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ABSTRACT

The purpose of this paper is to determine what the literature in mathematics education indicates as being trends in learning opportunities, objective selection, and evaluation procedures. In discussing learning opportunities, the focus is on equity in curriculum, access to good teachers, and access to quality learning experiences. Research-based suggestions for increasing access to quality learning opportunities in classrooms are included. The history of a variety of philosophical approaches to schooling is provided, along with the implications of these philosophies for the selection of the objectives for student learning. Aspects of student evaluation procedures and their effects on instruction and curriculum are summarized with a focus on problem solving and the effect that certain instructional strategies have on student problem solving abilities. Contains 21 references. (DDR)

Current Concepts in Teaching Mathematics

by Marlow Ediger

CURRENT CONCEPTS IN TEACHING MATHEMATICS

The purpose of this research study was to determine what the literature in the teaching of mathematics indicates to be trends in selecting objectives, learning opportunities, and evaluation procedures. In depth surveying pertaining to literature in teaching mathematics, I find there are selected concepts that recur rather frequently. A further purpose of this paper is to indicate from a research study of mathematics literature which concepts appear most frequently. By communicating relevant concepts, the mathematics teacher may benefit in upgrading the curriculum. Hopefully, pupil achievement will increase as a result of the teacher's increased knowledge pertaining to the teaching of mathematics.

Providing Equitably for All Pupils

A major concern in mathematics is providing equal opportunities to learn for all pupils. There has been much discussion on the pros and cons pertaining to tracking pupils. Davenport (1993) summarizes research studies pertaining to tracking pupils The results indicted that pupils in lower tracks, in particular, experienced the following:

1. inequities to a strong mathematics curriculum.
2. inequities to well qualified mathematics teachers.
3. inequities to quality classroom learning opportunities.

Davenport then recommends strongly that schools move away from homogeneous to heterogeneous grouping of pupils in a classroom. The homogeneous — heterogeneous grouping controversy has been in evidence for some time. The first recorded use of homogeneous grouping of pupils in the US was in Detroit, Michigan in 1920 (Shepherd and Ragan 1982). At that time Detroit public schools emphasized the X,Y,Z plan of grouping based on ability levels of pupils. Shepherd and Ragan (1982) give the following advantages of homogeneous grouping: gifted students may achieve more optimally with this plan of grouping; parents who have sons/daughters in the higher

ability groups favor this plan of grouping pupils; teachers find it easier to teach when pupils are of similar abilities in a classroom; and teachers can provide for individual differences better when uniformity of achievement is in evidence in a classroom. Disadvantages given are the following: the plan violates the pupil's right to be different; one trait only is then used for grouping and that is ability, ability grouping is a form of segregation in that high ability pupils come from upper socioeconomic levels of income; and parents frequently object to having their child in he slowest group.

Educational literature in mathematics is quite concerned in providing for equity among pupils in ongoing learning opportunities. Pupils should not be discriminated against due to race, creed, and national origin, among other items. Presently, there has been much writing about equality and equity in learning activities and experiences for pupils. Equal access is to be stressed be it in computer use, materials of instruction, quality teachers, school buildings and classrooms, as well as equipment in teaching and learning situations.

Ernst (1991) states that "a teacher working from a multicultural, social- reconstructionist approach attempts to create a learning environment that is 'as democratic and open as the power asymmetries of the classroom allow, but with explicit recognition of this asymmetry." He suggested that genuine discussion between students and the teacher with pedagogical processes that stress the following:

1. Cooperative group work, projects and problem solving to promote engagement and mastery.

2. Autonomous projects, problem posing, and investigative work to afford pupil opportunities for self-directed and personally relevant activities.

