematics learning disabilities (MLD). Approximately 6% of elementary school and junior high school children are diagnosed with a mathematics disorder, as compared with approximately 5% with a reading learning disability (RLD) (Badian, 1983; Geary, 1993; Torgesen, 1998). Moreover, 56% of the RLD children also showed poor mathematics achievement, and 43% of children with mathematical learning disabilities showed poor reading achievement. Although these studies suggest that MLD is common in children, "disorders of mathematics among the learning disabled remain relatively neglected (Sutaria, 1985, p.359)." Ginsburg (1997) also insisted that most research on LD has focused on difficulties in the area of reading, with the result being that little attention has been given to mathematics learning disabilities. Additionally, he thought of our culture's general reluctance to deal with things mathematical as a reason of the lack of popularity of this kind of research.

Despite the lack of systematic research in the MLD area, existing neurological, developmental psychological and educational approaches of MLD provide valuable insights. And then from these, we learn how many

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factors differently contribute to the poor math performance of students with disabilities. These three approaches have different perspectives of mathematical learning disabilities. Neurological theory has the longest history of research in this area, and hypothesizes the brain-behavior relationship and math learning disabled students' specific cognitive deficits which underlie mathematical disabilities. Developmental psychological perspective has a different view. They stress that U.S. education is not adequate and low mathematics achievement is prevalent, and suggest to examine the development of children's construction of knowledge in the context of schooling in order to catch not only a neurological factor but also the other factors of poor mathematics performance. Finally, educational aspect focuses on the importance of educational system and cultural environments which are deeply related to students' mathematics performance. It is clear that each approach contributes to understanding of the MLD, but at the same time, it will be harmful if we consider just one of them. We really can take advantage of gaining a deeper understanding of MLD if we consider all these three approaches at the same time.

The goal of this article is to suggest the integrative perspective of mathematical learning disabilities. For this, existing research with these three perspectives is reviewed first. Next, the integrative perspective and categorization of MLD are suggested based on the review. Finally, summary and recommendations for improving understanding of students with learning disabilities in math are shared.

II. Three different approaches of MLD

1) Neurological Approach

Neurological theories of learning disabilities commonly have a basic hypothesis of relation between brain and behavior. They originally started with the study of acalculia, but now developmental dycalculia also becomes their major concern.

(1) Acalculia and Developmetal Dyscalculia

Work in this area was primarily concerned with acalculia as an acquired disorder resulting from brain damage incurred after a relatively normal course of early development. The study of dysclaculia as a developmental disorder, and more specifically as a subtype of learning disability, is of much more recent origin. Disorders of calculation have a fairly long history in the neurological literature, extending at least as far back as the early years of this century. However many early neurological reports of patients with disordered calculation ability considered this symptom to be a manifestation of aphasia, and this perspective was eventually generalized to accounts of the relationship between developmental dyscalculia and dylexia. From this perspective, arithmetic is a derivative skill having a basis in linguistic competencies, and the persistence of this assumption has undoubtedly hampered progress in the study of arithmetic disabilities (Rourke & Conway, 1997).

In the recent review, acquired acalculia and developmental disabilities of arithmetic and mathematical reasoning each raise some interesting questions concerning lateralization and localization of function. Lewandowsky and Stadelmann (cited in Levin et al., 1993) were the first to publish a detailed case study that focused on an acquired disruption of calculation ability, distinct from aphasia and resulting from focal brain damage. Their patient had a right homonymous hemianopsia (no vision in the right half of the visual field) and difficulties with both written and mental calculation. The patient was described as often being unable to recognize arithmetic symbols, despite intact ability to follow the necessary computational procedures. Based on their observations of this patient, Lewandowsky and Stadelmann suggested that a specific type of alexia for numbers could result in a person being unable to read several combined digits as a single number. They proposed the left occipital region as the "centre for arithmetic facilities." Their paper was historically significant in that it was the first to propose that disorders of calculation resulted from a focal lesion that was distinct from one producing aphasic symptoms. Henschen (cited in Levin et al., 1993) was also the first to apply the label "Akalkulia" to disturbances of computational ability associated with brain damage. Similar results were obtained by others, providing further evidence that the neural substrate of calculation ability was anatomically distinct from that of language, and that the deficits producing acalculia may occur independently of aphasia (Badian, 1983; Levin et al., 1993).

Hécaen, Angelergues, & Houillier (1961) performed a detailed error analysis and classified acalculia into three types. The classification presented below continues to have a strong influence on the study of disorders of arithmetic, and many investigators still employ this scheme with very little modification:

Type 1. Acalculia resulting from alexia and agraphia for numbers, in which the patient is unable to read or write the numbers required for successful calculation.

Type 2. Acalculia of the spatial type is associated with impaired spatial organization of numbers, such as misalignment of digits in columns, inversions(6 for 9), reversals(12 for 21), visual neglect, and difficulties maintaining the decimal place.

