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ABSTRACT

The purpose of this paper is to provide a set of criteria within a format that teachers, student teachers, and supervisors can use to better understand what inquiry is and how to evaluate the extent to which it is being incorporated into classroom activities. The evaluative criteria are organized into an instrument and are divided into the following categories: the lesson, student behavior, teacher behavior, and questioning techniques. Twenty-five criteria are included in the instrument. Properly used, the instrument should assist the user in determining where he is now and how, with continued application of the criteria, he can become a more inquiry-oriented individual. The instrument can be used to evaluate one lesson or a series of lessons. (MLH)

# HOW'S YOUR I.Q. (INQUIRY QUOTIENT)?

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Have you been doing any inquiry teaching lately? Are you one of the many educators who responds positively to the idea of teaching science through inquiry as advocated by programs such as the Science Curriculum Improvement Study (SCIS) and the Elementary Science Study (ESS)? Are you a traditional teacher who has struggled with the implementation of one of these new programs? Or perhaps you are someone convinced that you have always been an inquiry teacher without the benefit of new materials. Our experience has shown that despite a widespread acceptance of the desirability of promoting inquiry in the classroom, a great deal of misunderstanding exists regarding what is meant by teaching through inquiry and how one can evaluate whether or not inquiry is actually taking place in the classroom.

The purpose of this paper is to provide a set of criteria within a format which teachers, student teachers and supervisors can use to better understand what inquiry is and how to evaluate the extent to which it is being incorporated into classroom activities. The authors

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believe that the major objectives of teaching science in today's schools are to encourage the student to develop:

> ... the ability and confidence to pose questions and problems and to seek answers and solutions.
>
> ... an understanding of the physical and biological aspects of the ecosphere in terms of matter, life, energy, and their interactions.
>
> ... a command of the rational powers.[1]

We believe that these objectives can best be met using the inquiry process.

The evaluative criteria have been organized into four major categories which are intended to serve as focal points for analyzing the inquiry process. They are: the lesson, student behavior, teacher behavior and questioning techniques. Properly used, the instrument should assist the user in determining where he is now and how, with continued application of the criteria, he can become a more inquiry oriented individual. The criteria can be used to evaluate one lesson or a series of lessons. While not a necessity, the use of audio or video tapes of the lessons will facilitate the effective utilization of the criteria. Ideally a series of lessons should be recorded and evaluated over a period of two to three months. Through repeated application to a wide variety of lessons the criteria should function as a learning device as well as an evaluation instrument.

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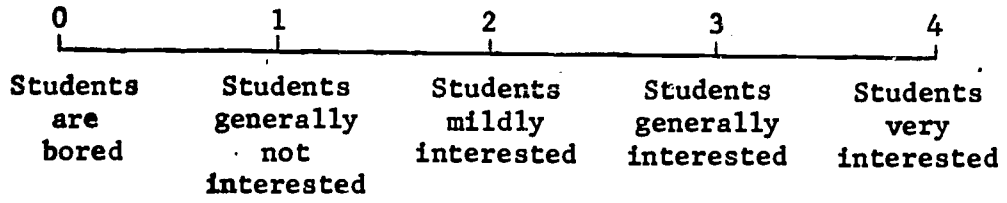
1. Educational Policies Commission, The Central Purpose of American Education, National Education Association, Washington, D. C., 1961, p. 5. The rational powers are listed as the processes of: recalling and imagining, classifying and generalizing, comparing and evaluating, analyzing and synthesizing, and deducing and inferring.

In addition to the criteria, scales are included which can be used to analyze and record the extent to which each aspect of the inquiry process is incorporated into the lesson. For example, criterion number one asks: Does the lesson involve materials or activities which are of interest to students? The scale to be used in conjunction with this question is shown in Figure 1.




Criterion Evaluation Scale

Figure 1.

Scales for the other criteria are shown in Table I. Most scales are to be scored on a 0 to 4 basis. In general, a 4 indicates a superior performance while a 0 indicates poor performance. The scales for criteria 8, 9, and 10, however, vary somewhat in that they involve student inquiry behavior and reflect a 0 percent to 100 percent range of class time. With reference to criteria 8, a superior lesson may or may not involve students in making observations and collecting data for 100 percent of the time. The evaluator will have to make a judgment as to the appropriateness of the amount of time spent by the students in various activities before awarding the score.

Also in Table I is a column labeled criterion score. This column

is to be used to record the evaluations on each criterion. In all cases, except for criteria 8, 9, and 10, this simply involves a transfer of the number from the scale to the score column. The numbers in the score column are then summed to obtain a total criteria score.

