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DESCRIPIORS *CONTENT READING, MATHEMATICAL CONCEPTS, *MATHEMATICAL VCCABULARY, MATHEMATICS TEACHERS, READING COMPREHENSION, *READING INSTRUCTION, READING LEVEL, *READING RESEARCH, SYMBOLS (MATHEMATICS), *TEXTBOOK CONTENT, VOCABULARY SKILLS

ABSTRACI

IN A SYNTHESIS OF LITERATURE ON READING IN MATHEMATICS, IT WAS NOTED THAT THERE IS A BROAD BASIS OF RESEARCH IN THIS AREA ON WHICH TO BASE INSTRUCTION OF DEFINITE READING SKILLS IMPORTANT IN ARITHMETIC ACHIEVEMENT. IT WAS STRESSED THAT THE VOCABULARY OF ARITHMEIIC TEXTS RUNS AT READABILITY LEVELS HIGHER THAN THE PERFORMANCE LEVELS OF STUDENTS IN THE GRADES IN WHICH THE BOOKS ARE USED AND THAT THE VOCABULARY OF ARITHMETIC TEXTS DOES NOT GREATLY PARALLEL OR OVERLAP THAT OF READING TEXTS; THUS CHILDREN MUST BE TAUGHT SPICIAL WORD ATTACK SKILLS AND VOCABULARY FOR ARITHMETIC COMPREHENSION. THEY MUST RECOGNIZE THAT VERBAL ARITHMETICAL MATERIAL IS CONCEPTUALLY PACKED WITH A HIGH DENSITY FACTOR WHICH REQUIRES AT LEAST THREE KINDS OF READING ADJUSTMENT: ADJUSTMENT TO A SLOWER RATE THAN THAT USED FOR NARRATIVE MATERIALS, VARIED EYE MOVEMENT INCLUDING TYPES OF REGRESSIVE EYE MOVEMENTS, AND INTENTIONAL REREADING. TWO OR THREE SETS OF SYMBOLIC MEANING MAY BE INVOLVED WITHIN ONE CONTEXT; THUS A STUDENT'S VOCABULARY MUST INCLUDE TECHNICAL WORDS, SIGNS, AND SYMBOLS. ALL OF THIS REQUIRES AN ATTITUDE OF AGGRESSIVENESS AND THOROUGHNESS; THE STUDENT MUST READ TO GRASP THE TOTAL IDEA AND THE SEQUENCE AND RELATIONSHIP OF IDEAS. SPECIFIC ATTACK STEPS, TABLES, AND A BIBLIOGRAPHY ARE INCLUDED. (BT)

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READING IN MATHEMATICS

Session: Friday, May 2, 10:45 - 11:45 a.m.

In speaking to the Harvard Teachers' Association on March 9, 1912, E. L. Thorndike said, "As you well know our measurement of ability in arithmetic actually is a measurement of two different things: Sheer mathematical insight and knowledge on the one hand; and acquaintance with language, on the other." (36) Since that time there have been numerous studies of vocabulary in arithmetic and studies of the relationship between reading and arithmetic ability. Some of these studies have dealt with such specifics as relatedness of comprehension in reading to problem solving abilities and the vocabulary and readability of arithmetic texts.

Studies on the effect of variously designed educational programs of reading in arithmetic have been a natural outgrowth of linking reading to arithmetic.

A continuing concern for the linguistic ramifications of all content subjects including arithmetic and mathematics is evidenced by the steady flow of writing on this topic appearing in all types of journals and professional texts since the great educational age of the twenties. That no easy solutions have been found is attested to by the fact that today's teachers continue to assert that the majority of children have difficulty in reading content material.

An examination of professional reading texts and children's basal reading texts indicate some concern on the part of the authors of such texts for skills appropriate to reading in content subjects. Most such work, however is general to the use of informational type materials. Practically all authorities include work on locating information, using textbook aids, taking notes, setting a purpose for reading, etc., most of which tend to be more appropriate to such areas as social studies, health, and science rather than mathematics.