Type 3. Anarithmetria refers to a disruption of calculation per se. It refers to an inability to carry out arithmetic procedures despite intact visual-spatial skills and the capacity to read and write numbers.

There is some question as to whether knowledge obtained from the study of adults generalizes well to brain-behavior relationships in children. There is little doubt that analogies drawn between childhood and adult syndromes are conceptually useful and may provide a first step in the development of clinical classifications (Denckla, 1973). However, in many respects, the behavioral manifestations of brain damage in adults differ quite dramatically from those seen in children (Rourke & Conway, 1997). For example, the type of damage most typically seen in adults differs from that seen in children. Focal intracerebral lesions resulting from cerebral vascular accidents, tumors, or penetrating head injuries are more common in adults, whereas more generalized impairments arising from perinatal trauma, anoxia, inborn errors of metabolism, or closed-head injuries are typical of children.

On the other hand, developmental dyscalculia is properly considered to be a reflection of brain dysfunction, and Kosc (1974) defined it as follows:

> Developmental dyscalculia is a structural disorder of mathematical abilities which has its origin in a genetic or congenital disorder of those parts of the brain that are the direct anatomico-physiological substrate of the maturation of the mathematical abilities adequate to age, without a simultaneous disorder of general mental functions. (p.47)

This definition makes three essential points. First, developmental dyscalculia involves a specific impairment of mathematical abilities, within the context of normal general mental abilities. It is distinctive from definitions of mental retardation or other general intellectual impairment. Second, developmental dyscalculia is defined and identified according to the relationship that exists between the child's current mathematical abilities and those that can be considered normal for his or her age. Third, dyscalculia is a developmental affliction distinguished from acquired forms of acalculia occurring in adulthood. Thus, the term developmental dyscalculia is reserved for those disorders that have their origins in hereditary or congenital impairment of the growth dynamics of the brain centers, which are the organic substrates of mathematical abilities (Kosc, 1974).

In addition to identifying essential defining features, Kosc(1974) classified six subtypes of developmental dyscalculia.

① Verbal dyscalculia: disruption of the ability to name mathematical terms and relations.

② Lexical dyscalculia: impairement of the ability to read mathematical symbols, including digits, numbers, and operational signs.

③ Graphical dyscalculia: disability of writing numbers and operational symbols.

④ Operational dyscalculia: direct impairement of the ability to carry out arithmetic operations per se.

⑤ Practognostic dyscalculia: disturbance of the ability to manipulate real or pictured objects for mathematical purposes.

⑥ Ideognostical dyscalculia: impairment to the ability to understand mathematical ideas and relations required for mental calculation.

(2) Core Concepts

The fundamental hypothesis of neurological perspective of learning disabilities(LD) is that the processing problems underlying students' performance problems are neurologically based. It is closely related to the brain-behavior relationship underlying three core concepts: (a) students' potential, (b) specificity of cognitive defects, and (c) lateralization and localization of brain function (Rourke & Conway, 1997; Stanovich, 1986; Torgesen, 1998; Wong, 1991).

Firstly, the neurological view supposes that MLD students have average to above average potential. The traditional approach to identifying the population of interest is to select children of normal IQ who receive low achievement scores in ordinary schools. These children with LD possess normal intellectual ability, but they are not mentally retarded. Of course, they suggest that there is a deficit in intellectual performance, but this deficit depresses only a limited aspect of contextually appropriate behavior. Traditionally, this depression of contextually appropriate behavior is described in terms of a discrepancy between some aspect of academic performance and intellectual behavior (Swanson, 1990). For example, a child may be identified as learning disabled if he or she displays reading performance 2 or more years below grade level, but nevertheless tests in the overall average IQ range.

Secondly, the neurological perspective suggests that MLD students have specific, rather than generalized processing deficits. If the child's intelligence is normal, if instruction is adequate, and if sociocultural opportunity is present, then any failure to learn must result from some defect within the child, namely, a specific incapacity, a cognitive disorder. The traditional view sees this defect as residing in the child - a characteristic that is the immediate cause of poor mathematic performance in children of normal intelligence (Ginsburg, 1997). Starnovich (1986) argued that the "assumption of specificity" is central to these conceptions of LD. This assumption holds that LD students' unexpectedly low performance on a task in light of their potential can be accounted for by problems in basic processes required by that task and not by more generalized cognitive deficits.

