ISSUES AND CHALLENGES IN ADULT NUMERACY

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TECHNICAL REPORT TR93-15
DECEMBER 1993

This work was supported by funding from the National Center on Adult Literacy at the University of Pennsylvania, which is part of the Education Research and Development Center Program (Grant No. R117Q0003) as administered by the Office of Educational Research and Improvement, U.S. Department of Education, in cooperation with the Departments of Labor and Health and Human Services. The findings and opinions expressed here do not necessarily reflect the position or policies of the National Center on Adult Literacy, the Office of Educational Research and Improvement, or the U.S. Department of Education.

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The National Center on Adult Literacy (NCAL) was established in 1990 by the U.S. Department of Education, with co-funding from the Departments of Labor and Health and Human Services. The mission of NCAL addresses three primary challenges: (a) to enhance the knowledge base about adult literacy; (b) to improve the quality of research and development in the field; and (c) to ensure a strong, two-way relationship between research and practice. Through applied research and development and dissemination of the results to researchers, policymakers, and practitioners, NCAL seeks to improve the quality of adult literacy programs and services on a nationwide basis. NCAL serves as a major operating unit of the Literacy Research Center at the University of Pennsylvania.

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Revised January 18, 1995

ACKNOWLEDGMENTS

This report was written with the research assistance of Elizabeth Sower, Meg Cristofalo, and Paté Mahoney. The author thanks Richard Venezky, Bonnie Mullinix, Mary Jane Schmitt, and Esther Lionelli for helpful comments on an earlier draft.

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ISSUES AND CHALLENGES IN ADULT NUMERACY

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Abstract

National interest has been increasingly focused on improving adults' functional and employment-related skills. However, despite its apparent centrality in people's everyday and work functioning, the "numeracy" component of literacy has received little visible attention. Numeracy includes facility in dealing with numbers and quantitative problems, including tasks where information of a numerical nature is embedded in a text-rich context, and understanding of basic mathematical ideals and patterns. Current programs and instructional practices in adult education may not fully meet learners' numeracy needs. This report discusses the place of numeracy in adult education, examines conceptions of what numeracy and numeracy provision might include, and explores links between literacy and numeracy provision. Questions pertaining to teacher preparation and instructional frameworks are raised, and tentative implications for policy and practice are discussed.

INTRODUCTION

Quantitative skills traditionally have been considered in the United States to be a basic skill area—one of the three Rs. Even a cursory review of tasks or problems common in many adults' lives is sufficient to reveal the range and richness of contexts in which some quantitative skills are required. Consider the following sample:

- shopping for groceries or supplies;
- filling out tax forms;
- monitoring and handling personal finances, paying bills, and writing checks;
- calculating a tip in a restaurant;
- applying for a loan or mortgage and negotiating terms;
- planning a car trip, getting directions, and using a map;
- measuring, ordering, and installing carpeting or wallpaper;
- using a recipe for cooking;
- sewing a dress by using a pattern;
- reading a bus or work timetable;
- reading a newspaper article presenting results of a national survey;
- judging the meaning of data upon which calls for community action are founded (e.g., regarding a proposed incinerator or biases in hiring practices of local government);
- comprehending medical information (e.g., genetic counseling or AIDS testing); and
- helping a child with schoolwork in math or science.

In addition to these activities, adults frequently encounter phenomena or engage in situations that may not necessarily appear to present strong functional quantitative requirements but that could be better understood or appreciated if some of their embedded mathematical properties could be discerned and understood. Structural, kinetic, visual, and temporal patterns and shapes with mathematical properties can be observed in living organisms such as plants, artistic and architectural creations, folk arts and crafts, or games of chance—any of which, at some point or another, may constitute elements in the fabric of adults' lives. Some understanding of mathematical ideas and terminology is often required for fuller comprehension of many technical, scientific, medical, economic, or social developments and processes, such as those presented in the media or those that are the topics of public discussion and debate (e.g., ecological issues and options for waste disposal/recycling and growth trends in health care costs and options for public investment in health care reform).

These situations bring several questions regarding adults' functional quantitative skills to the forefront: (a) How should adults approach situations or tasks with quantitative elements when they arise? (b) What knowledge should adults have about such situations, and what dispositions or beliefs should they possess regarding what is useful to know or do in such situations? (c) What should adults be able to do with the numbers or data inherent in quantitative situations when action is required? and (d) How well prepared are adults to handle functional quantitative tasks of relevance in their lives?

At present, there is no comprehensive information about the full range of quantitative skills of the general adult population in the United States. However, several indicators suggest that the quantitative skills of American adults are probably much lower than desired levels. The results from the recent National Adult Literacy Survey (NALS) are most informative in this regard. Data released so far from the NALS (Kirsch, Jungeblut, Jenkins, & Kolstad, 1993) suggest that many individuals can perform simple arithmetic operations when both the numbers and operations are made explicit. Yet, when the numbers to be used have to be located in or extracted from different types of forms or documents (that also contain similar but irrelevant information), or when the operations to be performed have to be inferred from printed directions, quantitative literacy tasks become increasingly difficult. Comprehension or evaluation of quantitative arguments or statistical information embedded in technical documents or in prose was likewise found in the NALS to present difficulty to many adults.

In all, the NALS results imply that roughly 50% of American adults would either have major difficulty with or be fully unable to handle real world tasks such as (a) using a bus schedule to determine departure time for a bus going to a certain destination, or how long it takes to travel from one spot to another; (b) identifying a trend on a simple graph showing yearly changes in sales figures; (c) using a calculator to find the difference between the regular and sale price printed in an advertisement; (d) estimating the cost-per-ounce of a grocery item based on the "unit price" label that is found in many supermarkets; (e) reading and understanding a table summarizing results from a survey of parents and teachers about school-related issues; or (f) calculating interest charges associated with a home loan. An additional one quarter of adults interviewed for the NALS had difficulty with even simpler tasks such as determining the shipping charges for office supplies and completing an order form, finding the overall difference in cost of buying theater and bus tickets for attending two different shows, or identifying a certain figure on a pay stub. Performance on these and other tasks used in the NALS suggests that many everyday or work-related literacy tasks involving either manipulation of numbers or comprehension of quantitative information that are embedded in various types of text prove difficult for a large proportion of adults in the United States.

In general, the NALS results published so far (Kirsch et al., 1993) corroborate and extend findings from the Young Adult Literacy Survey (YALS; see Kirsch & Jungeblut, 1986), which examined the literacy skills of young American adults between the ages of 16 and 24. While actual performance on the many everyday tasks that were simulated in the NALS and YALS might vary somewhat from the reported figures, the overall pattern of results from these two large-scale surveys is very disturbing.

In evaluating the significance of the NALS results, one needs to consider that it used text-related quantitative tasks and that quantitative literacy skills were only one of several types of literacy skills assessed. Thus, little is known about adults' mathematical skills in areas that fell outside the scope of the NALS study, such as those involving knowledge of measurement or geometry or performance on tasks in which numbers or quantitative information is embedded in print to a lesser degree (e.g., deciding how many tiles are needed to cover the kitchen floor, doubling a recipe, etc.). While direct information about such quantitative skills is not available, the fact that the mathematical achievement of American students has been lower than desired for many years needs to be taken into account.

Results from the National Assessment of Educational Progress (NAEP) have shown repeatedly over the last 20 years that many high school graduates leave the classroom without adequate skills. For example, results from the 1990 National Assessment of Educational Progress (NAEP; see Mullis, Dossey, Owen, & Phillips, 1991) found that 9% of the 12th graders tested did not show mastery of fifth-grade content involving a grasp of how to apply the four basic arithmetic operations in solving simple whole number problems. Only 46% of the high school seniors tested demonstrated consistent mastery of fractions, decimals, percentages, and simple algebra, while only 5% showed an understanding of geometry and algebra that suggested preparedness for the study of relatively advanced mathematics. Performance was lower among Hispanic and African American students in this large sample. Interestingly enough, the 1991 NAEP assessment also found that while many students enjoy mathematics, most have negative views on the nature of the field and limited expectations of its relevance in their future lives. In general, the 1990 NAEP results are similar in nature to those obtained in earlier NAEP surveys, implying that as these high school students become adults they are likely to have difficulty with quantitative tasks.

Employment is another domain in which questions arise regarding the adequacy of adults' quantitative skills. Forecasts of future demographic and economic trends in the United States suggest that more adults will need to have higher skills in the coming years (e.g., Johnston & Packer, 1987). Such forecasts may anticipate the amount of additional education required better than the content of such education (Bailey, 1991). Yet, the growing emphasis in U.S. companies on quality technology and improved productivity (Deming, 1986; Dertouzos, Lester, & Solow, 1989; Fluharty, 1991)—combined with competitive pressures on employees, created in part by layoffs and restructuring or by upgrading of product lines and of workplace technologies and procedures (Bailey, 1990)—suggests that many adults are and will be hard-pressed to upgrade their skills, including quantitative and scientific skills. This conclusion is strongly emphasized in recent summaries of the educational implications of changing workplace demands (e.g., Carnevale, Gainer, & Meltzer, 1990; Secretary of Labor's Commission on Achieving the Necessary Skills [SCANS] 1991, 1992).

Closing the gap between the existing and the desired skill levels of adults, including quantitative skills, is a key goal of many adult education programs in the United States. Thus, several questions arise: If adults should seek help to improve their quantitative skills, among other skills, what forms of relevant assistance and education can they expect to find? Is the need to enhance the quantitative skills of adults recognized by the adult education/adult literacy system in the United States? Are programs adequately prepared to service such needs?