In a multicultural social –reconstructionist approach in teaching, equity and fairness within the framework of democratic tenets should be stressed in mathematics. The subject matter of mathematics is emphasized with critical and creative thinking as well as its use/application in the societal area. Cooperative learning stresses that

pupils be grouped heterogeneously so that the talented/gifted as well as slower learners may learn from each other. Quality human relations as well as acquiring vital subject matter in mathematics is being emphasized. Learning to respect each other as well as possess vital knowledge to solve problems is vital. To promote the concept of providing for individual differences, pupils individually may work autonomously on a project, activity, or independent study. There needs to be rational balance between group and individual pupil endeavors in mathematics. Thus pupils need to be able to work within committees effectively and work by the self in aiming toward optimal achievement. Life itself in the real world consists of being with others and with the self. Each person should learn to live abundantly as a member of a committee and profit from being able to achieve and grow as an individual. The National Council Teachers of Mathematics in their publication Professional Standards for Teaching Mathematics (1991) recommends that teachers of mathematics know and use the following:

1. How students' linguistic, ethnic, racial, gender, and socioeconomic backgrounds influence their learning of mathematics.
2. The role of mathematics in society and culture, the contributions of various cultures to the advancement of mathematics, and the relationship to other subjects and realistic applications.

All pupils need to attain optimally in mathematics. African-American, Hispanic, and Native Americans, among other minority groups, need to have a mathematics curriculum which harmonizes with preferred personal ways of learning. A pupil not speaking English in a proficient manner may need a mathematics curriculum written in whole or part for use in his/her native language. Racial and linguistic biases of teachers must be eliminated. With peer teaching and coaching, teachers can assist each other to respect all learners in the classroom with fair and conscientious teaching. Care and concern for each pupil is a necessity. Toward the beginning of my teaching career, I taught in a two teacher rural public school in which approximately one-fourth of pupils belonged to the Holdemann Mennonite Church where eighth

grade education is terminal. I referred very frequently to rural farm problems to make mathematics meaningful to these pupil. Thus referring to soybeans, wheat production, oats, and livestock when problem solving was emphasized, assisted the Holdemann Mennonite pupils to achieve well. For example, a pupil might determine how many bushels of wheat (60 pounds per bushel) were on a truck load of 1,700 pounds. Division problems in the abstract could very often be translated to a practical use for the pupil on his/her readiness level. Similar procedures have been taught by the writer in demonstration teaching in Old Order Amish Schools (Ediger 1989). Holdemann and Old Order Amish pupils are rural people and understand a culture emphasizing farming operations.

Female pupils need encouragement to develop and achieve optimally. Girls too frequently have not developed their skills in mathematics due to gender bias. They may also have not selected mathematics related careers due to not receiving needed encouragement in the school setting.

Diverse philosophies are in evidence to guide each pupil to attain more optimally. (Ediger, 1994-95) emphasized four philosophies that mathematics teachers may emphasize in the classroom. These are the following:

1. Mathematics as subject matter acquisition. Here, the teacher stresses pupils acquiring relevant facts, concepts, and generalizations. A subject centered curriculum is then in evidence. Abstract teaching materials are used largely. Concrete and semiconcrete experiences for pupils are stressed if this assists learners to attain more optimally in symbolic learnings.

2. Measurement driven instruction. Predetermined objectives have been chosen for pupil to achieve, Each objective is stated so that the measurement device in testing used will determine if the learner has/has not achieved the stated ends.

3. Humanism in the mathematics curriculum. There is considerable pupil -teacher planning in selecting objectives, learning opportunities, and evaluation procedures. Input from pupils is welcomed

in ongoing learning activities.

4. Mathematics as problem solving. In context as problems are identified, pupils with teacher guidance use subject matter in mathematics to solve the chosen problems. Problem solving is a utilitarian approach in teaching mathematics.