Finally, this approach produces the important ideas of lateralization and localization of brain function related to students' mathematical performance. Understanding brain-behavior relationships in children who exhibit disabilities of arithmetic and mathematical reasoning requires at least a general familiarity with some issues surrounding cerebral asymmetry. It has been known for some time that left and right cerebral hemispheres are not precise mirror images of each other. Each hemisphere has its own particular penchants, with some relatively straightforward lateralization of function being empirically demonstrable. For example, research has shown that the right hemisphere plays an important role in nonverbal stimuli relationships, intermodal integration, processing of novel stimuli, dealing with informational complexity, adaptive reasoning, visual- spatial-organizational dimensions of calculation and mathematical reasoning, such as using decimal places and "carrying" and "borrowing". On the other hand, left hemisphere is specialized for language function, processing of unimodal stimuli and routinized behavior acts, mediating the numerical symbol system, retrieval of number facts from semantic memory, and simple linear equation, basic arithmetic operations, number fact, and the concept of number itself (Geary, 1993; Goldberg & Costa, 1981; Grewel, 1952; Lezak, 1983; Rourke, 1982, 1993; Spiers, 1987). In brief, the integrative, complex, and novel dimensions of early mathematical learning and concept formation would be expected to draw heavily upon the resources of right-hemispheral systems. Only after successful initial learning would number facts and basic arithmetic procedures become sufficiently routinized to be executed primarily by left-hemispheral systems. Thus, elements of arithmetic that were once very novel, conceptual, and even visual-spatial in nature for the child become automatic in the adult, even to the degree that many so-called calculations are merely specific instances of fact retrieval from semantic memory. Related to this, Rourke & Conway (1997) predicted that early damage or dysfunction in either hemisphere will disrupt arithmetic learning in the child, with very profound effects to be expected from early right-hemisphere insults, whereas left-hemisphere leisions will predominate in the clinico-pathological analysis of acalculia in adults.

(3) Criticisms

The neurological perspective gives us many useful implications of brain-behavior relationships related to LD, but at the same time, there are criticizms we have to consider. Ginsburg(1997) criticized this traditional approach by three aspects: identifying children with LD, the concept of defect, and lack of useful theories. The traditional approach to identifying the population of LD students is to select children of normal IQ who receive low achievement scores in ordinary schools. Ginsburg insisted that this identifying procedure has two major flaws. One is that it assumes that ordinary schools provide adequate instruction. For example, the World Federation of Neurology proposed that dyslexia "is manifested by difficulty in learning to read despite conventional instruction, adequate intelligence, and sociocultural opportunity (Shaywitz, Escobar, Shaywitz, Fletcher, & Makuch, 1992, p.145)." But "conventional instruction" is precisely the problem: Ordinary mathematics instruction is simply not very good in the United States. The general conditions of mathematics education are so deplorable that many children of normal intelligence experience significant difficulty in learning mathematics. The most reasonable explanation for a nondisabled child's failure in mathematics is the conventional instructional system-the textbooks, teachers, cultural atmosphere, and curriculum. Another flaw is that the system of selecting children on the basis of IQ and achievement results is overly broad: It does not exclude enough children. Even under conditions of adequate instruction, children with normal IQs may fail in school for many reasons other than cognitive deficit.

Secondly, the traditional view goes on to assume that the basic cause of poor performance in children with learning disabilities is a specific cognitive defect. Poplin (1988) described this view as a "reductionist" scenario and suggested that the concept of the defect needed to be fixed. The problem of this point of view is that learning disabilities cannot be understood in the overly simple terms of a defect or set of defects in need of repair. Cognition is "situated." We cannot consider it apart from the many contexts in which it operates. For example, in selling goods on the street, largely unschooled children in Brazil develop sophisticated and effective means for mental calculation, but at the same time, they cannot perform the kinds of calculation required in schools (Carraher, Carraher, & Schliemann, 1985; Nunes et al., 1993). Research of this type argues that every cognitive act must be viewed as a specific response to a specific set of circumstances" (Resnick, Levine, & Teasley, 1991, p.4). To understand the child's failure, we need to consider how his or her cognition functions in its context of schooling, which cannot be assumed to be adequate.

Finally, a fruitful neurological explanation of learning disabilities must involve at least two components. One is an account of the particular defective cognitive processes that are the immediate causes of poor performance in children with LD. It is first necessary to identify such processes before one can provide a neurological explanation for them. A second component is an empirically based account that connects the identified cognitive process to a specific neurological disorder or area of brain damage. At present, neither of these components is readily available. Research has provided little information concerning the cognitive processes underlying MLD, and direct evidence linking defective cognitive processes with specific neurological disorders or areas of brain damage is minimal. Hence, at the present time, we lack useful neurological theories for explaining mathematics learning disabilities.

2) Developmental Psychological Approach

Developmental psychology has shown that how knowledge originally developed in the "natural environment" (informal knowledge) contributes to and becomes transformed by what is taught in school (formal knowledge). Therefore, they also try to understand learning disabilities in the transformational process from informal knowledge to formal knowledge.

(1) Informal Knowledge and Formal Knowledge

According to Piaget (1952), children have a biologically based propensity to learn. They accomodate environmental demands, and they assimilate what the environment has to offer. Children are natural learners; they are intrinsically motivated. They learn because their minds are biologically designed to develop concepts and modes of thought useful for adaptation to the environment. However, children do not simply absorb information from the world; they are not simply shaped by the environment. Rather, children actively construct concepts, understandings, strategies, and modes of thought (Noddings, 1990). Of course, each children develops constructions that are to some extent "unique." Nevertheless, at a given developmental level, children's constructions are similar, and often different from adults' (Ginsburg, 1997).