In regard to actual classroom practice relating to teaching reading in content subjects the comprehensive Harvard Reading Study report (3) states that in response to the survey questionaire the majority of respondents testified to teaching content reading skills. But based on the field study the following

statement seems more significant: "However on the basis of their own observations the study staff are inclined to agree with the minority opinion. Contrary to the majority of the questionaire and interview responses, other than for the development of technical vocabulary (rarely were common words with specialized meanings given consideration), there was only limited evidence that reading skills were being taught in the content areas. Apart from any consideration of the effectiveness of the teaching, only three reading skills --- skimming, outlining and map reading --- were observed as being taught with any degree of frequency." (3, p.50) The Harvard researchers also point out that although every content subject is mentioned by name, teaching pertinent to social studies and science was mentioned far more frequently than any others. The possibility that teachers may not teach any special reading skills in the content subjects and may not be well informed as to the nature and need of these skills is made more understandable by the study reported in THE TORCH LIGHTERS (2). In this report the researchers indicate that, in training teachers of reading, the major emphasis is on the basic reading skills as taught in the primary grades. The college instructors indicate concern for content area reading but admit to little emphasis on this particular area in undergraduate reading courses.

Recently the author asked some seventy-five student teachers to rate the reading success in content areas of the children in their classes. Although admittedly highly subjective it is perhaps significant that these young teachers who were familiar with

their classes, but without much personal ego involvement reported rather poor performance in these areas. Only one student teacher reported that her class did well in this area (The author knows this class and concurs with this report).

Some evidence has been presented which points out that reading in the content fields and particularly in mathematics has long been of concern. Subsequent sections will emphasize that the passage of time, concern of educators and even a significant amount of research have failed to make notable inroads in solving the problems of teaching these specialized content reading skills. Numerous sources including research serve to point up problems inherent in reading content type materials. The major finding and research on successful teaching practices are examined to suggest teaching that should be done. As a final point of this presentation several general recommendations in regard to teacher preparation, in-service training and the preparation of mathematics materials will be given.

Vocabulary Problems in Mathematics

Vocabulary studies form a basis for comparing arithmetic materials to those presently used. Comparison of data, taken from a study made by Hunt in 1926 as quoted by Buswell and John (5) and Repp (23) in 1956, of arithmetic texts suggests that very little vocabulary control change occurred over a period of thirty years in the writing of arithmetic books. These data should not be viewed as precise comparisons in that the ground rules used in

the word count possibly varied to some extent.

Table I

Vocabulary Comparisons of Arithmetic Texts

	Hunt's 1926 Vocabulary Study of 6 Third Grade Arithmetic Texts	Repp's 1956 Vocabulary Study of 5 Third Grade Arithmetic Texts
Total different words introduced in all texts	2,993	3,329
Words common to all texts examined	350	698
Words appearing in only one text	1,345	1,327

The figures in Table I are similar enough to strongly imply that although there is some slight increase in the use of a common core of words the number of words and their variation have not extensively changed. Hunt also reports that 980 or 33% of the 2,993 total words introduced in the six third grade arithmetic books of 1926 were not found in ten surveyed third grade readers. Repp has no parallel figure but Stauffer (31) in 1966 cites data in which 43% of tabulated words from three third grade arithmetic books were not to be found as vocabulary in seven current reading texts at that level.

Pressey and Moore (22) surveyed the degree to which youngsters gain mastery of 106 fundamental terms in arithmetic. Among their

conclusions they note that of these 106 terms only 36 are ever mastered by as many as 95% of the students. Their data further indicates that at the sixth grade level just 59 of the 106 terms had been mastered by 50% or more of the students in their study.

Whatever else the data of the various researchers may suggest, at least two important points seem clear. First, that the vocabulary of arithmetic books has not paralleled nor does it present a vast overlapping with that of reading texts. Secondly, it would be a matter of reckless conjecture to assume that children learn the needed vocabulary and meanings in arithmetic incidentally without the need for direct and intensive study. Obviously, in developing learning goals in arithmetic consideration must be given to word attack work and vocabulary study.

While one might readily assume that some vocabulary, particularly that of a technical nature, would present an additional learning burden; the question might be raised as to the general problems involved in reading arithmetic material. Recent studies on the readability of arithmetic and mathematics materials underscore the implications of vocabulary studies. Smith and Heddens (27) have recently published the results of a study in which they made use of various readability formulas on elementary level experimental mathematics materials. The results of this study indicate that the experimental materials in most instances have a readability level that is above the grade level for which the materials are intended.