I strongly recommend problem solving procedures in mathematics teaching more so as compared to the other three above named approaches. There are times when individual decision- making (humanism) by pupils in mathematics can provide excellent opportunities for the teacher to plan with the learner which activity, project, or investigation the latter is to engage in. Certainly, individual needs, interests, and purposes are important to provide for in ongoing lessons and units of study. Mathematics tends to be a rather precise objective academic discipline: thus behavioral stated objectives with its criterion referenced tests (measurement driven instruction) may be used at selected intervals in teaching and learning. A strong argument can also be made for emphasizing a subject centered approach in teaching. Certainly, pupils should attain structural properties of mathematics such as commutative, associative, and distributive properties of addition and multiplication. Thinking of and reflecting upon these structural ideas when taught requires abstract learning ultimately. Sequentially concrete, semi-concrete, and abstract materials of instruction be used to think abstractly. Bruner (1960) was a strong advocate of pupils achieving structural ideas inductively and with the use of the following sequential materials: manipulative, iconic, and symbolic. He believed strongly that pupils need to have key or structural ideas so that new content can be analyzed in terms of the subject matter already possessed. Bruner also stressed the importance of a spiral curriculum whereby each structural idea is achieved at a more complex level by the learner as he/she progresses through the sequential years of schooling. The structural ideas then are met up with again and again as pupil achieve on different levels of the public school. Each pupil then is aided in achievement when possessing a structure of the academic discipline of mathematics. Newly acquired content is related to the already

possessed structure.

The mathematics teacher should use an appropriate philosophy of teaching at a given time which stresses each pupil learning as much as possible. Pupils differ from each other in many ways such as abilities, interests, purposes, and attitudes. It behooves the mathematics teacher to guide pupils individually to attain optimally be it working by the self or within a committee setting.

The behaviorally stated objectives approach stresses pupils attaining at different rates even though they are following the same mathematics curriculum. Thus with predetermined objectives such as in MDI, each pupil may work at his her own optimal rate of speed to attain the objectives sequentially. Slow learners may need more assistance as compared to other learners in the classroom. Thus, time becomes the variable; selected pupils need more time as compared to the others to attain the stated objectives.

There are educators who believe that high standards should be set for all pupils to attain regardless of their ability levels. The same objectives should then be achieved by all learners in a class. There should be no tracking or ability grouping of pupils for instruction. Rather the class is taught as a whole. Distinctions are not made among pupils in this definition of democracy. All pupils are to receive the same sophisticated knowledge in the class. The teacher must have high expectations for all pupils in class. Careful monitoring of each pupil's progress is a must. Evaluation needs to be in evidence to notice if each pupil is learning and achieving.

Gandal (1995) lists and discusses criteria in setting standards for pupil achievement. These are the following:

1. Standards must focus on academics.
2. Standards must be based in the core disciplines.
3. Standards must be specific enough to assure the development of a common core curriculum.
4. Standards must be manageable given the constraints of time.
5. Standards must be rigorous and world- class.
6. Standards must evaluate performance.

7. Standards must include multiple levels of performance.
8. Standards must combine knowledge and skills.
9. Standards must not dictate how the material is to be taught.
10. Standards must be written clearly.

The above standards indicate a strong subject centered curriculum with demanding goals for pupils to attain. Individual differences are provided for in standard seven where Gandal (1995) wrote, "France and Germany have high standards for all their students, but they don't expect all to meet the same standard. It's just not realistic to expect the same from everyone."

Dewey's experimentalist philosophy of education (1938) emphasized that knowledge is subjective as experienced and amenable to change. He stressed that absolutes do not exist in life. One can only know what has been experienced, not what is outside the framework of human experience. Since these conditions exist, knowledge is tentative and as new experiences are encountered subject to modification and change. That is why problems arise and new approaches are necessary in the solving of problems. Since school and society are integrated, not separate entities, Dewey believed that problem solving is important in each arena. In society, people tend to work in groups to solve problems. Thus pupils in the school setting also need to work in committee endeavors. Lifelike, real problems need identification and related solutions found. Knowledge is used to solve problems and is not an end in and of itself. There should be no barriers as to which pupils are involved in the solving of problems. All should use the methods of problem solving in the school curriculum and the curriculum of life. Dewey was a strong believer in democracy as a way of life. Each pupil could then achieve optimally.