The almost inevitable outcome of the child's encounter with the quantitative environment is the construction of an elementary form of mathematical knowledge that we call "informal". Vygotsky (1978) called this form of knowledge "spontaneous" and declared that "children have their own preschool arithmetic, which only myopic psychologist could ignore (p.84)." This kind of knowledge commonly has three characteristics: powerfulness, intrinsic motivation, and universality. The child's informal mathematics is so powerful and can serve as the formation for later school learning, and continues to develop throughout the life span. Children develop an informal mathematics because they find it useful or because they are curious about the world. They usually appear to enjoy learning and to engage in it with enthusiasm. Needless to say, the affect associated with the learning of informal mathematics bears little resemblance to the discomfort many children exhibit in school. Finally, cross-cultural research shows that informal mathematics is virtually universal. The general finding is that although they differ in many important ways, children from various cultures, literate and preliterate, rich and poor, of various racial and ethnic backgrounds, all display a similar development of various aspects of informal mathematics (Klein & Starkey, 1988).

Schools are artificially created social institutions designed to pass on to children the accumulated social wisdom, one aspect of which is formal mathematics. In contrast to children's informal system, formal mathematics is a written, codified body of material conventionally defined and agreed upon. Formal mathematics is a "scientific system" - coherent, explicit, organized, and logical.

We adults want children to learn formal mathematics because of the intellectual power it can grant. Formal mathematics contrasts sharply with children's informal, "spontaneous" system - intuitive, emotional, implicit, and tied to everyday life (Vygotsky, 1986).

But the problem is that the course of learning formal mathematics is often far from smooth, and children's learning of mathematics cannot be understood in isolation from the larger ecology-the culture, schools, teachers, and texts that constitute U.S. education. Although possessing an adequate informal mathematics, children often encounter a culture that tends to devalue mathematics, schools that are inadequately equipped, teachers who do not like or understand mathematics, and textbooks that make little sense. Furthermore, a closer examination of thought processes reveals that ordinary children (a) experience difficulty in using symbolism, (b) use buggy strategies, (c) hold harmful beliefs about mathematics, (d) engage in rote learning, and (e) fail to connect their informal mathematics with what is taught in school (Ginsburg, 1997). Children's difficulties tend to accumulate over the years. As mathematics becomes more complex, children experience increasing amounts of failure, become increasingly confused, and lose whatever interest and motivation they started out with.

(2) Core Concepts

Related to LD, research of developmental psychology suggests that new concepts of informal and formal thought and of cognition situated in context may help researchers to understand the development of learning disabilities. They think of environments in which children live, children construct informal knowledge and children are given formal knowledge as an important element in learning mathematics. In addition, they propose the new version of the concept of cognitive defect: children's failure is context-dependent, in other words, cognition is situated. Therefore, it naturally leads us to the idea that LD are less general than we ordinarily suppose.

A developmental perspective stresses that ordinary children not only LD children are at risk in the U.S. educational system. They criticize the classical approach to identifying children with LD in several respects: it assumes that ordinary instruction is "adequate", and that a discrepancy between achievement and IQ is a sufficient basis for selecting children with learning disabilities. They guess that this has the effect of misidentifying many children whose poor performance can be explained simply on the basis of the inadequate mathematics instruction prevalent in U.S. schools. In other words, many children are in fact not learning disabled at all. Similarly, Ginsburg (1997) suggested to eliminate from consideration those children whose failure can be explained on the basis of inadequate instruction, poor motivation, and other noncognitive factors. If that instruction is particularry inappropriate or inadequate, children's poor achievement needs not be attributed to LD.

A developmental perspective also suggests that researchers concerned with LD abandon the traditional deficit model. The traditional view assumes that the basic cause of poor performance in children with LD is a specific incapacity, a cognitive disorder, and sees this defect as residing in the child. However, according to a developmental perspective, LD cannot be understood in the overly simple terms of a defect or set of defects in need of repair. They insist that cognition is situated, context-dependent, so we have to consider how his or her cognition functions in its context in order to understand the child's failure.

Finally, they recommend undertaking a research agenda that involves the use of such sensitive research methods as clinical interviews, ethnography, and microgenetic method to examine (a) children's informal knowledge, (b) their construction of different forms of knowledge in school, (c) the adequacy of ordinary instruction, (d) children's response to good teaching, (e) children's motivation, (f) the interaction between modes of thinking and educational context, and (g) the development of children's thinking over time.

(3) Criticisms

Developmental psychology contributes by providing us a new version of poor achievement of mathematics as well as mathematics learning disabilities. Their experts really worry about the present education by which ordinary students experience academic failure in mathematics and are sometimes misidentified as MLD students. However, in spite of their contribution to a new understanding of LD, this approach has three major problems.