In a subsequent study of the readability of elementary arithmetic textbooks Heddens and Smith (12) again concluded that the commercial texts tend to be above the assigned grade level in reading difficulty. However, they do point out that the average readability level for commercial texts is easier than that of the experimental materials.

In order to indicate that these findings are consistent with other levels Wiegand's study (38) of secondary level mathematics texts might be cited. He compared the readability levels of nine mathematics textbooks with the tested reading abilities of youngsters in the Pittsburg schools. There were indications that readability levels of texts were consistently higher than the actual performance levels of students.

A consideration of vocabulary load and readability does not present the entire scope of reading problems in arithmetic. The experiences of a college class bear out some additional obstacles. This group of twelve students spent some three hours discussing their solutions and classifications of twenty verbally presented ratio type problems. There were many disagreements as to answers and interpretations of answers. Not a single word in any problem could be classified as a difficult one for these students. The computations gave no real trouble to anyone in the group. As an observer with the particular purpose of noting the cause of disagreement the author is confident in saying that fully two-thirds of the differences came from problems of reading interpretation.

A dimension is added to this observation with the consideration of the contention by Young that the child must experience more than words if he is to understand arithmetic. He uses the statement: "The square of the sum of two numbers is equal to the square of the first number added to twice the product of the first and second numbers added to the square of the second number." (42, p.174) as an example. All of these words appear in the first 2,000 of Thorndike's list of common words. Most fourth grade children would have difficulty interpreting the statement. Thus the difficulty of understanding is not simply a matter of vocabulary but is complicated by the conceptual structure produced by a composite of simple terminology. In brief, simple words combine to produce concepts that are hard to understand. Often these seemingly simple words are used singly or in combination to represent concepts of some magnitutude. For years reading experts have recommended that the interpretation of various meanings of words according to contextural settings be taught. Not often, however is there reference in the literature to the need for teaching uses of common words in mathematical settings where the general context is not very helpful.

A study of fifty reading difficulties encountered in reading American history, mathematics material and general science material was conducted by McCallister (18). He found sixteen of these difficulties to be exclusive to the area of mathematics. Twenty-three of the fifty reading errors were found to occur in

mathematics; more than in either of the other areas. The two general areas in mathematics reading that reflected the greatest consistency of errors were: Firstly, those errors arising from inadequency of conceptual knowledge and secondly, errors arising from deficiencies in vocabulary knowledge.

The concern for teaching children about rate of reading may reflect more effort toward <u>increasing</u> rate rather than <u>adjusting</u> rate. The reader is made to feel inept if he doesn't handle any material at the rate of several hundred words per minute. In the typical reading program there is a distinct impatience with the slow, deliberate reader. However, children must be brought to recognize as suggested by Trump (<u>37</u>) that there is a density factor in reading to which the rate must be adjusted. Smith says in this respect: "One of the special characteristics of mathematical text is compactness. Every word and every symbol is important. Skipping an unfamiliar word or filling it in from context has no place in reading mathematics." (<u>28</u>, p. 100) Throughout her analysis of mathematics content material Smith continues to point up the need for great care in reading this material. The need for alteration of eye movement, relating context and the "worked out" example step by step, and the need to "read" several forms of symbolism are underscored in this analysis.

With the preceding perspective one can readily see why the child whose primary training in reading has prepared him to cope with the comprehension of easy narrative material would need to make conscious adjustment to read compactly written conceptually

dense material. The readability difficulty may also be such that he is constantly at his frustration level. Further, this material may not have the immediate broad interest appeal that narrative materials do. There is little wonder that students have difficulties; the suggestions of Pressey and Moore from their 1932 study are pertinent in this respect:

> "The present textbooks, and the instructional techniques based on these books, are not adequate to teach the fundamental vocabulary upon the daily use of which the work of the book obviously depends. Either the textbooks should be rewritten to fit the meager vocabularies of the children who use them, or much better, a drive should be made by everyone concerned (with probably some revision of textbooks in order that the use of nonessential words may be cut down and thus a better chance be given for mastery of the essentials) upon this matter of acquisition by the pupils of those meanings in terms of which they must work." (22, p. 454)

Heddens and Smith echo this basic idea for the present day putting it even more succinctly: "If educators are to be successful in teaching arithmetic, either the reading level of the arithmetic material must be lowered or the reading level of the child must be improved, or both." (12, p. 468)

Significant Research on Teaching Reading in Mathematics

Many studies have dealth with the teaching of reading as it relates to various facets of arithmetic and mathematics. The studies have tended to deal with the effect of vocabulary study and/or general reading instruction on arithmetic achievement or problem solving abilities. Some have sought to ascertain if any significant relationships exist between reading and aspects of arithmetic.