Objectives of Instruction

The National Council Teachers of Mathematics (1989) developed high quality standards for mathematics teachers to use in planning for teaching- learning situations. These standards provide objectives of

instruction as well as criteria to gauge one's own mathematics curriculum. One's own mathematics curriculum then may be compared with the NCTM standards. Revisions and modifications in the local curriculum might well be an end result. As examples, the NCTM standards that pertain to numbers and numeration for grades K-4 emphasize the following:

1. construct number meanings through real world experiences and the use of physical materials;
2. understand our numeration system by relating counting, grouping, and place value concepts;
3. develop number sense;
4. interpret the multiple uses of numbers encountered in the real world.

To achieve standard number one above, pupils need to experience life like problems in society in which mathematics is used. Markers and objects should be used to aid pupils in understanding the abstract. For standard number two, pupils need to have good command of counting using the set of counting numbers. Initial counting emphasizes a one to one correspondence between the oral number counted in sequence and the related number of objectives in a set. Being able to group markers in terms of five or ten in a set when asked to do so , among others, indicates that meaningful learning is taking place. Sequentially the pupil should understand place value such as the ones, tens, and hundreds column. It is always important for pupils to understand and comprehend what is taught so that meaningful learning is taking place; This would emphasize standard three above. Standard four places much stress upon pupils attaching meaning to the numeration system as it relates to use and application in societal endeavors. The National Council Teachers of Mathematics (1989) emphasizes four standards that are broad in scope that apply to all grade levels. These standards encompass problem solving, communication, reasoning, and mathematical connections. In addition to these four broad standards, nine topical standards are listed for each level of instruction. These are

estimation, number sense and numeration, concepts of whole number operation, geometry and spatial sense, measurement, statistics and probability, fractions and decimals, and patterns and relationships. Maturity and capability levels of pupils are emphasized when the standards are stressed in the mathematics curriculum.

To have pupils achieve well, the teacher should use recommended principles of learning from educational psychology. Ediger (1994) recommends that teachers use the following agreed upon criteria when teaching pupils:

1. meaningful lessons in units of study. With meaning , pupils understand and comprehend that which was contained in ongoing learning opportunities.

2. interesting content and skills in the curriculum. With interest, the pupil and the curriculum become one, not separate entities. Pupils attend and achieve from ongoing lessons and units of study.

3. purpose in learning. With purpose for learning, pupils accept reasons for attaining relevant facts, concepts, and generalizations presented.

4. sequence in learning. With quality sequence, pupils relate newly acquired content with that previously achieved. Previous knowledge attained provides readiness for the new objectives to be achieved. Pupils need guidance to perceive relationship of knowledge in teaching- leaning situations.

5. balance among objectives stressed. Thus knowledge, skills, and attitudes — three kinds of objectives need to be achieved by students. These objectives interact and are not in isolation from each other. For example, if pupils possess positive attitudes, they should achieve needed knowledge and skills more readily.

To achieve objectives of instruction, pupils need to experience a multimedia interactive mode of teaching. Hatfield and Bitter (1994) provide the following characteristics of a multimedia approach:

1. Promotes active versus passive learning.

2. Offers models or examples of exemplorary and nonexemplorary instruction.

3. Is illustrative and interactive.

4. Facilitates the development of decision- making and problem solving abilities.

5. Provides user control and multiple pathways for assessing information.

6. Provides motivation and allows for variability of learning styles.

7. Facilitates the development of perceptual and interpretational abilities.

8. Offers efficient management of time for learning and less instructional training time.

9. Allows for numerous data types, e.g. animation, graphics voice, texts,, and motion video.

10. Offers multilingual presentation. The technology exists whereby programs and units can be presented in different languages.