In the United States, the 1991 National Literacy Act's definition of literacy recognized the need to attend to adults' quantitative skills:

> *[Literacy is] an individual's ability to read, write and speak in English, and to compute and solve problems at levels of proficiency necessary to function on the job and in society, to achieve one's goals, and develop one's knowledge and potential. (p. 1)*

Although broader than ever before, this definition leaves latitude for wide interpretations by curriculum designers, program directors, and educators regarding what might be included in the term *computational skills.* Under such circumstances, the adult education community in the United States, including policymakers, administrators, and practitioners, would be expected to have opened and engaged in a dialogue to clarify aspects of the goals, methods, and mechanisms for enhancing adults' quantitative skills. (In the text below, the term *numeracy* will be used interchangeably with *quantitative skills;* a later discussion expands on what numeracy might encompass.) Oddly enough, there are few if any signs of the public discourse on numeracy-related issues within the adult literacy/adult education community. Hence, at present, there is little closure on important questions pertaining to the provision of numeracy skills, including: What is the nature of the quantitative skills and related knowledge that should be emphasized in adult education programs? How should numeracy skills be developed and instruction coordinated with education in reading, writing, and communication skills? What types of training, resources, and professional development opportunities should be established to ascertain that practitioners develop and maintain high quality services?

This report is organized into four parts. Part one surveys the sparse information available about mathematics education for adults in the United States and examines gaps in current instructional practices, teacher training, and research. Part two provides a discussion of numeracy from the perspectives of employers, mathematics and science educators, and assessment programs. Part three discusses the notion of adult numeracy and explores some of the links between literacy and numeracy. Part four provides a summary and discussion and presents implications for policy, practice, and new directions for research and development.

A. Mathematics Education for Adults

This section takes a critical look at how much attention is being paid to mathematics education in adult education/adult literacy programs, while it examines research reports, program summaries, and other information that can shed light on adult numeracy provision in the United States. A key purpose of this section is to draw attention to the issues to be considered in a public discussion of the place of numeracy in adult literacy education.

1. Practice and Field Activities

There is a general dearth of detailed information about math instruction in formal reports at either the federal or the state level. A recent review of adult literacy programs in the United States provides state-by-state data suggesting that only a minority of states have programs that recognize mathematics as a separate topic (Pelavin Associates, 1991). In examining additional data collected through the Educational Resources Information Center (ERIC) and more recent state activity reports for 1991, it was discovered that less than one quarter of the states mentioned any explicit math-related activity (excluding GED preparation programs, which always contain a math component). When mathematics instruction was mentioned, it was listed only as one of several topics that were also covered, in addition to reading, writing, and other literacy skills. As is usually the case with state reports, few details were given about the content of programs. Thus, it was impossible to evaluate whether services provided under the general rubrics of basic skills or ABE also included math-related instruction (although it is suspected that math may be included in many of them; see below).

Another source of information about math-related instruction in adult education programs is test data. Unfortunately, most states tend to report test results only in terms of grade levels in reading (Pugsley, 1992), not in math, even though widely used standardized tests such as the Tests of Adult Basic Education (TABE) and the Adult Basic and Literacy Education (ABLE) test have separate math sections that could yield viable data. Along the same lines, practically none of the states reviewed either in the Pelavin Associates (1991) report or in this survey discussed the effectiveness of math-related instruction or provided gain scores in mathematics.

An exception to the above can be found in data provided through the Comprehensive Adult Student Assessment System (CASAS), which usually reports reading scores and math scores separately. Recent data provided by CASAS (Simon & Rickard, 1990) on the achievement of learners in the California-based Greater Avenues for Independence (GAIN) program—for over 191,000 clients serviced in 58 counties between 1986 and 1990— showed that (a) the mean scale score on the GAIN Math Appraisal test indicated that, on average, "this GAIN population can perform basic math tasks at only a marginal level" (p. 6); and (b) approximately 54% of the GAIN participants studied scored lower on the Math Appraisal test than on the Reading Appraisal test. These data suggest that attention to only reading scores can obscure important underlying trends in the mathematics skills of adults, thus emphasizing the importance of separate reporting of math scores. Unfortunately, there is no simple way to evaluate the significance of the CASAS data on math performance in connection with data provided by standardized tests such as the TABE or ABLE, since CASAS is geared to evaluate functional skills, while the other tests employ different item formats examining knowledge of specific mathematical topics or operations.

While official reports may convey the impression that little math instruction takes place, any tour of the field of adult education programs suggests that numeracy-related activities abound. This is evident from the large number of commercially available mathematics instructional materials. These are prominently displayed in various publishers' booths at all adult education conferences. For the most part, such materials (by publishers such as Contemporary, Steck-Vaughn, New Reader Press, Literacy Volunteers of America, South-Western, Glencoe, and others) are produced exclusively for adult learners.

To support the above contention regarding the actual level of math instruction in the field, additional data were obtained through phone interviews with program directors and teachers from 30 randomly selected adult literacy programs in three states. Practically all of the respondents reported some independent numeracy provision in their programs, in addition to any GED preparation activities. Site visits to literacy programs in the Philadelphia area and in Seattle, Washington, as well as discussions with a focus group of adult educators from the Delaware Valley (encompassing Philadelphia and surrounding counties in Pennsylvania, New Jersey, and Delaware), corroborated the survey findings, suggesting that the level of numeracy-related activity is much higher than officially reported and that most adult literacy programs are likely to be doing some numeracy work with at least some students. This situation brings up questions regarding the qualifications and preparation of the teaching force involved in mathematics instruction with adults.

2. Staff and Professional Development

The question of whether instructors and tutors are well prepared to teach mathematics and to develop the numeracy skills of adults is also a concern. Only sporadic information is available in official reports addressing issues of staff training. A recent study of staff development in ABE and ESL programs across the United States (Tibbetts, Kutner, Hemphill, & Jones, 1991) estimated that most volunteer tutors (who constitute between 25% and 75% of the teaching force, depending on the state) receive between 8 and 20 hours of preservice training prior to working with adult students (see also Pelavin Associates, 1991). Tibbetts et al. (1991) suggested that preservice training is likely to focus mostly on reading and writing, but provided no estimates of time invested in preparing tutors to engage mathematical issues. In the absence of any other data on this issue, an informal survey was taken of several literacy providers in the Philadelphia area; the estimates obtained ranged between 1 and 4 hours only.

There are also no data on the amount of preservice training in math teaching given to educators who work on a paid basis or who are interested in becoming certified to teach adults (a growing trend in some states). Despite this fact, at present, there is no known university-based course on teaching math to adults in the United States. In comparison, the preservice training program for individuals interested in becoming adult educators in the Netherlands, where the adult education system was fully professionalized in the late 1980s, allocates about 90 hours of instruction to teaching math as part of an overall program of 360 hours.

Data are also lacking on the attention to quantitative issues at in-service workshops. In general, adult educators attend only a few hours of in-service training each year, given funding difficulties and the part-time nature of their work (Pelavin Associates, 1991). Results from several needs assessments conducted in Pennsylvania in 1992 suggest that educators show little interest in further training in mathematics when answering needs assessment questionnaires. An examination of directories of Section 353 demonstration projects in several states uncovered very few math-related projects. These projects almost always presented curricular materials for specific populations (e.g., for a workplace literacy program, or for LEP students) and did not involve systematic staff development efforts.

General resources aimed at adult educators, which can be used for professional development or to support practice, also pay little attention to instruction on quantitative issues. One example can be found in the *ABLE Sampler* (Royce, 1991), a professional development guide for practitioners in ABE, GED, ESL, and literacy programs, created by a panel of leading adult educators in Pennsylvania. The 103 resources reviewed in the *Sampler* were those most recommended by over 200 practitioners from all 50 states, and thus are of interest here since they directly reflect the preferences of adult educators. Out of 103 resources mentioned in the *Sampler,* only one is devoted exclusively to teaching math to adults—Schmitt and Jones' (1990) *Changing the Rules: Teaching Math to Adults,* which includes a videotape and a 16-page booklet. Only one other guide that addressed instructional strategies related to math was mentioned, the 1990 *Basic Literacy Tutor Handbook* from the Center for Literacy in Philadelphia. What is important for the current discussion is that the ratio of math versus nonmath resources that practitioners saw as most relevant to their practice was very low.

Another example of the lack of attention paid to the need to consider the place of numeracy instruction in literacy classes can be found in *The Complete Theory-to-Practice Handbook of Adult Literacy: Curriculum Design and Teaching Approaches* (Soifer et al., 1990). This guide, while providing useful advice on many issues, does not include numeracy or quantitative issues in its definition of literacy; it devotes only a few paragraphs to math instruction, fails to suggest any need to integrate the provision of literacy and numeracy, and provides no reference to literature that practitioners can consult if they find it important in incorporate math instruction into their practice. To be sure, the intention here is not to single out publications such as Soifer et al. (1990) or the *ABLE Sampler*, as similar ones exist. Rather, the purpose of this discussion is to suggest that conceptions of literacy provision in existing guides illustrate how little encouragement is given to practitioners to consider numeracy in their practice. Such omissions are surprising, given the multiplicity of important everyday and work situations in which numeracy and literacy are linked, especially those classified under the label of *quantitative literacy* as one of three main facets of literacy tasks (see Kirsch & Jungeblut, 1986; Statistics Canada, 1991).