One is that they seem to consider that the external problems of students are more severe to math learning than the internal problems of students. They focus more on the problems of learning environments adults offer to students - culture, schooling, teacher and parents, curriculum, text, etc. - than the problems of students' cognitive charateristics. The learning environments are important because they help children to form both informal knowledge and formal knowledge, and also provide the chance for transforming informal knowledge into formal knowledge. But it is also true that there is a certain population of children suffering from brain damage related to mathematics learning disabilities. It has been shown that there are connections between specific parts of the brain and specific cognitive abilities. We never have to ignore this population of students until they do not need our help, even though the population is very small. Moreover, today's environmental problems are not limited to only the MLD group, rather they are the problems of all the students. A student has to be specially treated if he or she is proved to have a learning problem under even the same condition of other students.

The second problem is that their main ideas are absolutely based on constructivism, but it has to be thoroughly checked. It is clear that constructivism is a main stream of society of mathematics education for the present. But at the same time, there is a basic problem. It is said that they have too high expectation of students' abilities: all the students have desire to learn and capabilities to learn. It may make the position of LD students more difficult. LD students' naive difficulties can be ignored or misunderstood by this perspective. Results of constructivism movement, both today's increased academic standards and the inclusion movement - the concept that students with LD should receive their academic instruction in general education classrooms- are really threatening LD students.

The third problem is that the research methods they sugget - clinical interviews, ethnography, and microgenetic method - easily fall into subjective judgement and it is hard to manage big population, and they have still not provided any useful alternatives for identifying LD, even though they criticize the traditional method.

3) Educational Approach

Miller and Mercer (1997) suggested that many various factors contribute to the poor math performance of students with disabilities. Compared to the preceeding two approaches, this one does not have any theoretical background, but it has important implications omitted in the preceeding two approaches. It concerns national reform movements that have influenced math instruction, learner characteristics and math instruction.

(1) National Reform Movement

Related to today's national reform movement, two main characteristics have largely influenced the LD area. The first one is NCTM Standards and the other is an inclusion movement. Numerous educators have expressed concern regarding the application of the Standards (Carnine, 1992; Hofmeister, 1993; Hutchinson, 1993; Mercer, Harris, & Miller, 1993; Rivera, 1993) and inclusion system (Carnine & Kameenui, 1990; Fuchs & Fuchs, 1988; Roberts & Zubrick, 1992) to students with disabilities.

The National Council of Supervisors of Mathematics (1988) advocated national reform in mathematics and issued their position on the essential components of a math curriculum. The NCTM(1989) endorsed and published these essential components in a document, "NCTM Standards". The standards outline what students should learn in mathematics during grades K through 12, and represent an attempt to change both math curricula and method pedagogy nationwide (Hofmeister, 1993). Generally speaking, the Standards represent increased expectations for student performance in mathematics. They emphasize that students must understand mathematical processes in order to communicate the language of math. Moreover, students should not memorize math without understanding the processes. The Standards also emphasize problem-skills and the importance of students' gaining mathematical power and promote earlier instruction in advanced skills, such as algebra and geometry (NCTM, 1989, p.5). Concerning LD, the problem is not a high expectation, but a lack of references to LD students in the Standards document, a lack of research related to the Standards, and an overall vagueness of the document (Miller & Mercer, 1997). It will not be difficult to guess how much difficulty teachers feel when they have to face students with learning disabilities.

The inclusion means that students with disabilities study with students without disabilities in general classrooms. This movement coincides with the trends related to increased academic standards, competency testing, and more stringent graduation requirements. Development of social skills, positive relationships and friendships and the improvement of attitudes toward students with LD were identified as important benefits of integration (Snell, 1991). Given these potential benefits, it makes sense that many of the strongest supports of full inclusion are advocates for students with severe disabilities (Fuchs & Fuchs, 1994). However, Roberts & Zubrick (1992) found that integrated students with disabilities were less frequently accepted and more frequently rejected than their peers without disabilities in general education classrooms. Moreover, it is reported that main streaming has not resulted in a high level of academic effectiveness. Many investigators reported that these students were significantly more likely to fail in general classes than in special classes due to some limitations (e.g., curricular materials, class size, knowledge of specialized teaching strategies) of general education settings (Silver, 1991; Mather & Roberts, 1994; Wagner, 1990). Therefore, we need to keep in mind that this inclusion movement may deepen the degree of learning disabilities unless it fits the needs of LD students.

(2) Learner Characteristics

The general characteristics of students with mathematics learning disabilities are worthy of investigation, because it can give us a clue for the solution of problems in the MLD area. In this article, just four characteristics of MLD will be chosen and discussed: information-processing, language, metacognition, and emotional characteristics.

Firstly, many MLD students frequently exhibit problems that are pertinent to information-processing: attention deficits, visual-spatial deficits, auditory-processing difficulties, memory problems, and motor disabilities. The information-processing model provides many implications to the MLD area. This theory focuses on which information is acquired and how. Its main features include attention, sensation, perception, short-term memory, long-term memory, and response (Bos & Vaughn, 1994).