In one of the earliest studies Wilson (40) found evidence which indicated that specific training in the reading of problems in arithmetic resulted in improved performance. By analyzing errorson the Stanford Achievement Test, Lessenger (17) ascertained students' "mean loss" in arithmetic due to faulty reading. For example, he found that in the case of sixty-seven poor readers, their "mean loss" due to faulty reading averaged 10.1 months of arithmetic age. After one year in which emphasis was placed on instruction in reading with some specific skills being stressed, gains were significant. "Mean loss" due to faulty reading in arithmetic was all but eliminated. The poor readers, on the spring tests, had only 1.0 months loss due to faulty reading.

In a study dealing with arithmetic problem solving and comprehension in reading Stretch (34) found rather a high correlation between these two sets of ability. Harlan (11) had previously found a high positive correlation. The focus of Stretch's study was a comparison between two fifth grade groups, one taught special techniques in arithmetic problem solving and the other a control group. A part of the special problem solving technique was that of specific reading instruction. Results in this well controlled study were highly significant favoring the experimental group. Interestingly, the evidence of the study indicated that the students also increased significantly in reading comprehension.

Balow (4) in an extensive study dealing with 1400 children found that general reading ability does have an effect on problem

solving ability in arithmetic. This finding was true of learners of all reading capabilities when the effect of mental ability was controlled.

Johnson (14) found that specific instruction in the vocabulary of mathematics resulted generally in gains in problem solving ability and knowledge of vocabulary. This was the case on both an immediate post test and delayed post test. Vocabulary gains in the study were specific to those terms that had been taught.

Patterson (20) taught college freshmen specialized vocabulary and study techniques for forty-five one hour periods. The exercises were pertinent to English, science and mathematics. Some emphasis was placed on speed with short, timed exercises being used. Only in the last two weeks, however, were speed reading exercises used. The experimental group students significantly improved in mathematics achievement as a result of vocabulary and reading instruction.

In an interesting study with high school students Call and Wiggin (7) compared the effect of a reading oriented approach to teaching problem solving to a conventional teaching approach. Call, an experienced mathematics teacher, taught a unit to the control group on problem solving using conventional techniques. Wiggin, an English teacher with little training in mathematics, taught the experimental group the same unit with emphasis on vocabulary, use of context to get meaning, seeing relationships, and other skills. Using careful controls and matching pairs of students on the basis of all major conceivable variables the

researchers concluded: "No matter how you slice it, the results point to a better response by the group which was taught reading." (7, p. 156)

The studies of which those described are representative indicate the following among other things. Firstly, a knowledge of arithmetic vocabulary is pertinent to achievement in arithmetic, particularly problem solving. Secondly, reading comprehension and arithmetic achievement tend to be positively related. Thirdly, almost without exception instruction in vocabulary and/or reading skills in arithmetic have paid off in terms of greater achievement, especially in the area of problem solving.

There is a broad basis of research in the area of reading in arithmetic on which to base instruction. There are some rather definite reading skills which have already been pointed up as important in arithmetic achievement. Perhaps the next major thrust of research should be that of searching out procedures which are effective in teaching these skills.

The Focus of Teaching

Yoakim (41) contends that all teachers should be reading teachers regardless of their content specialization. The reading teacher specialist can effectively work on some content skills, but the only place to teach some of the reading pertinent to a content area is in the class dealing with that material. Teachers of self-contained classes must also be warned that reading instruction must in fact go

on all day --- out of the social studies text, the arithmetic book, from reference materials, from all the symbolic sources the child encounters.

Suggestions dealing with reading in arithemtic follow. There is a remarkable agreement among researchers and authorities on the importance of these. Teachers will be able to discern from them some of the actual procedures that might be used in classrooms to furnish instruction. In respect to others, teaching activities need to be devised and tested. Even from this cursory treatment, however the thoughtful teacher engaged in classroom practice should be able to create effective learning experiences.