Interestingly, the introductory sections to the teacher's edition of math textbooks for adults or accompanying teacher's guides almost always start with a section on the math anxiety of the tutors or teachers, rather than that of their students. The following quote from *Basic Math Skills: A Handbook for Tutors* (Lutz & Pollak, 1982), published by Literacy Volunteers of America for tutors teaching reading to beginning readers, is typical. Following the phrase "Reading tutor + a little help = math tutor," which is probably meant to alleviate the fears of reading tutors unaccustomed to teaching math, the guide suggests that:

> *[M]any tutors are uneasy about teaching math. Some are not sure of their own skills; others are not sure how to begin, what to include, and how to integrate the math skills into their reading lessons. This uncertainly can lead to math anxiety. This handbook...is designed to help relieve math anxiety by giving specific information on:*
>
> *1. What the basic analysis and computational skills (+, -,x,÷) are;*
>
> *2. How to integrate math into your regular lessons;*
>
> *3. How to determine what computational skills your student has;*
>
> *4. How to introduce basic skills and concepts;*
>
> *5. How to create some activities and games to provide practice and drill (including ideas for consumer applications);*
>
> *6. Where to go for more help: workbooks, texts, games, materials; you can develop your students math programs in the same way you develop their reading or ESL lessons: out of their needs and wishes. (p. 1)*

This quote highlights the difficulties faced by tutors, and probably by teachers, working with larger classes. Armed only with a brief guide, a few hours of preservice training (at best), and most likely some apprehension about mathematics instruction, these educators need to handle initial assessment, decide on the content and proper sequencing of instruction, and develop lesson plans and assessment schemes. Educators are also left to struggle with questions regarding which skills are helpful for the everyday functioning of their students, how to integrate their literacy and numeracy teaching, and how to devise methods to ascertain mastery of learned skills. Under these circumstances, many educators without extensive training in teaching math to adults may be tempted to turn to existing commercial resources.

As suggested earlier, commercial textbooks and workbooks are widely available and heavily promoted by publishers. They appear to address, at least in part, the rich assortment of work and everyday contexts requiring some sort of quantitative skills. However, even a cursory examination of such resources reveals that they largely resemble traditional drill-and-practice K-12 materials and that they include many long sections with repetitive computational exercises. The new vision of the National Council of Teachers of Mathematics (NCTM, 1989) regarding what “knowing mathematics” is all about, as well as its recommendations for far reaching reform in the scope and nature of mathematics teaching and assessment, seems to have gone relatively unnoticed by those writing textbooks for adults.

To the extent that educators choose to rely on such existing resources, they are likely to encounter the language of traditional mathematics instruction (i.e., the basic analysis and computational skills [+, -, x, ÷]), which perpetuates the separation between mathematics and other aspects of literacy education and locks students into a system with which many had difficulty in the past. The following comment from Dalbera (1991), made in the context of discussing literacy programs in developing countries, unfortunately may also hold true for many programs in the United States:

> *...only too often we find literacy programmes which include a highly “revolutionary” section aimed at providing access to written speech, increasing social awareness, encouraging development, etc., but a highly “reactionary” section for providing access to written arithmetic; adults find themselves faced with an old-fashioned method directly traceable to traditional primary education, childish and superficially adapted to their environment. [Marbles have been replaced by eggs to create a “rural” impression], leading to poor results or none at all. (p. 4)*

3. Reflections on Current Practices

It was suggested earlier that significant activity in numeracy provision is currently happening. If this is the case, why does it go unreported? Overall, the lack of official data on the provision of mathematics education or on math skills of adults begs the question of whether states and programs that do not mention math in their reports either (a) have no math-related activity in state-sponsored programs (which is most likely not the case); (b) have no way of knowing how much mathematics is being taught and in what particular content areas, due to the nature of existing reporting mechanisms and the limited scope of assessment frameworks; or (c) cannot know the extent of math instruction since it is integrated with literacy education, which raises many interesting questions (e.g., regarding instructional strategies used to integrate numeracy and literacy education).

There are few visible indications that mathematics education is fully integrated with other types of literacy instruction. This report’s analysis of the content of textbooks and of interviews with adult educators and learners tentatively suggests that numeracy-related activities in adult education programs too often tend to resemble traditional K-12 math instruction. Learners who were observed during classroom visits were often seen laboring over math problems characteristic of old-fashioned, drill-and-practice techniques. They plodded their way through workbooks and worksheets, with few opportunities to develop their communication skills about quantitative issues, to explore multiple solution approaches, or to apply or adapt their skills to new, realistic situations.

Adult education teachers' mathematical and pedagogical skills—as well as their feelings of inadequacy about these skills—may explain their instructional practices. There are many similar findings on K-12 teachers' knowledge of subject matter (e.g., Simon, 1993). Some adult educators are themselves graduates of ABE or GED programs who returned to teach and who may have only limited exposure to modern methods of teaching math (Lytle, Belzer, & Reumann, 1992). Teachers with certification to teach K-12 math could presumably be considered qualified to teach math to adults. However, the fact that many of these teachers have previously practiced in the K-12 school system, which is still struggling to raise its achievement levels in math and science (Mullis et al., 1991), cannot be ignored. While some former K-12 teachers may prove to be successful with adult learners, others may need more guidance and assistance in managing the transition to working with adults whose goals, life experiences, beliefs, and motivations may require different approaches than those used with children. Furthermore, teachers with prior experience in teaching math at the high school level may be used to separating math instruction from other subject areas and placing little emphasis on communication skills (Silver, Shapiro, & Deutch, 1993), and this may prevent them from effectively addressing the need to link literacy and numeracy instruction.

Several teachers who were interviewed, while very motivated to provide students with high-quality instruction, attested to varying degrees of confidence in their own mathematical skills. Even those who were very comfortable with their knowledge of mathematics said that they had little initial training and little access to resources or people to consult when it came to math instruction. Overall, they found that their best choices were either to resort to the tried and true teaching model with which they were familiar, based on their own childhood experiences, or to follow whatever math textbook was available in their program. This state of affairs could also cause teachers to discourage students from investing heavily in math learning, as it might expose teachers' inadequacies or difficulties with the subject.

While the observations in the above sections are based on pilot data, they nonetheless point to the need to invest significant efforts in changing and expanding educators' and managers' conceptions of what numeracy provision should involve. Since programs are not presently asked to assess or report math-related activity separately from other activities, the current level and limited scope of math education for adults may continue uninterrupted. As a point of comparison, the amount of attention paid to numeracy in the adult education systems of the United Kingdom and Australia should be noted. Both are presently viewing literacy and numeracy as separate, yet related, domains of almost equal importance, as reflected in official reports, survey results, teaching materials, and accreditation frameworks for both teachers and students (e.g., Adult Literacy and Basic Skills Unit (ALBSU), 1982, 1984; Riley, 1984).

4. RESEARCH

Except for the work of Sticht and his colleagues with military personnel (e.g., Sticht & Mikulecky, 1984), no research appears to have been published in the United States relating to the unique aspects of teaching math to adults. These aspects include the effectiveness of different teaching techniques, the beliefs and training of adult educators involved in numeracy provision, and the actual impact of adult education on learners' everyday numerical functioning. This fact clearly emerges in recent work by Darkenwald (1986), who has identified 60 studies worthy of inclusion in a comprehensive review of research of relevance to adult educators. None of these studies address numeracy-related topics, nor have any numeracy studies been published since then. Darkenwald (1986), whose study aimed to create a research and development agenda for the Literacy Assistance Center in New York City, also took two additional innovative steps. He asked 10 prominent researchers in the area of adult education, as well as 12 experienced practitioners from the New York metropolitan area, for their views on the highest priorities for future research in this field. None of the individuals surveyed mentioned any numeracy-related issues as being either important or bothersome.

Similarly, little systematic research on adult numeracy was found in international literature addressing adult education/adult literacy topics; this is despite UNESCO's recognition of arithmetic as one of the components of literacy. Dalbera's (1991) comment is instructive: "It must be admitted that although literacy in general has generated a great amount of specialized literature, this is not the case with arithmetic in particular. In view of their small number, no particular skill is needed to count the studies devoted to this subject, of which even fewer have been published" (p. 3). Surveys of the mathematical skills of workers and the quantitative demands of different occupations, as well as discussions of the problems related to the applicability of K-12 or vocational math education to the working lives of adults, have been published in Australia (Foyster, 1990; Wickert, 1989) and the United Kingdom (Adult Literacy and Basic Skills Unit, 1984; Cockroft, 1982; Harris, 1991).

It is surprising that no attempts have been made so far to synthesize, interpret, replicate, or extend research of relevance to adult numeracy education that has been published by workers in other disciplines such as mathematics education, cognitive psychology, and teacher education. Areas of particular interest include mathematical reasoning and mathematical performance of adults in everyday and work-related contexts, including people with little or no formal schooling, and transfer and application of quantitative skills and of related cognitive and problem-solving skills. Starting points for research and relevant findings in these areas can be found in Carraher, Schliemann, and Carraher, 1988; Harris, 1991; Nisbett, Krantz, Jepson, and Kunda, 1983; Nunes, 1992; Poon, Rubin, and Wilson, 1989; Resnick, 1987; Rogoff and Lave, 1984; Saxe, 1988; Scribner and Sachs, 1991; or Singley and Anderson, 1989. (An interesting example for implementation of results from research on skill transfer and on functional-context learning in the design of a framework for math-related instruction in occupational contexts can be found in Sticht & McDonald, 1993.)

Few attempts by adult educators have also been made to examine the implications of K-12-based research on the teaching and learning of specific quantitative skills that prove difficult for many learners (e.g., place value, fractions and percentages, measurement) and to consider it in light of adults' extensive experiences with such issues in everyday contexts (e.g., familiarity with numerical and proportional issues in the context of money, cooking, or workplace tasks). Likewise, research on the effects of linguistic skills on learning of mathematics by children with limited proficiency in English (e.g., Laborde, 1990) is seldom addressed by adult educators working with ESL students.

These and other topics, based on work with K-12 students, have generated very large bodies of research literature, which should be consulted for their relevance for the adult education community.