Secondly, MLD students also have difficulty with metacognitive processes. Students who lack awareness of the skills, strategies, and resources that are needed to perform a task and who fail to use self-regulatory mechanisms to complete tasks will undoubtedly have problems with mathematics. Especially, these students are described as having difficulty in (a) assessing their abilities to solve problems, (b) identifying and selecting appropriate strategies, (c) organizing information, (d) monitoring problem-solving processes, (e) evaluating problems for accuracy, and (f) generalizing strategies to appropriate situations (Brownell, Mellard, & Deshler, 1993; Cherkes-Julkowski, 1985; Goldman, 1989).

Thirdly, language disabilities can also cause math learning disabilities. Because math symbols represent a way to express numerical language concepts, language skills become very important to math achievement. In particular, the use of language is requisite for calculation and word problems. In computing, language skills are needed to systematize the recall and use of many steps, rules, and math facts.

Finally, the affective domain is an important variable in the math performance of LD students. It includes low self-esteem, emotional passivity in mathematical learning, incorrect belief system, math phobia, avoidance behavior, etc..

(3) Math Instruction

Curricula and instruction are undoubtedly an important factor in learning math, and in particular, poor curricula and instruction cause poor math performance among students with disabilities. Related to LD, Miller and Mercer (1997) worried about today's spiraling curriculum approach. The typical basal curriculum uses a spiraling approach to instruction, in which numerous skills are rapidly introduced in a single graded book, and then they are reintroduced in subsequent graded books at higher skill levels. However, the result seems to be superficial coverage of many different skills, and skill mastery is unlikely because new skills are introduced too quickly in an attempt to "get through the book." Research has demonstrated that the basal approach to teaching mathematics is particularly detrimental to students who have learning difficulties (Engelmannn, Carnine, & Steely, 1991; Silbert & Carnine, 1990; Woodward, 1991).

The lack of adequate math textbooks and materials, or the inadequate use of texts and materials are also problematic. They really compound the problem of poor curricula and instruction. Ginsburg (1997) found that most teachers continue to employ traditional textbooks, parts of which are confusing and do not make a great deal of sense, despite the forward-looking recommendations of the NCTM (1989). Cawley, Miller, and School (1987) reported that high school math teachers put more emphasis on solving problems in the textbook than on solving novel or life-based problems. Such an approach to teaching reduces the likelihood of generalization and limits adequate development of cognitive and metacognitive strategies needed by many LD students.

School teachers' math avoidance or their insufficient knowledge of math are also problematic. In particular, research shows that many elementary school teachers are uncomfortable with mathematics and share the general U.S. aversion to it. Moreover, many teachers simply do not know enough mathematics, and only a minority of teachers are able to explain their solutions in a pedagogically acceptable manner (Post, Harel, Behr, & Lesh, 1991, pp. 195-196). It is also shown that many teachers think of mathematics learning as a rote activity, an occasion for frequent drill (Thompson, 1992).

Education in the United States is characterized by inequalities in the educational opportunities (Kozol, 1991). Poor and minority children are more likely than their white, middle class peers to attend inadequately equipped schools. Many schools, in particular in low income areas, are decrepit, overcrowded, poorly supplied, and in general, terrible places in which to spend any amount of time, let alone attempt to learn a subject as demanding as mathematics (Ginsburg, 1997).

(4) Core Concepts and Criticisms

This educational approach provides us with a possible explanation for the poor math performance of LD students. They assume that these students have several characteristics that make learning math difficult, but try to focus on our present social and educational contexts which can evoke LD. Inclusion movement, rigorous curriculum with higher expectations, inadequate and inequable instruction are described as main factors which contribute to poor achievement of LD students. The NCTM Standards, math competency testing, and increasing math requirements for high school graduation are also criticized as being related to LD, for the reason that the intensity of these trends have provoked students' frustration and anxiety, and then increased student retentions and the dropout rate. Instead, they suggest the need for close examination of what is happening to students with math disabilities in present educational contexts. Finally they recommend the following three points for improving math education: firstly, develop a refining rather than reforming posture, secondly, accomodate learner characteristics and needs, and finally implement practices with research support (Miller & Mercer, 1997).

This approach has several weak points. Firstly, it doesn't have any clear theoretical background of LD. In other words, it is not a theoretical approach. It doesn't start from the endeavor to identify the LD group.

Instead, it starts from the investigation of treatment for already selected LD group. Therefore, we cannot easily get any implications of what LD is from this perspective. Next, they don't much stress the potential of LD students which is a major premise of the preceding two approaches. Instead they focus on understanding of LD students' difficulties in many ways. They seem to be oriented more toward weaknesses of MLD students rather than their strengths.

III. The integrative approach of MLD

As mentioned above, research of mathematics learning disabilities has been developed in three different approaches - neurological, developmental, and educational - in parallel. In particular, this article is written about the core ideas contained in each concept of LD and the flaws in them. Throughout this work, several implications were caught: (a) Educational environment has to be considered important factor of mathematics learning disabilities more than we have valued so far; (b) Relation between brain and students' behavior cannot be ignored in LD area; (c) MLD can be caused by developmental, linguistic, metacognitive and emotional defects as well as neurological defects.