Children must be brought to understand the nature of verbal arithmetical material. They must recognize that it is conceptually packed material with a high density factor which requires at least three kinds of adjustment: Adjustment of rate, this must be read much slower than narrative materials; varied eye movement, much more right-to-left and other types of regressive eye movements will be used; Rereading, even the most advanced reader may need to read a problem or explanation several times. The nature of arithmetic material is also such that the child is likely to be dealing with two or three sets of symbolic meaning witnin one context. The child who incorporates conceptual meaning for regular verbal symbols, numerical symbols, and literal symbols in one passage is dealing with a complex task. One of the lesser obstacles with which he must deal is that of word attack. He must have the

proper conceptual background for understanding the verbalism and the arithmetical symbolism before he can read effectively. The latter part of this need must be met by the arithmetic teacher. The child who has a weak conceptual background in the vocabulary, signs and symbols of arithmetic will read poorly no matter how much reading instruction he has had. One additional point on the nature of printed arithmetical material; often there is a parallel structure where the reader must follow both verbal context and a work-out example or where he must relate context to tabular material at the same time. Young children have difficulty with this. Phillips (21) has suggested that such a procedure as using both hands as well as eyes might be helpful to the children who are in the learning stage of doing this. However it may be done, a real attitude of aggressiveness and thoroughness in discerning and following the relationships of this type must be developed in children.

In regular reading instruction the child is entreated to read for some particular purpose. He is enabled to concentrate on one thing or purpose at a time. Russell (30) suggests that the child seldom reads in arithmetic for just one purpose. This reading is frequently done in the light of multiple purposes: To get the grasp of the total idea; To note sequence; To relate two significant ideas; and To find the key question to name a few. This implies why, in the section on problem solving, several readings are recommended. Authorities do suggest that children should at times be given a purpose or purposes for reading in the arithmetic textbook.

Questions or a particular direction may be used to do this. A different purpose for each of two or three readings of a passage could be used.

Symbolic devices such as graphs, charts, and diagrams are related to all areas of the curriculum but are more pertinent to mathematics than any content field. Noting and using the relationship that is usually being portrayed in these devices is invaluable training for reading in arithmetic. The child should be taught to read all titles and labels and note the means used by the writer of showing the relationships. Using these aids as a corollary to verbal context to furnish needed data in problem solving is a worthwhile procedure. In the typical classroom youngsters could doubtlessly learn much more about charts and graphs by making them. At any time that data are available in the routine work of the class it should be organized in some such form. The author recently observed first grade groups successfully making and reading graphs.

Every content area has its own technical language. Arithmetic probably has more distinctly technical language at the elementary level than any other school subject. Thus there is no alternative to the consistent, planned and thorough teaching of vocabulary. The hear-say-see-write approach can be effective in teaching the actual terms, but inductive work where possible is additionally recommended in order that children develop the concept underlying the terminology. Even the child who can give a "textbook"

definition of a vocabulary item may have little grasp of the concept involved. The teacher must seek to find if, in terms of performance, the children in the class understand both vocabulary and the underlying conceptual structure.

In teaching vocabulary and conceptual development special attention is due specific uses of common words. Langer has pointed up the problem in this way: "Many of the most common words are also the most difficult. These abstract, multiple meaning words indicate relationships among words and their accompanying concepts." (16, p. 452) Children, in reading materials, must be pressed to explain: "What this word means as used here" or "Does this familiar word make sense as it is used in this problem?"

The numerals, signs of operation, signs denoting relationships, literal numbers, abbreviations, and special symbols such as π are all parts of the vocabulary of mathematics. One would conclude, of course that these constitute major mathematical teaching tasks. But there are reading problems involved with these. The child must have experiences in which these symbols are viewed as a part of reading. Again the conceptual interrelationships must be stressed. In work with these the teacher teaches both mathematics and reading.