The Numeracy Project at the National Center on Adult Literacy (NCAL) is presently engaged in research on some of the issues outlined above, specifically those dealing with the beliefs, attitudes, expectations, and prior experiences of adult learners and teachers regarding mathematics education. The only other funded research effort on adult numeracy currently underway is Research into Adult Basic Education in Mathematics (Project RABEM), which is conducted by World Education, Massachusetts, with funding from the Office of Educational Research and Improvement (OERI). This project aims to identify key inputs into ABE mathematics instruction in Massachusetts and to develop a detailed picture of the adult basic education environment. Many additional and important research topics related to the teaching of quantitative skills to adults are presently unaddressed and may remain so for quite some time, given the current level of interest in and funding for research on adult learning.

B. PERSPECTIVES ON NUMERACY

The term *numeracy* is less commonly used than *literacy,* and so far it has gained no consensus on meaning. One view of numeracy equates it with basic math skills, much in the same way that literacy may be viewed as basic reading and writing skills. In this sense, numeracy encompasses the lower end of mathematics, or whatever math educators attempt to achieve in the early grades. Another view of numeracy covers a much larger set of issues than basic computational skills, which can be seen as a way to view and interact with the quantitative aspects of the adult world. Baker and Street, 1993, discuss several perspectives on numeracy in connection with historical developments in the literacy field. It is important to examine in some detail perspectives that might be included in a discussion of numeracy and its place in adult education, because the definitions adopted may have important implications for the training and infrastructure needed to develop desired skills.

For some years, three different communities—employers, mathematics and science educators, and those involved in assessment programs—have been presenting and exchanging ideas relevant to a discussion of the nature of the quantitative skills adults should seek or may need to possess. These ideas are reviewed below.

1. EMPLOYERS

Several initiatives have been taken in recent years to identify the basic skills that employers expect of their workers and to explicate the role of trainers and educators in this regard. Some of these initiatives are aimed at informing K-12 educators and school systems, while others are aimed at informing educators who work with adults in literacy programs, in ABE and job-training programs, and in training in industry. The most well known efforts are a study by the American Society for Training and Development (see Carnevale et al., 1990) and recent work by the Secretary of Labor's Commission on Achieving the Necessary Skills (SCANS, 1991, 1992). These and several other important surveys of basic skills are summarized and contrasted in a recent report by the National Center for Research on Evaluation, Standards, and Student Testing (see O'Neil, Allred, & Baker, 1992). For the purpose of the present discussion, it is important to note that all of the above surveys of basic skills view quantitative skills as one of several foundation skills, usually in addition to reading, writing, and related communication skills.

The SCANS report (1992), for example, distinguishes between the arithmetical and mathematical basic skills expected of a worker as follows:

> *SCANS arithmetical skills: Performs basic computations; uses basic numerical concepts such as whole numbers and percentages in practical situations; makes reasonable estimates and arithmetic results without a calculator; and uses*

tables, graphs, diagrams and charts to obtain or convey quantitative information.

SCANS mathematical skills: Approaches practical problems by choosing appropriately from a variety of mathematical techniques; uses quantitative data to construct logical explanations for real world situations; expresses mathematical ideas and concepts orally and in writing; and understands the role of chance in the occurrence and prediction of events. (p. 83)

Surveys of employers' perspectives on basic skills also provide numerous examples of workplace situations in which numeracy skills are critical. SCANS, for example, explains that numeracy skills are involved when workers deal with, or communicate about, tasks or situations involving resources such as time (scheduling and time allocation), money (use or prepare budgets, make forecasts, handle sales, keep records), or materials and facilities (allocate, store, or use materials, supplies, or space). While surveys of employers focus on work-related skills, many work-related situations, such as those quoted from SCANS above, may have important similarities to nonwork or everyday tasks or problems and are thus likely to require similar numeracy skills.

Emphasis on math skills is found in many workplace literacy programs. The Education Writers Association (1988) recently reported that studies by the Southern Technology Council of industrial adaptation to technology in the South revealed that the central issue in most training programs was math and the analytical skills that it enhances. As EWA argued, discussions of the literacy problem in the United States almost always focus on reading and writing; in contrast, except for business office skills, workplace literacy translates into adeptness in the language of math, including dealing with abstractions and analysis; making sense of statistical data, charts, and graphs; assessing probability; and analyzing problems.

A possible reason for emphasis on math in workplace literacy programs may be found in observations made by staff at a National Workplace Literacy Demonstration Project of the Associated Builders and Contractors in Baton Rouge, Louisiana (P. Wall, personal communication, December 1992). These results suggest that workers with literacy levels much below that of the level at which training materials have been written can still be successful in training if an instructor tells the worker exactly what information is needed. Workers can then learn information necessary for the performance of tasks and duties through verbal explanations, bypassing the need to read training or actual work materials.

It is frequently more difficult, however, for workers to compensate for deficiencies in mathematical skills in this way. These observations are compatible with results from other studies of workplace literacy programs. Ethnographies of the ways in which workers actually conduct their duties (e.g., Gowen, 1992; Hart-Landsberg, 1992) suggest that workers can successfully obtain information about work tasks through social networks and peer support, possibly without the knowledge of supervisors. In contrast, there may be no substitute for a worker's own knowledge of math when tasks call for the use of measuring tools, estimation of quantities, or reading of gauges. This might be especially true in some production jobs in which workers are expected to be able to react swiftly—for example, to stop a production line—if measurements point to errors in an item being produced or if data indicate that a manufacturing process is going out of control.

The above studies suggest that the quantitative skills desired by employers are broader than mere facility with the mechanics of addition, subtraction, multiplication, and division and familiarity with basic number facts; these skills also include some knowledge of statistics, probability, and mental computation strategies. These demands point to the importance of general problem-solving skills and the need for skills that are useful in the real world. Of equal importance, these definitions introduce demands for communication skills about quantitative issues or with quantitative information, considerably expanding what is considered under the heading of basic quantitative skills.

2. Mathematics and Science Educators

The mathematics and science education communities, both in the United States and abroad, have persistently been making the case for the importance of developing mathematical and number-related skills and have contributed details as to what such skills might include (see, e.g., American Association for the Advancement of Science, 1989; Cockroft, 1982; Gillie & Kloosterman, 1988; National Council of Teachers of Mathematics, 1989; National Research Council, 1989; Steen, 1991; or Willis, 1990 [for an Australian perspective]).

While employers have focused mostly on practical or job-specific numeracy skills, educators associated with the mathematical sciences have paid more attention to the importance of numeracy, or quantitative literacy, in civic and social contexts. One influential report, *Everybody Counts: A Report to the Nation on the Future of Mathematics Education*, (National Research Council, 1989) states:

> *To cope confidently with the demands of today's society, one must be able to grasp the implications of many mathematical concepts—for example, change, logic, and graphs—that permeate daily news and routine decisions....functional literacy in all of its manifestations—mathematical, scientific and cultural—provides a common fabric of communication indispensable for modern civilized society....mathematical literacy is especially crucial because mathematics is the language of science and technology. Discussions of important health and environmental issues (acid rain, waste management, greenhouse effect) is impossible without using the language of mathematics; solutions to these problems require a public consensus built on the social fabric of literacy. (p. 13)*

The above quote highlights the difficulty of separating numeracy and literacy, implying that it might be impossible to speak of developing full literacy—in terms of reading, writing, and communication skills—without also establishing an understanding of various quantitative concepts and the ability to communicate them effectively. Those familiar with theoretical perspectives on the nature and role of literacy would find the above view of numeracy quite close in spirit to Freire's (1985) view of literacy, which advocates a political view of literacy as a vehicle that emancipates people to form independent and informed views of the world around them.

The *Curriculum and Evaluation Standards for School Mathematics* of the National Council of Teachers of Mathematics (NCTM, 1989) expand the scope and nature of what mathematics teaching and learning may entail well beyond traditional notions of drill-and-practice instruction. NCTM's new *Standards* encourage a view of mathematics that enables and requires reasoning, problem solving, communication, and connections to other contexts and disciplines. Teachers are urged to foster in their students an understanding of the value and utility of mathematics, the ability to use mathematics in their everyday lives, and the ability to communicate about the use of numbers and about mathematical problem solving. Thus, as definitions of adult literacy expand to include quantitative issues (as this report suggests), definitions of K-12 mathematics are being expanded to include language arts.

In addition to the importance of quantitative skills in functional, civic, and personal contexts, mathematics educators have also highlighted the gatekeeping role of quantitative skills, since they are needed at varying levels to prepare for further study in many academic and professional fields (NCTM, 1989) and to enter or advance in certain careers or occupations. The gatekeeping role of quantitative skills is clearly at work in adult education. One reason that many adult learners offer for entering adult education programs is to obtain a GED diploma, which is often a prerequisite for postsecondary studies or for hiring and job advancement. Passing the math section of the GED test, therefore, becomes a hurdle and a goal for many adults, and whatever skills are required to pass this part of the test enter into the de facto definition of numeracy. Given the present format of the GED test (answering multiple-choice items under time limit), many skills and capacities proposed by NCTM's new *Standards* are likely to be left outside those assessed by the GED test.

Unfortunately, as with preparation for other standardized tests such as the SAT, preparation for the math component of the GED test may be limited to teaching for the test instead of supplementing and enhancing the skills of learners in order to bring them up to a level of equivalency with graduates of regular high schools. This raises questions about the particular skills enhanced by GED math preparation. Surprisingly, almost no published research to date has examined either the quality and nature of skills afforded by GED preparation (as opposed to its effect on self-esteem or employment opportunities, which are also important outcomes of GED certification) or how well learners can transfer and apply knowledge acquired through GED math preparation to everyday or work-related problem solving. (An NCAL report by Kaplan & Venezky, 1993, *What Can Employers Assume About the Literacy Skills of GED Graduates?* examines this question in some detail.)