1) The need for research with the integrative approach

Now, it is time to discuss the need for research with an integrative perspective. The development of an integrative perspective of LD, in particular, MLD means that we cannot fully understand LD with just one-sided approach. As already shown, each of three approaches focuses on only part of the whole LD, moreover, it turned out that their ideas have a couple of flaws which need some corrections. Therefore, it will be worthy to develop an integrative perspective of MLD, and it will give us a clue of the core problems in the LD area; "what is LD?", "where is LD originated from?".

Integration is more than a simple sum. Therefore, the integration of these three perspectives has to be more than the sum of the three. But, this work is by no means easy, and it cannot be achieved by just one step. I think it really needs gradual progression and complementary work in the future. Based on this idea, this article suggests a comprehensive perspective which includes existing perspectives. Its basic idea can be characterized by the following four items. A student is identified as MLD if he or she (a) records low achievement in mathematics, (b) has normal or above normal intellectual abilities, and (c) has one or more defects in neurological, developmental, emotional, linguistic, or metacognitive aspects, but (d) his or her cognitive defects have both faces: context-dependent or context-independent.

Additionally, each factor of MLD in (c) is summarized as follows:

① Neurological factor. Many researchers have been trying to show the brain-behavior relationship for long time. Some relations between brain and mathematical performance have already been proved. In particular, acalculia and developmental dyscalculia have been studied in relation to arithmetics and mathematics learning. Acalculia is an acquired disorder resulting from brain damage incurred after a relatively normal course of early development, while developmental dyscalculia is a structural disorder of mathematical abilities which has its origin in a genetic or congenital disorder of those parts of the brain. As a result of a brain damage, we can expect visual-spatial defects, auditory-processing difficulties, memory problems, motor disabilities, etc which can cause mathematics learning disabilities.

② Developmental factor. Many children have some informal mathematical knowledge but fail to use it in dealing with written mathematics problems. They are living in two worlds. One is Vygotsky's (1986) world of spontaneous mathematics, a world in which he can get correct and sensible answers by counting backwards mentally; the other is Vygotsky's world of scientific mathematics, a world in which the child uses buggy procedures like taking away the smaller number from the larger in order to get incorrect and absurd results. Many children usually don't make connections between the two worlds. They can do their sensible, informal math largely in the everyday world; and they save their absurd, formal math for school. The educational system is not successful in helping them to connect the two worlds.

③ Emotional factor. The affective domain is also recognized as an important variable in the math performance. For example, it is believed that repeated academic failure frequently results in low self-esteem and emotional passivity in mathematical learning (Cherkes-Julkowski, 1985). The emotional reaction of some individuals to math is so negative that they develop math anxiety. This condition is believed to stem from a fear of failure and low self-esteem and causes students to become so tense that their ability to solve, learn, or apply math is impaired (Slavin, 1991). Confused thinking, disorganization, avoidance behavior, and math phobia are common results (Conte, 1991; Zentall & Zentall, 1983). Difficulty maintaining attention to critical instruction and learning (Attention deficit) can be also a fundamental reason for learning disabilities. Especially, sustaining attention to steps in algorithms or problem solving or teacher modeling is important to mathematics learning.

④ Linguistic factor. Because math symbols represent a way to express numerical language concepts, language skills become very important to math achievement. The use of language is requisite for calculations and word problems. In computing, language skills are needed to systematize the recall and use of many steps, rules, and math facts. The reading demands of word problems increase in each grade level. Irrelevant numerical and linguistic information in word problems is especially troublesome for many students with learning disabilities (Englert, Culatta, & Horn, 1987). Moreover, many students with learning disabilities have reading difficulties that interfere with their ability to solve word problems (Smith, 1994).

⑤ Metacognitive factor. Research has shown metacognitive deficiencies for learners of all ages, even experienced students at the college level (Pressley & Ghatala, 1988; Walczyk & Hall, 1989). At the same time, research also suggests that the metacognitive problems of students with LD are often more pronounced than those of more successful peers (Butler, 1998; Miller & Mercer, 1997). Students who lack awareness of the skills, strategies, and resources that are needed to perform a task and who fail to use self-regulatory mechanisms to complete tasks will undoubtedly have problems with mathematics. They attempt to use cognitive strategies, but the strategies they use may not be sufficient for solving the problem. For example, students may use numerous strategies with word problems, but will not seem to have a working knowledge of strategies associated with representing problems. Problem representation involves converting linguistic and numerical information into mathematical equations and algorithms. Many students with disabilities find this task very difficult. In relation to this, Miller & Mercer (1997) picked out the following concrete six difficulties these students have: (a) assessing their abilities to solve problems, (b) identifying and selecting appropriate strategies, (c) organizing information, (d) monitoring problem-solving processes, (e) evaluating problems for accuracy, and (f) generalizing strategies to appropriate situations. Similarly, Butler (1998) selected four examples of metacognitive difficulties: (a) recognizing task requirements, (b) selecting and implementing strategies, (c) monitoring and adjusting performance, and (d) motivation and emotion.