The verbal problem, word problem, story problem or whatever one might choose to call the problem in a short paragraph setting has traditionally been difficult for children. Reading has

consistently been shown by research to be a factor in this poor performance. Several worthwhile suggestions for improving problem solving can be made outside the facet of reading. However, space limitations preclude doing this --- these remarks will relate to the reading problem. From the initial work with verbally stated problems children should never be given the idea that a single reading will be adequate to discern the total situation. Left to their own procedures there have been instances where children only read until they encounter a number, then they work with that number and any other they see (usually using the computational process then being studied) without actually reading the entire problem. Insofar as reading procedure is concerned the following steps are widely prescribed in the literature on problem solving:

1. Use a first reading to visualize the situation, to get a general grasp of it. The child need not pay much attention to the actual numerals this reading. The child may in fact be asked to read orally and leave the numbers out of this reading, i.e. "Tom had some stamps ..." rather than "Tom has 123 stamps ..."
2. Reread to get the facts with particular attention paid to the information given and the key question which is the basis for programming the problem.
3. Any problem vocabulary or concepts should be noted and explored with the teacher helping to point up where problems may occur and providing help in attacking vocabulary study.

4. The problem may be reread as a means in planning the steps for solution. On this reading some arithmetic authorities have the child state the situation in a mathematical sentence. A sensible estimate of the answer may be made also prior to actual processing of the problem. Screening out irrelevant data or noting the need to seek out additional data may be involved in this very careful reading. (Problems containing irrelevant data and also those in which the child must seek elsewhere for relevant data should be included in th arithmetic program.) Teachers should be able to see many key questions and statements they can use to set specific purposes for children in the various readings. Often the problem should be read orally and developed through extensive class dialogue as a means of teaching effective reading with the teacher actually guiding the discussion.
5. Even after the processing has been done the child must be taught to read the problem again to check his procedure and solution, to note if all work has been done.

Thus, several readings are entailed in properly approaching problem solving in arithmetic. Various other helpful techniques may be used such as having the child state a problem in his own words after two or three readings to check his understanding of concepts and vocabulary. The alert teacher will actively work on this process by having specific lessons using the text and related materials.

For many children the arithmetic text is merely an exercise book. Few really know the organizational structure of the text. Too often the child must be directed specifically to use such an aid as the glossary. The child who needs review to recall an idea or process may have no idea how to seek this out in the text. Thus occasional work designed to help the child learn to use parts of the text should be planned by the teacher. As a final note, the special typographical aids such as italics, indentations, bold type, or underlining should be pointed out to the class and used by both teacher and children.

Some General Recommendations

The preceding sections set forth the problem of reading in arithmetic. That teaching in this area can be effective is borne out by research. Ideas for teaching are being increasingly publicized. More than five years ago, in THE FIRST R Austin and Coleman entitled the final chapter, "Will Tomorrow be Another Day?" (3) In respect to this Kress and Johnson recently editoralized:

> "...that repeated advice along these lines had not been heeded. Has tomorrow now come? If it has, did tomorrow turn out to be another day? If it did, another day of what? Are we, like King Hassam still sleeping in the faith that tomorrow will be another day? Sleeping in that faith hardly seems the way to prevail." (15, p. 264)

Action must be taken which will find its way into the elementary classroom. Three forms of action could become effective and make tomorrow another day.

Teacher training must be "beefed up" in the total area of

reading in the content subjects. Course time and practice in reading in arithmetic must be given to undergraduate trainees in elementary education. One general course in reading or the language arts does not allow time for teaching the specialized skills. Recommendations five and six of THE TORCH LIGHTERS (2) point up the direction but fall short of the need.

In-service programs for practicing teachers must be used to help broaden classroom reading programs. Reading specialists, supervisors and curriculum experts should be brought into play in the effort to work with teachers in devising programs of content area skills which the teachers can use in the classroom. In-service programs in reading, like training courses in reading, tend to emphasize fundamental reading skills. The proposed program would be an intensive one dealing with reading specific to each content area. In-service teachers and teachers-in-training must be informed of the skills of the content subjects and impressed with the importance of teaching them.

The ephemeral "they" are the focus of the final recommendation. The writers of mathematics materials are "they." The author examined five current series of arithmetic texts and in only one did the writers furnish evidence of carefully working on readability and vocabulary control. Children often work at their frustration level in reading the arithmetic texts. The technical vocabulary will always need to be introduced and taught but other than this vocabulary can be better controlled. If those who use the texts voice enough concern for readability levels the writers of texts and other materials will meet the demands to scale down the difficulty of reading these materials.

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