One should not assume that the current content of the math section of the GED test can serve as a complete road map for what adult numeracy provision should encompass. The GED test, which accounts for roughly one sixth of all high school diplomas awarded in the United States in recent years (Baldwin, 1990), was modeled after the curricula of 4-year high schools and is not particularly well suited to assess the quantitative skills that adults may need. Such analyses of needed work-related skills have been offered recently by a task force of the American Society for Training and Development (see Carnevale et al., 1990) and by the SCANS commission (see SCANS, 1991, 1992). Further, one needs to consider that the appropriateness of high school mathematics curricula has been under debate for years. The key issue has been the tension between the preparation of students for college-level mathematics and the preparation of the forgotten half of students for vocational training and employment; this tension is likely to be reflected in the content of the GED test. The recent release of the NCTM's new *Standards* (NCTM, 1989) further testifies to the need for K-12 educators to revise their views on what and how to teach in schools. However, as K-12 educators slowly adjust to and debate the adequacy of these new statements of instructional goals, the math section of the GED test may for some years continue to reflect earlier, and potentially outdated, instructional goals or practices.

In the past, K-12 math educators have shown little explicit interest in adult education activities in the United States and may have been less concerned than adult educators about issues of utility, transfer, and adaptation of skills acquired through schooling. A welcome initiative in this regard is that by the National Council of Teachers of Mathematics, which, in 1990, was asked by a group of adult educators from within its membership to increase its attention to issues of mathematics education for adults. Some of these concerned members were appointed by NCTM to a Task Force on Adult Mathematical Literacy. A report with various recommendations for the establishment of curriculum standards for adults was submitted to NCTM in January, 1992 (Azzolino, Cicmanec, Gaston, Manley, & Schmitt, 1991). This led to NCTM's decision earlier this year to collaborate with adult education agencies on initiatives aimed at promoting the quantitative literacy skills of adults.

The relevance for adult learners of curricular standards or goal statements originally developed for K-12 students is a current issue. The Massachusetts ABE Math Team—a self-initiated group of adult education practitioners supported by the Massachusetts Department of Education, the Massachusetts System for Adult Basic Education (SABES), World Education, and community-based ABE programs in Massachusetts and led by Mary Jane Schmitt and William Arcand—has been using the NCTM *Standards* as a starting point in exploring instructional goals for adult learners in ABE, GED, ESL, and workplace contexts, as part of the STANDARDS Project, funded by the National Institute For Literacy. A first draft is expected to be released by the ABE Math Team later this year and will hopefully be used by adult educators in the United States as a basis for discussion regarding frameworks for adult numeracy provision.

3. Assessment Programs

Dimensions of numeracy, and any links between numeracy and literacy, are also reflected in frameworks, content, or item formats of tests and surveys of general literacy and/or basic skills. Most influential in this regard has been the ETS/NAEP approach developed for the Young Adult Literacy Survey (Kirsch & Jungeblut, 1986), and used for assessment of literacy skills in the National Adult Literacy Survey (Kirsch et al., 1993), and for national surveys in Canada (Statistics Canada, 1991) and Australia. This approach to assessment of literacy skills—which has been developed for large-scale survey purposes, not for classroom use or diagnostic purposes—views literacy as comprised of three interrelated, yet separate, facets: prose literacy, document literacy, and quantitative literacy. In their 1986 survey of the literacy skills of young adults in America, and in the recent survey of literacy skills of adults of all ages in America, Kirsch and his colleagues (Kirsch & Jungeblut, 1986; Kirsch et al., 1993) defined *quantitative literacy* as the knowledge and skills needed to apply arithmetic operations embedded in written materials and assessed this skill by using realistic functional tasks that varied the arithmetic operation to be performed, the number of operations to be performed, and the degree to which the operations were embedded in text. Examples of such tasks included filling out a bank deposit slip (which involved writing two check amounts in designated places on a deposit slip and summing their values) and reading a menu and computing the cost of a specified meal to determine the correct change from a given amount (which involves two sequential operations, addition and then subtraction).

As mentioned earlier, the NALS approach to assessment of quantitative literacy skills focuses on tasks involving arithmetic operations only—as opposed to tasks involving skills from other mathematical domains, such as measurement or understanding graphs. Further, it focuses primarily on the performance of operations that have only right or wrong solutions, even though many everyday or work-related tasks do not necessarily seek a precise answer, or require people to plan and optimize the use of resources. What is important for the present discussion is that the NALS approach, the above constraints aside, highlights the strong links between numerical and linguistic skills in functional contexts and the difficulty of defining what numeracy is without taking into account literacy issues, a perspective that was less evident in views of numeracy discussed earlier.

A somewhat similar approach to the assessment of adult quantitative literacy skills in terms of its emphasis on functional skills—but one that has been developed for diagnostic and evaluation purposes—is found in the California-based Comprehensive Adult Student Assessment System (CASAS, 1991). Math skills, as well as reading and other skills assessed by CASAS, are linked to competencies and relevant competency-based curriculum materials, thus providing a view of numeracy-related skills targeted by programs linked to CASAS. Taking a somewhat different approach, the Kansas Adult Student Comprehensive Assessment and Delivery Educational System (KASCADES) also views the application of arithmetic operations and mathematical concepts as a component of basic skills, yet perceives mathematics as a vehicle for intellectual development—a common notion with many mathematics educators. Computer literacy, understanding of technology, critical thinking, and problem-solving abilities are all part of a KASCADES-related curriculum, setting it apart from more functional views of numeracy.

Finally, a de facto definition of adult numeracy can be found in the content of standardized tests used in adult literacy programs. The most well known of these tests, the Tests of Adult Basic Education (TABE), includes two math-related sections assessing basic mathematical computations and concepts/applications skills. The test, which uses only multiple-choice items, is frequently used to screen incoming students and to evaluate their reading and math grade levels to prescribe appropriate placement. Educators often decide what math skills to emphasize in instruction based on performance on particular TABE items, sometimes using charts directing students who fail particular TABE items to specified pages in textbooks or workbooks. It is important to note that the math sections of the TABE have only tenuous connections to the kinds of functional tasks assessed by NALS or CASAS. In a review of tests used in adult basic education, Jackson (cited in Sticht, 1990) writes about the TABE: “Of the 40 items on math concepts and applications there is only one item on calculating the correct change for a given transaction, no item on savings from bulk purchases, and no item on the total cost of a purchase with installment plan financing charges” (p. 20). In reviewing the ABLE test, another well known instrument, Jackson mentions that its advanced math section “...includes only a few very simple algebra and geometry problems. Some learners who score high may find themselves required to take remedial math when enrolling in technical schools and colleges” (p. 13).

Since tests such as the TABE or ABLE are also used to assess postprogram performance for program evaluation or accountability purposes, they are likely to direct teachers’ attention to particular types of computational and algorithmic skills, thus establishing a specific, narrowly defined focus for adult numeracy provision. As a result, the content of these tests should not be taken as a statement on what numeracy encompasses. More generally, the above discussion suggests that official statistics on literacy levels or gains, such as those reported by local programs or by federal agencies, unfortunately may be based on assessments having very different characteristics (i.e., in terms of item types, response modes, content areas, etc.), as well as somewhat different views of which numerical skills are important. The range of assessment methods, each with a somewhat different set of skills being assessed, complicates understanding of actual levels of numeracy in specific programs—or in the nation as a whole—and may undermine the quality of policies or programmatic decisions based on such assessments.

C. Toward Defining Numeracy

The preceding sections suggest that the tasks and demands adults face at work (SCANS, 1992) or in daily life and civic contexts (Kirsch et al., 1993; Statistics Canada, 1991) may require much more than simply the ability to apply basic computational skills. The author prefers to use the term *numeracy* to capture an expanding terrain that is broader—and also more functional in nature—than what has been traditionally covered by the term *mathematics education.* With the above discussion as a starting point, this report views numeracy as encompassing a broad set of skills, strategies, beliefs, and dispositions that people need to autonomously engage in and effectively manage situations involving numbers, quantitative or quantifiable data, or information based on quantitative data.

Since the field of adult numeracy is in an early, formative stage (Baker & Street, 1993), a dialogue within the adult education community should begin to explore the nature of the skills that people will need to possess to be considered *numerate.* This dialogue will help to provide a vision for adult numeracy education and may, in turn, have repercussions for K-12 mathematics education. The following discussion outlines key questions and issues on which public discourse should focus.

1. Is there a certain level of mathematical knowledge that qualifies a person as numerate?

In light of existing views of literacy (e.g., Venezky, Wagner, & Ciliberti, 1990) and the definition of literacy in the 1991 National Literacy Act, it appears essential to discuss what the concept of *numeracy* might include, as well as what constitutes being numerate or acting in a numerate way, in relative, rather than absolute, terms. Numeracy demands may depend on the characteristics of a particular community or workplace and may change over time, depending on personal life circumstances, job transitions, and changing realities and technological shifts in everyday and work contexts.

To be sure, one should not assume that ever higher mathematical sophistication will be required as the world becomes more technologically advanced. Processes of both “skilling” and “de-skilling” can be observed in jobs and daily tasks (Bailey, 1991). For example, the advent of calculators and computers has saved many people the need to memorize and be fluent with the mechanics of many mathematical operations and processes that were the focus of K-12 mathematics for many years. In many stores today, cashiers scan products on a bar code reader instead of totaling prices by hand, and consumers may be tempted to trust computer-generated bills without verifying every figure or transaction. At the same time, demands have increased for other kinds of information-processing skills, including higher quantitative reasoning skills.