2) Characteristics of the Integrative Perspective

This integrative concept of MLD apparently looks like traditional one, because it hypothesizes students' low achievement and high potential. But its internal meaning is a little different. Firstly, this comprehensive view of MLD suggests that low mathematics achievement caused by many various factors-developmental, linguistic, metacognitive, and emotional-as well as a neurological factor have to be considered as MLD. But poor performance caused by an environmental factor is excluded from MLD group, because environmental problems are restricted not to a person with LD but to all of today's students.

Of course, this idea is, to some degree, opposite to both the neurological perspective and the developmental perspective. It has been shown that recently around 6% of the U.S. students are classified as MLD. With respect to the neurological perspective, all the students of this group have commonly one or more cognitive disorders connected to neurological defects. They focus on only the neurological problems, and try to approach these problems by using brain-behavior relationship. However, research has shown that many different causes as well as a neurological factor can affect students' low achievement in mathematics. On the contrary, the developmental perspective suggests that many students who are classified as MLD by some traditional criterion have to be excluded from MLD group, because their poor mathematical performance can be caused by not only a neurological defect but also many different factors. The neurological and developmental perspectives agree that LD is a kind of neurological disorder, but they have a different idea of the population of students with LD. If we accept the idea of a developmental perspective, the population of LD group gets very small, much lower than 6%, and then MLD will no longer be a severe problem in mathematics education. In my personal opinion, this idea is too restricted to study the area of LD. In particular, today's mathematics education is suffering from the spread of students' low achievement. There is no reason we must restrict our concern to a neurological aspect, only a part of low achievement. We should have a more comprehensive view of LD than the traditional views.

Next, this integrative perspective suggests that both context-dependency and context-independency can be considered as characteristics of LD students' defects. If the defect is related to a neurological disorder caused by a brain damage, it can be independent of context. For example, if a student has a brain damage related to adding function, he or she may perform poorly in adding in any contexts. However, if the defect is caused by a developmental or emotional factor, then it is dependent on context. For example, a student can add successfully with real apples at home, but he or she can fail to add the numbers in school. Generally the former idea is the dominant view in cognitive science, but recently research of developmental psychology has led many theories in cognitive development to challenge the traditional cognitive science. However, as for now, we can not deny any aspects of cognition. Rather, accepting both sides of cognition may give us many more advantages in understanding the various characteristics of LD and developing the mediation techniques fitted to each characteristic.

IV. Conclusions

The issue of identifying of mathematics

learning disabilities is the core and a starting point of research of mathematics learning disabilities. It has been developed in parallel with three different perspectives: neurological, developmental psychological and educational. However, there is still no consensus of "what is mathematics disabilities" or "what causes learning disabilities in mathematics?" among scholars in spite of today's increasing population of students with learning disabilities in math. Therefore, the integrative perspective in this article will be a starting point of MLD research.

This integrative perspective suggests that we abandon an extrem view of MLD which makes us focus on a limited part of the whole MLD and instead takes a comprehensive view which includes the present different perspectives. In the process of integration in this article, the various factors which can cause learning disabilities in math were classified into five categories: neurological, developmental, linguistic, metacognitive, and emotional factors. This classification ruled out an environmental factor, for the reason that today's mathematics educational environment is not good, therefore it can not be a personal problem of students with MLD but a social problem of all the students. However it doesn't mean that today's environmental problem in mathematics education is less urgent to research than the problems related to mathematics learning disabilities. Inadequate curriculum and instruction, the quality of math teachers and material, social and cultural atmosphere against mathematics, and physical conditions of schools are all the objects we have to consider for successful mathematics education.

In conclusion, the basic idea of this article is opposite to the idea which tries to rule out as many students as possible from MLD group. Rather, this article suggests that we include as many students as possible among MLD group in order to get them under our concern and help.

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수학학습장애의 통합적 접근

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수학학습장애는 독해장애와 더불어 학습장애의 주요영역으로 인식되고 있다. 그러나 독해장애에 대한 연구와 비교하였을 때 상대적으로 주목받지 못한 분야로, 과연 수학학습장애는

무엇이며, 수학학습장애아를 판별하는 기준을 어떻게 설정할 것인가의 문제가 여전히 논란이 되고 있다. 본고에서는 수학학습장애에 대한 최근의 세 가지 관점-신경학적 관점, 발달심리적 관점, 교육적 관점-의 고찰을 통해, 수학학습장애를 진단하기 위한 하나의 통합적 관점이 필요함을 제안하고 있다. 이것은 수학학습장애를 신경적 결함으로만 해석하려는 전통적 관점에 대한 발달심리학자들의 비판을 수용한 것이며, 오늘날 파행적인 교육체계에서 희생되고 소외되어온 학생계층을 포용하기 위한 한 가지 제안이 될 것이다.