Learning Opportunities

There are numerous beliefs pertaining to how learning should be encouraged and optimized in mathematics. B.F. Skinner was a strong advocate of reinforcement theory of learning. Thus there must be clearly stated objectives to achieve, written in measurable terms. The teacher teaches so that pupils might attain the precise objectives. If the pupil responds correctly, a reward should follow. The reward could be given on a ratio or time basis. In the ratio approach one reward, for example, for every five correct responses given could be stressed by the teacher. In terms of time, a reward is given for five minutes of concentrated attention to the lesson at hand, would be a further example of reinforcement theory of learning. Extrinsic motivation is then in evidence.

Bruner (1977) advocated intrinsic motivation as being vital in teaching- learning situations. Learning is its very own reward. Challenging questions through inductive procedures of instruction would assist pupils to value learning for its own sake in problem solving. There has been a long debate in the extrinsic versus intrinsic approaches in helping pupils learn. Good and Teller (1973), in writing

about the Lancastrian Monitorial School that was brought to the US in 1805, stressed the rewards that pupils received for doing well. These were badges, offices, and orders of merit. The reward system had been used in England prior to the early 1800's. As an example of intrinsic motivation stressed in the history of education, Cole (1950) emphasized that Pestalozzi in the latter 1700's and early 1800's advocated pupils developing from within, not from without. The teacher then would motivate achievement rather than lecture or force pupils to learn. Instead of stifling a pupil's individuality, the pupil should be encouraged to develop his/her talents. A love for learning by pupils was important in Pestalozzi's thinking. Pestalozzi emphasized progressive methods of teaching pupils in that they should desire to learn from within with no prizes given for learning.

Should a developmental approach be used in teaching and learning situations or should high standards be set for all pupils to attain at the same time? Piaget (1950) whose educational writings based on clinical research have almost become a classic in education. For example, Piaget emphasized the following sequential stages that pupils go through in the school years:

1. preoperational — ages 2 to 7 approximately.
2. concrete operations — ages 7 to 11.
3. formal operations — above age eleven.

Piaget believed that each stage had tremendous implications in terms of what pupils can learn. Within each stage, there would also be important variations as to possible achievement levels of learners. In contrast, Ganal (1995) advocates that high academic standards for pupil attainment should be developed. All need to achieve goals and objectives pertaining to these standards. However in the evaluation process, there might be differences in how pupils of different achievement levels are evaluated.

As a further issue, should mathematics be taught as a separate subjects curriculum or should there be increased correlation, fusion, and integration with other academic disciplines and with the real world in society? The "get back to the basics" movement is very strong on the

part of selected lay people. President Reagan frequently stressed during the 1980's the need to teach the basics. The basics emphasizing the separate subjects curriculum has a rather lengthy history. Among others, William Chandler Bagley (1938) was an essentialist, another name for one who advocates the basics in the curriculum for all pupils. Bagley believed strongly in maintaining a separate subjects curriculum. The academic disciplines were not to be integrated in terms of content to be studied by pupils. He believed a "watered down curriculum" resulted when subject matter areas failed to show their differences. The National Council Teachers of Mathematics, as well as Growth in Education through a Mathematical Mentorship Alliance (GEMMA), advocates that subject matter be related in the curriculum. GEMMA brings together individuals from different walks and professions in life to ascertain what can be done to improve the mathematics curriculum. To emphasize relationships among different curriculum areas, GEMMA (Farrell 1994) stresses the following objectives, among others:

1. helping pupils discover connections between mathematics and science, engineering, and other disciplines used in the workplace.

2. disseminating to teachers materials about current real world applications of mathematics.

3. providing students with examples of mathematical applications that require problem- solving skills in school and in life after school.

4. forming a network between mentors and teachers, mentors and other mentors, and teachers and other teachers.

5. Empowering a group of teachers to become leaders through a unique learning experience and reinforcing their leadership skills with opportunities to interact with other professionals at local, state, and national meetings.

6. Allowing teachers and mentors to examine how present curriculum and instruction follow guidelines set forth in the NCTM's (1989) Curriculum and Evaluation Standards for School Mathematics. Teachers need to notice how these standards can improve student's preparation for careers in science, business, and industry.