It might be useful to reflect on what being numerate entails in the context of a K-12 school system that, in the United States as well as in many other countries, seems to have adopted a more or less agreed upon ladder of mathematical skills (Schmitt & Jones, 1990). From learning the four basic operations, students routinely move to proportional topics (fractions, decimals, and percentages), then to algebra, geometry, trigonometry, and calculus. Measurement and some graphing skills are visited at various points. However, several questions arise: Is there a certain point on this ladder above which one is considered numerate? If so, what might it be? How high on this ladder does one need to climb in order to be an effective citizen, worker, shopper, or parent? Do some of these roles entail a separate ladder with different steps? Finally, to what extent is the ladder metaphor relevant or helpful to an adult educator who has to plan instruction for adult students seeking to improve their functional skills?

Numerous educators would probably argue that many mathematical skills have to be acquired hierarchically. For example, one cannot understand and use percentages without having mastered earlier concepts such as the four basic operations. Yet, unlike children, many adults possess significant life experiences and varied coping skills and problem-solving strategies. Adults are routinely engaged, informally or formally, with quantitative phenomena in their daily lives. Handling money, shopping and commercial exchanges, planning around time and distance constraints, playing games, and participating in creative arts and crafts generate many encounters with counting, quantities, volumes, patterns, and shapes (Bishop, 1992). Research is needed to determine to what extent these experiences enable adult students to follow different learning trajectories of quantitative skills than those that are thought to be appropriate for school children.

The usefulness of trying to define what numeracy might mean is that it focuses attention on the goals of developing mathematical skills. Children learning math in school are expected by teachers to reach the top of the ladder. To the extent that they cannot cope with what many high school teachers view as real mathematics (i.e., algebra and beyond), they are usually banished to the likes of a general mathematics course (Steen, 1992), which many mathematics educators consider a dead end. Buying into this system assumes that the goal of studying mathematics is to climb as high as possible on a single ladder.

Given that adult students come to adult education programs with multiple goals and needs and attempt to address them under constraints of time and other resources, the question is how to conceptualize the goal of math learning for adults. In this context, adult educators should think in terms of *developing numeracy,* traveling with adult students along one of several possible trajectories compatible with their life goals and circumstances, as opposed to *learning math,* which implies climbing up a single ladder. Schmitt and Jones (1990) offer a related discussion of a *spiral approach,* which entails drawing out the interconnections between different mathematical concepts and teaching them in concert with, not separate from, each other from the start of a program. A discussion of multiple learning trajectories also requires an examination of the need for interim points at which learners' achievements are recognized and formally accredited, in addition to the single recognition endpoint currently offered by passing the GED test. Preliminary work on accreditation frameworks that can guide teachers' work on multiple trajectories and serve to formally recognize learners' achievements at multiple points is now being done in Australia (ARIS Bulletin, 1992) and the United Kingdom (Morphy, 1989).

2. What does it mean to act in a numerate way?

While the answer to this question will vary for different people, it was suggested above that, in order to be considered numerate, adults should be able to autonomously engage and effectively manage situations involving quantitative information. These terms are used to indicate that, when confronted with real life situations or tasks, adults frequently have to assess personal and situational demands (What am I trying to achieve?), severity of consequences (How accurate should I be? What if I make a mistake?), and resources (e.g., time, effort, technical aids such as calculators, and people who can provide assistance).

On the basis of the above factors, adults reason, plan, initiate, choose, and execute a course of action that they see as sensible for themselves. In the course of attempting to deal with a situation, adults, like managers, may apply different tools, employ the resources at their disposal, assess progress, and revise plans as needed. This process may also include sacrificing the precision or quality of the desired product in the interest of time, effort, or motivational constraints.

How well a numeracy-related situation or task is managed depends not only on the technical know-how of its manager (i.e., knowledge of mathematical rules, operations, and principles), but also on his or her dispositions, beliefs, habits, self-concept, and feelings about the situation (McLeod, 1992; Schoenfeld, 1983; Tobias, 1979). Frequently, adults—including those who are highly educated—decide that they are not good with numbers and elect to postpone or avoid solving a problem with quantitative elements, or they address only a portion of it and deal with the consequence. Likewise, recalling prior failures in similar situations (e.g., from previous school experiences) adults may prefer to delegate or subcontract a problem by asking a family member or a salesperson for help. Such actions may enable adults to reduce both their mental and emotional loads, yet may fall short of "autonomous engagement" and a feeling of "at-homeness with numbers" (Cockroft, 1982).

Thus, it appears that one of the basic goals of adult numeracy education should be to help students recognize instances where quantitative information is present, to bring them to a point where they are able to positively approach situations with quantitative elements, and to help them appreciate the costs of engaging in actions that do not take into full account all of the quantitative information in a problem. This may be quite different from what adult learners encountered in K-12 mathematics classes, where the goal was probably to learn how to do mathematics within the constraints of school-oriented problems controlled by teachers, rather than by students. Instead of, or in addition to, seeking to develop adult learners' appreciation for *mathematics as problem solving* (NCTM, 1989)—which might perpetuate the traditional belief that mathematical learning can occur entirely in class, independent of the larger context of learners' lives—adult educators should consider numeracy education as taking place in the context of learners' general reasoning skills and experiences.

In addition to developing the functional skills of adult learners, numeracy educators may also find it important to develop learners' understanding of the mathematical characteristics of situations where no problem requiring a solution is evident. As suggested above, this may occur when recognition of patterns in visual, kinetic, temporal, or other modalities can enhance learners' understanding of how mathematical tools can be used to describe or analyze complex phenomena in natural, scientific, social, or creative domains. To enable adult learners to further develop their existing numeracy skills, adult educators need to find ways to maintain a balance between problem-oriented and pure mathematics instructional techniques.

3. WHAT LINKS SHOULD BE MAINTAINED BETWEEN LITERACY AND NUMERACY INSTRUCTION?

Obviously, the subject matter of numeracy is distinct from that of literacy. However, the fact that computation is now included in the definition of literacy, the suggestion that quantitative literacy is one of three main facets of literacy (Kirsch & Jungeblut, 1986), and the realization that literacy instructors often end up having to teach mathematical issues as well, necessitate a discussion of the linkages between literacy and numeracy—a discussion that has both theoretical and practical significance.

Such a discussion sparks several questions: What speaking and listening skills do adults need to communicate with others about real world quantitative issues (e.g., on the job, at the supermarket)? How do adults' reading and writing skills affect their understanding of, and ability to cope with, real world situations and tasks with quantitative elements (e.g., reading and responding to a police report with statistics about crime rates in the neighborhood)? Why do many students find mathematics textbooks difficult to read and word problems difficult to solve? Answers to these and other questions can add to a general understanding of what numeracy might encompass and are also of practical importance to adult educators. Practitioners need to make ongoing instructional decisions about how to coordinate the development of quantitative skills with literacy instruction and to be concerned about the influence that students' reading, writing, and communication skills have on their understanding of and achievement in mathematics.

Work by many linguists and mathematics educators (e.g., Halliday, 1979; Kane, Byrne, & Hater, 1974; Laborde, 1990; O'Mara, 1981) points to various types and degrees of interaction between learners' literacy skills and the language of mathematics. Learning and using this language may involve

- reinterpreting or attaching new meanings to existing words in everyday language, such as difference, set, model, table, and volume (The meanings of terms used in a mathematical context are often more constrained or precise than those used in everyday speech, such as average, sample, carry, and borrow);
- learning new words that have only a mathematical usage and meaning (e.g., binomial, numerator) or word clusters (e.g., lowest common denominator, standard deviation,

control chart) in which the cluster has a meaning different from those of its components;

- translating mathematical symbols and phrases (e.g., 2 x 3) into natural language (and vice versa) or describing the results of a mathematical transaction in language terms;
- reading and decoding written or spoken words in context (e.g., in word problems or spoken instructions, such as, “occasionally, check the machine to make sure...”);
- being aware that some quantitative information might be conveyed by certain terms or embedded in displays even if no numbers are used (e.g., information about time, degrees of uncertainty, or trends);
- reading and decoding numerical and mathematical symbols and comprehending their meanings and implications for action; and
- writing about numerical issues for various purposes (e.g., notes, definitions, instructions, explanations, descriptions, or reports).

As is often pointed out, a teacher may speak to a class using the rules, terminology, and implicit understandings of everyday language, but the concepts being explained are embedded in mathematical language (Laborde, 1990). This requires students to continuously switch between the two systems in order to judge which interpretation should be applied to the terms encountered. This process may prove difficult not only for students with a weak mastery of English (e.g., Kessler, Quinn, & Hayes, 1985), but also for students who have a relatively good command of the language. Both K-12 and adult students in America come from a variety of linguistic backgrounds. Some may speak little or no English; some may be native English speakers who grew up in a bilingual environment; still others may have different ethnic and cultural heritages (Nunes, 1992; Secada, 1992), which result in subtle differences in language usage that eventually affect comprehension. Overall, degree of proficiency in English and degree of bilingualism appear to have some relationship to mathematics achievement (Duran, 1988).

Kane et al. (1974) discuss the difficulties that students have with reading mathematics textbooks and argue that effective reading of such texts requires literacy skills in addition to those used in dealing with ordinary English materials. In addition to problems with specialized mathematical vocabulary and words with multiple meanings, Kane et al. address issues such as (a) the terse nature of mathematical texts (i.e., there are few if any built-in redundancies, which require the reader to slow down, read carefully and monitor comprehension or to translate mathematical phrases into spoken language to verify meaning), (b) the problems of direction and order (i.e., readers have to go in directions other than left-to-right when reading a graph, table, or complex formula), and (c) the special use of adjectives and phrases (i.e., proper subset, the union of the two sets) that have meanings different from their component words of which readers may be unaware.

Learning mathematics requires the interpretation and understanding of mathematical passages, requests, and explanations in textbooks (Rothman

& Cohen, 1989). Orr (1987), in her book *Twice as Less*, addresses the language problems of the African American students to whom she taught mathematics. She states, "Our study of students' work had convinced us that underlying their difficulties was the language they spoke...perhaps the students picked up no signals at all from these [function] words" (p. 12). Only after Orr began asking students to elaborate on the answers they provided in class did she realize that students had attached meanings to terms used in instruction that were very different from those used by teachers, meanings that were incorrect for the purpose of mathematics but were nonetheless a valid part of their everyday language. Tobias (1979) encourages teachers to use the terms "enlarge upon" and "elaborate" instead of "read" to describe gaining information from mathematical text and suggested that readers not expect to gain full meaning of mathematical passages instantly. Readers should expect to flounder with the passage in order to gain understanding from it.

Unfortunately, little is known about the interaction between literacy and numeracy when verbal communication about quantitative issues is involved, despite the fact that employers view verbal skills as highly desirable (Carnevale et al., 1990), and this leaves the area fertile for further research. The book *Speaking Mathematically* (Pimm, 1987) may serve as a starting point for work in this area. Likewise, little is presently known about the literacy skills involved in learning emerging topics in mathematics such as statistics and probability and communicating about them in job-related contexts (e.g., when collecting data to monitor product quality indicators as part of a statistical process control [SPC] program). Preliminary work in this area can be found in Gal (1993) and Gal, Mahoney, and Moore (1992).

In summary, our review suggests that a discussion of what it might mean to *know mathematics* or *do mathematics*—in the classroom or in the real world—cannot be accomplished without considering adults' literacy and language comprehension skills. In addition to being intimately involved in the process of learning mathematics, language skills are ultimately a vehicle through which adults communicate with each other to obtain information, make requests, or clarify statements. These points suggest that there are significant areas where literacy and numeracy blend into a single skill and that both are supported by general problem-solving skills. However, there are also many quantitatively rich, real world situations (and definitely many classroom situations) that require minimal use of language skills. Therefore, adult literacy educators may have to view numeracy as semi-autonomous from literacy.

4. What Specific Skills Should Be Emphasized in Numeracy Education?

The sources referenced above provide long and detailed discussions of domains of mathematical knowledge that should be considered by adult educators seeking to define what numeracy education should encompass. (e.g., Carnevale et al., 1990; Cockroft, 1982; Gillie & Kloosterman, 1988; National Council of Teachers of Mathematics, 1989; National Research Council, 1989; SCANS, 1991; Steen, 1991; Willis, 1990). Given the volume of relevant material and the different levels of specificity possible, a complete answer to the above question is beyond the scope of this paper and most likely would be premature. At present, work by the Massachusetts

ABE Math Team on the Math Standards Project may provide the first statement by adult educators—as opposed to K-12 math educators—regarding curriculum goals specifically tailored to the needs of an adult population.

Even when a proposal for broad curriculum standards in adult numeracy is released, there are several reasons to not expect any quick consensus regarding the types and levels of mathematical skills that should be emphasized in numeracy instruction. First, as with attempts to define literacy (e.g., Venezky et al., 1990), conceptions of numeracy may employ different levels of specificity. Numeracy may be variably discussed in terms of component abilities or knowledge of specific subject areas in mathematics; functional skills for handling various everyday or workplace tasks; or as more holistic problem-solving skills, where quantitative skills are not easily separable from, or integrated with, certain literacy or language skills. Each of these levels of specificity may have different implications for educators and trainers.

Second, in discussing the content aspects of numeracy, it is unclear to what extent one ought to (a) stay close to traditional domains of mathematics instruction (e.g., whole numbers, fractions, measurement, geometry, pre-algebra); (b) travel through more advanced terrains (e.g., trigonometry, calculus); (c) visit areas that have only recently been emphasized by NCTM and others (e.g., statistics, probability and uncertainty, modeling of mathematical phenomena, understanding of variability in natural and industrial processes); or (d) wander towards more distant, yet potentially very relevant, territories (e.g., scientific reasoning and scientific literacy, design of experiments and surveys, financial literacy, decision making and calculations of personal utility).

Third, as suggested earlier, numeracy should be discussed in relative terms; being numerate may involve different subsets of skills for different people, and the routes to becoming numerate may take different trajectories, depending on personal goals or societal circumstances. Thus, it may be unrealistic to define a single ladder with fixed steps on which all learners will be expected to climb.

Fourth, attempts to determine the scope of what numeracy provision should include need to consider that the skills required for access to higher or further education, where formal knowledge of mathematics and mastery of relatively advanced topics such as algebra or calculus is often required, are not necessarily those desired by employers or those that adults see as useful in their everyday life. This situation is often encountered when adult educators have to prepare students for taking tests (including the GED) which serve as gatekeepers for further education or training. The content, structure, and domains of coverage of such tests serve as a de facto definition for the goals of adult numeracy provision, creating a conflict situation for adult educators who have different, and often broader, conceptions of what adult numeracy should encompass. The need for numeracy education to open avenues for further learning creates a pressure to expand the range of skills that should be addressed in numeracy education, yet carries a price for learners and teachers alike.

Fifth, and in connection with the previous point, the *affective* aspects of numeracy development, while difficult to fit into conceptions of numeracy provision that are couched in cognitive terms, appear to be of critical importance (see McLeod, 1992, for a recent discussion of the growing awareness to and role of affective, attitudinal, and belief factors in mathematics learning). Given that some adult learners report negative attitudes towards mathematics, numeracy education should aim to reduce math fright and to increase feelings of at-homeness with numbers (Cockroft, 1982). It should also engender a positive view of mathematical practices and propose quantitative reasoning as a viable way to approach life's challenges. This increases the likelihood that learners will feel confident enough to engage in numeracy-related tasks after leaving the program. Furthermore, given that most learners will end up working on only a subset of the topics that numeracy educators may want to cover (and that learners overall spend in literacy programs much less time than children spend in schools), it is vital that numeracy education serves as a gate opener, instead of a gatekeeper; learners, after leaving a program, should be motivated to further develop their numeracy skills and should feel comfortable tackling additional or more advanced numeracy topics, either through additional classes or through informal learning. Unfortunately, learners may be intimidated by the reality that almost all math textbooks are intended for classroom use, usually as resources teachers can use to drill students. They are often not designed as vehicles for individual learning at home, as are textbooks in other disciplines.

The above discussion suggests that curriculum goals for particular groups of learners (e.g., in GED, ESL, ABE, or workplace programs) and learning plans for individual students may need to be specified within a *numeracy learning space,* or course matrix, defined along the following dimensions:

- *Skill/content areas:* Both the NCTM *Curriculum and Evaluation Standards* and the upcoming recommendations of the Massachusetts Math Standards project include a comprehensive list of content areas, or standards, deemed central by K-12 or adult mathematics educators. Some key content areas were mentioned earlier in this section. Some of these may be acquired hierarchically and must be taught sequentially, while others can be developed relatively independently of each other or taught with no particular sequence in mind, allowing for various learning trajectories that learners could follow.
- *Levels*: Levels may be defined by such criteria as beginning, intermediate, or advanced math skills, or they may be defined separately for each content area. Yet, one key consideration is that the skills level on which a learner should focus should be coordinated with learners' language skills. Learning routes need to be designed so that learners' literacy levels can support rather than hinder the development of numeracy skills.
- *Purposes*: As suggested above, adult learners may need to acquire mathematical skills for different purposes, such as handling functional, everyday tasks or applications;

paving the way for further academic learning of formal mathematics; satisfying workplace requirements; helping one's children with homework; or passing a math test administered for certification or admission purposes. Each of these purposes may necessitate a somewhat different route through the numeracy learning space.

Over the years, many K-12 educators have standardized a sequence of topics through which all learners are taken in more or less the same way. However, given the time constraints and different goals that adult learners may have, adult educators may not be able to follow a traditional K-12 sequence. Instead they may have to chart individualized routes for visiting selected topics in numeracy, given the expected contexts in which the acquired knowledge and skills will be applied. Such a numeracy learning matrix could be a valuable tool for discussions by adult educators. It could aid in setting goals and instructional objectives for programs, classes, or individual students. It could be used in discussions with learners about their goals or developmental needs. It could serve as a conceptual map in an evaluation of the scope of programs or the adequacy of tests or other assessment tools. Such uses, however, will be adopted only to the extent that numeracy is a concern of the adult education community.

CONCLUSIONS AND IMPLICATIONS

Reading, writing, and related communication skills appear to be the major concerns and foci around which adult literacy and many adult basic education programs revolve (Soifer et al., 1991). However, if one accepts that a mandate of learner-centered programs is "to allow learners to participate in citizenship...and function effectively in society" (Illinois state plan for adult education for 1990-1993, cited in Burroughs & Leininger, 1989), it follows that adult literacy/adult education programs, among other goals, should aim to help adults develop their numeracy skills and improve their ability to deal with quantitative problems.