Educational psychologists believe, through research results, that knowledge perceived as being related will be remembered longer as compared to that which is compartmentalized.

Evaluation of Pupil Achievement

How should learner progress be evaluated? Numerous workshops, staff development programs, faculty meetings, and professional organizations have emphasized the importance of quality means of appraising learners in mathematics. Sharing ideas pertaining to evaluation guides teachers to develop a larger repertoire of strategies to use in effectively appraising pupil progress. Cain, Kenney, and Schloemer (1994) wrote, "Although there are many possible scenarios for establishing the link between professional development and classroom assessment, perhaps the best one involves 'teachers helping teachers.' As teachers develop the necessary strategies and skills necessary for becoming successful mathematics assessors, it is important that they share their knowledge with their fellow teachers. One single teacher who becomes hooked on using effective methods of alternative assessment in the classroom can serve as an available resource to other teachers in the school."

Collegiality and collaboration in sharing objectives, learning opportunities, and evaluation procedures are needed for teachers to determine the best methods of evaluating pupil achievement in mathematics. These three components of teaching mathematics cannot be separated from each other. Nor should they be. As the teacher teaches, he/she evaluates each pupil's progress. The mathematics teacher then raises questions, in terms of self evaluation, pertaining to the following in teaching- learning situations:

1. how are pupils thinking about problems being discussed? It is essential that teachers understand how each learner processes information in mathematics.
2. how can I make mathematics dynamic and useful to learners?
3. how might my observations assist in providing improved sequence in learning for each pupil? Pupils solve problems in specific

identifiable ways; the teacher must observe how this is done in order to make quality instructional decisions.

4. how may I guide my pupils to perceive reasons for learning in ongoing lessons and units of study?

5. how can I incorporate adequate manipulative items, pictorial visual materials, and symbolic experiences to aid pupil thinking and reflection?

6. how might the concepts of diagnosis and remediation be used more effectively in my teaching?

7. how can I secure my pupils' attention so that time on task will be more in evidence?

8. how can pupils be guided to appreciate and use mathematics in every day life's situations?

9. how can interests be developed within pupils toward mathematics which will be applicable in the work place?

10. how might pupils be assisted to perceive the relationship of knowledge in mathematics to other curriculum areas and to life in the societal arena?

Self evaluation by the mathematics teacher is vital to improve the curriculum. Each teacher needs to view the self in terms of what is being emphasized in teaching and learning as compared to what should be, a normative approach. Quality evaluation is the key to make necessary modifications in mathematics instruction. Ediger (1988) lists and discusses he following techniques to use in appraising pupils progress in mathematics: teacher written test items including multiple choice, matching, true - false, short answer, and essay; rating scales and checklists with accompanying relevant standards as a basis for evaluating pupil progress; standardized norm referenced tests; criterion referenced tests; anecdotal records and journal entries; discussions and cooperative learning with quality standards used; teacher observation; pupil diary entries and logs; sociometric devices to notice social growth of learners; assessment of peer learning; and portfolios

of pupil work. A variety of evaluation procedures should be used to appraise pupil achievement. The results from each approach may be used to compare with other procedures. No one approach is perfect; Thus different procedures need to be used to evaluate learner performance to secure the best appraisal results possible. The National Council Teachers of Mathematics emphasizes a broad based assessment program:

> The advantage of using several kinds of assessments, some of which are embedded in instruction, is that students' evolving understanding can be continuously monitored. The disadvantage is that such a procedure is perceived cumbersome. Records of student progress should be more than a set of numerical grades or checklists; they can include brief notes or samples of students' work. Such records are evidence of students' continued growth in understanding. Students should also maintain their own records. At all grades, students can keep portfolios of their work; in the higher grades, as they become more verbally fluent and reflective, they should be encouraged to keep a mathematics journal. These journals contain goals, discoveries, thoughts, and observations, as well as descriptions of activities. Journals allow students, not only to chart their progress in understanding but also act as a focus for discussion between student and teacher, thereby fostering communication about mathematics itself.

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