This paper promotes a conception of *numeracy* that covers a significantly broader territory than what traditional views of *computational skills* or *basic math skills* might include. As proposed earlier, depending on personal and societal circumstances, numeracy may encompass an interrelated set of beliefs and dispositions that interact with a broad range of skills and knowledge. Such skills can be discussed in terms of content areas (e.g., whole numbers, proportional reasoning, data and chance, patterns, and geometry) or relevance to adults' life contexts (e.g., daily functioning, work, civic, natural, and technological phenomena). A theme that was emphasized throughout the discussions above is that literacy and numeracy are separate, yet connected, areas, which may require that adult educators accord numeracy a semi-autonomous status. Given the conceptual and functional links between literacy and numeracy, it was argued that one cannot define and provide for literacy—at least in the United States—without considering numeracy as well. Similarly, one can neither teach and assess quantitative skills nor improve learners' ability to use them in the real world without consideration of literacy issues including, but not limited to, linguistic features of mathematical tasks and communication, learners' vocabulary skills, and demand characteristics of the real world contexts in which adults have to operate.

As long as definitions of literacy exclude numeracy provision, it is difficult to foresee any significant increase in the extent and quality of numeracy provision. Furthermore, as long as the microcosm of adult education reflects the macrocosm of American society in its *math fright* (Paulos, 1990) and practitioners and students alike carry potentially restrictive images about what math teaching encompasses, demand for numeracy instruction and its possible contribution to adult learners will remain limited. To overcome such barriers, effective ways to communicate the vision of numeracy—and how it differs from traditional drill-and-practice math instruction—need to be found for educators and students alike.

As mentioned above, it is difficult to find any discussions in the professional literature over what numeracy might comprise, how numeracy skills should be developed, or how numeracy provision fits into the general goals and structure of adult literacy/adult basic education programs. Given the importance of numeracy skills in both everyday and workplace functioning, as well as the richness and diversity of numeracy skills that different individuals may need, it is peculiar that the adult education community has paid little attention to numeracy provision thus far. As suggested earlier, educators may be content with traditional drill-and-practice math instruction and see no reason for alarm. However, traditional modes of instruction have not enabled American educators to bring the mathematical achievement of K-12 students to the same level as other industrialized countries (as indicated by international studies of mathematics proficiency; see Lapointe, Mead, & Askew, 1992).

Overall, it would be difficult to expect educators with limited training in teaching math to have the desired impact on the mathematical knowledge and skills of adult learners. Even if individual adult educators or specific programs are presently able to lead adult learners to large gains in quantitative skills, it seems unlikely that overall adult numeracy levels will rise, given the present level of activity in this area. The gatekeeping function of quantitative skills may further prevent many adult learners from being able to take advantage of educational and employment opportunities and achieving personal goals.

To improve general numeracy levels in the United States and to reach National Educational Goal 5 (every adult American will be literate and will possess the knowledge and skills necessary to compete in a global economy and exercise the rights and responsibilities of citizenship), several interrelated areas of concern should be addressed. Implications are discussed below for practitioners and program managers, researchers, and policymakers. However, it should be recognized that this grouping is for convenience only; many of the issues raised (e.g., teacher training, assessment) have ramifications for all of those involved in adult education. Thus, all three groups should jointly work to promote numeracy provision.

1. Practice and Program Implications

First, practitioners and trainers in adult education must develop a broad view of numeracy and its possible facets and engage in a discussion of the place of numeracy instruction in adult literacy education.

Second, the conceptual and functional links between literacy and numeracy should be recognized by practitioners and programs directors. This recognition should be reflected in decisions regarding programming, staffing, training, and assessment frameworks. Educators and curriculum developers need to come to terms with the fact that literacy and numeracy are inextricably connected in order to explore ways in which the goals of literacy can be promoted through instructional experiences seemingly more related to numeracy, and vice versa.

Third, the teaching force, including teachers and tutors, needs to be trained in numeracy provision. The current teaching force, while dedicated and well intentioned, is clearly at a disadvantage when it comes to numeracy provision. The lack of extensive efforts to upgrade the numeracy-related skills of educators, as indicated by the almost complete absence of materials and professional development opportunities in numeracy, is clearly a cause for concern.

Fourth, an important step that can facilitate the work of educators is the creation of updated instructional guides and support materials. Such materials should

- *Incorporate the recent perspectives of employers (see, e.g., SCANS, 1991) regarding the nature of quantitative skills that are useful in workplace situations and the links between numeracy skills and other job-related skills.* Increased attention should be paid to new frontiers, such as the need to develop statistical literacy and to lay the foundation for the use of statistical tools to monitor and improve the quality of work processes and products.
- *Incorporate the recent perspectives of mathematics educators (e.g., NCTM, 1989) and science educators (e.g., as represented in the benchmarks for science literacy currently under development by the American Association for the Advancement of Science) regarding the various types of quantitative reasoning skills that should be developed.*
- *Incorporate designs to maximize the applicability and transferability of knowledge gained in the classroom to everyday and work environments (e.g., through the extensive use of word problems in mathematics textbooks).* The extent to which such problems comprise proper simulations of complex, real life events that require adult learners to apply quantitative skills is a matter for further research. It is possible that adult numeracy education may have to employ more than word problems to make a measurable contribution to adults' ability to function in certain real world situations. In turn, research could employ the techniques of either formal, academic-style studies or the systematic inquiries of practitioners, such as those being explored by the Adult Literacy Participant Inquiry Project (Lytle et al., 1992) or the ABE Math Team in Massachusetts.

2. POLICY IMPLICATIONS

First, planners and decision makers should be aware of the importance of numeracy skills in adults' lives and should recognize numeracy as both interrelated with and independent from literacy. Thus, they should take special measures, such as increased funding, staff development, and resources, to improve numeracy provision.

Second, a closer examination is warranted of the perspectives on numeracy used in the United Kingdom, Australia, and the Netherlands. This should include an evaluation of the modular approaches used in the United Kingdom (see, e.g., ALBSU, 1992a) and the literacy and numeracy accreditation frameworks for learners currently being proposed and field-tested in Australia (ARIS, 1992).

Third, programs should be encouraged to dedicate special resources to workshops and staff development activities in numeracy, perhaps by earmarking a set portion of funds for numeracy provision.

Fourth, mathematical issues should be incorporated into initiatives and programs related to family literacy, such as Even Start. At present, work on intergenerational activities seems to focus almost exclusively on reading and writing; no conceptual and instructional links seem to have been established between family literacy initiatives in adult education and family math initiatives in K-12 education (such as the Lawrence Hall of Science Program for Family Math; see Stenmark, Thompson, & Cossey, 1986).

Fifth, assessment instruments and placement procedures need to be examined for how they define numeracy. With new federal accountability requirements and pressures to provide more hard data on learner achievements, the old adage that assessment drives instruction is likely to be influential for a long time to come; the type of testing instruments used (including the GED test) may exert a powerful influence on the nature of what educators attempt to accomplish. Innovative, alternative assessment approaches emerging in K-12 mathematics education, including the recently announced NCTM initiative to develop professional standards for assessment, should be examined.

Sixth, reporting procedures should be reviewed to make sure that programs provide information related to numeracy instruction and student progress. As suggested earlier, the current practice of categorizing students entering or leaving programs only in terms of reading grade levels may mask important information about their numeracy skills.

Professional organizations, such as the National Council of Teachers of Mathematics and the American Association for Advancement of Science, and academic institutions should be encouraged to contribute to the further professionalization of adult education and to the increased integration of and coordination between K-12 and adult education systems. This can be accomplished by adapting existing or emerging curricular standards and professional guidelines for K-12 teachers to adult educators or by developing academic courses on numeracy provision for adult educators, comparable to math methods courses for K-12 teachers. The creation of the NCTM Task Force on Adult Mathematical Literacy is an important first step in fostering such links.

3. Directions for Further Research and Development

Research is lacking in most areas related to numeracy provision. As suggested earlier, a critical examination of the possible uses of the large body of research about mathematics learning with K-12 students and about teacher education and methods used in K-12 schools is obviously warranted. However, findings and methods based in K-12 education may not fully transfer to adult education, given the different goals and characteristics of adult learners, the unique learning and personal development trajectories that many adult learners follow, and the various contexts in which adult education takes place (e.g., one-on-one teaching, instruction by tutors who are not professional teachers, workplace literacy instruction, or classes with a wide range of skill levels). Thus, new efforts that take into account the unique aspects of adult education need to be considered. In this context, the use of systematic inquiries by practitioners, such as those being developed by the Adult Literacy Participant Inquiry

Project (Lytle et al., 1992) should be explored. Some key areas in which research is critically needed include

- instructional areas in numeracy that are particularly difficult for adults (e.g., fractions, decimals, and percentages);
- different teaching methods for developing the numeracy skills of adults (e.g., resources, such as manipulatives, used in K-12 math instruction; the applicability of functional context learning to adults learning in different contexts, such as GED or ABE);
- factors affecting the transfer and generalization of numerical skills from the classroom to actual practice;
- an appreciation of how adults' everyday experiences and knowledge (e.g., with handling money or consumer transactions) can be used to facilitate learning, as well as the challenges involved in developing teaching methods and materials that take advantage of learners' knowledge;
- studies of the impact of an adult literacy program on learners' beliefs and attitudes towards mathematics and on their actual quantitative practices after exiting a program (For example, do adults who receive some instruction in quantitative skills conduct their supermarket shopping any differently than before? Do they become smarter consumers? Do they change the way they help their children with mathematics studies, and, if so, how?);
- development of assessment methods for evaluating numeracy skills that encompass all of the facets of numeracy as outlined above (this includes adapting the emerging assessment frameworks being developed for K-12 mathematics education to the adult education context, in order to ensure that all facets of learners' knowledge are evaluated); and
- an exploration of the curricular and instructional implications of new workplace numeracy requirements, especially those stemming from the quality movement in industry and the emerging need for skills that can enable companies to implement quality monitoring and statistical process control (SPC) schemes (also important in this regard is the need to develop scientific reasoning, group problem solving, and communication skills around mathematical issues).

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