You will notice that not all items may apply to all lessons. For example, item 13 asks: Does the teacher act as a classroom secretary when data need to be organized for class analysis? In the particular lesson you are recording, the student inquiry may not have reached the point in which data are ready for class analysis. If this is the case, then this question will not serve as a point of evaluation for the lesson and it should be disregarded. Since some questions will not be answered for particular lessons, a total score from all lessons would not serve as consistent measures of comparison. For this reason the following formula is provided to enable standard lesson scores to be obtained from the total criteria scores which will serve as consistent comparisons.

$$\text{Total Criteria Score} \times \frac{25}{\text{Number of Questions Answered}} = \text{Standard Lesson Score}$$

A trial lesson record (see Table II) can be used to summarize important information about each lesson, including the standard lesson scores. Also a graph (see Figure 2) is suggested to enable the standard lesson scores from each lesson to be plotted and compared over a period of time.

Teaching using the inquiry process is not an easy task. The

teacher must be a careful organizer, a provider of materials, a skillful questioner, and an expert guide. Only through practice and careful evaluation can proficiency be obtained. With this in mind, try to be as objective as possible as you score each item. Progress towards high scores and excellent inquiry lessons will come, but not all at once. The evaluative criteria follow.

## Evaluative Criteria

### The Lesson

1. Does the lesson involve materials or activities which are of interest to the students?

Perhaps the primary factor in any investigation and in any classroom is motivation. Before meaningful inquiry can take place the students must be interested and motivated. It therefore, becomes imperative that the lesson contain materials or activities which appeal to the students and provoke interest and curiosity.

2. Does the lesson involve materials or activities which lead the students to think, question, and discuss meanings?

The central purpose of today's schools, and consequently any science lesson is to encourage the use and development of the ten rational powers. As stated by the Educational Policies Commission in its 1961 statement, The Central Purpose of American Education, the ten rational powers constitute "the essence of the ability to think." For maximum gains to be made toward this goal, the students must be confronted with situations which lead them to analyze, compare,

evaluate, infer and otherwise use their rational powers. Activities should be provided which involve students in collecting and analyzing data, sharing ideas, questioning findings and discussing meanings.

3. Are there provisions within the lesson for a variety of levels and paths of investigation to accommodate individual initiatives and directions?

Obviously not all students in a particular class work at the same pace, are equally interested, or are as intellectually able. It therefore, is imperative that each lesson involve some degree of flexibility. Much of this problem is solved when a teacher supplies the class with materials and activities which interest the students. When students are free to interact with materials and other students they will automatically do so on their own levels and in their own directions. Teachers should encourage individual initiative and direction.

4. Is the content of the lesson appropriate in terms of the intellectual level of the learner?

The idea of the intellectual level of the learner is extremely important in selecting what is to be taught and how it is to be taught. In the model of intellectual development proposed by Jean Piaget, a child passes through three preliminary stages in intellectual development to reach the fourth and final stage, adult thinking patterns. The first stage, from birth to about two years old, is labeled sensory-motor. The child's major objective is to learn about objects and their spatial relationships. Stage two, from age two to age seven, is called preoperational. The primary achievement during this stage is

the development of an understanding of symbolic meaning. The third stage, concrete operational, is characterized by the child's ability to perform what Piaget calls operations. Operations consist of mental manipulations based on the understanding of classes, relations, and quantities. Of primary concern to the teacher is the restriction that these mental operations must always originate with concrete objects or experiences. Abstract concepts such as, energy, molecules, genes, evolution, and inertia have no place in lessons designed for concrete thinkers. In the fourth and final stage, beginning (according to Piaget) around age twelve, the child develops the use of propositional thinking. These operations based on propositional logic, which Piaget terms formal operations, enable the child to see implications and develop an understanding of abstract concepts. In short, the child is no longer tied to concrete experiences but can think also in the realm of the possible. For students to develop the desired understanding it is imperative that the content of the lesson fit the intellectual capabilities of the students. Concrete thinking students must not be forced to deal with material which is too abstract for them. In addition, formal thinking students should not be forced to deal with concrete material which might bore them.[2]

5. Does the lesson involve a concept or concepts which are fundamental

2. A more complete discussion of Piagetian ideas and implications for education is beyond the scope of this paper. For more detailed analysis see: Richard Gorman, Discovering Piaget, A Guide for Teachers, Charles E. Merrill Pub. Co., Columbus, Ohio, 1972, or Herbert Ginsberg and Sylvia Opper, Piaget's Theory of Intellectual Development, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1970.

to developing an understanding of the nature of the discipline?

In selecting content for lessons the teacher must keep in mind that science instruction should lead students to develop an understanding of the world in which they live. Our understanding of that world is facilitated by the invention of concepts such as organism, population, gravity, energy, atom, ecosystem, and interaction. It is through investigations involving these and other fundamental concepts, not through trivial activities or ideas, that students are able to gain meaningful insights and understandings. A meaningful evaluation of the lesson from this point of view implies that the evaluator has at least a reasonable understanding of the nature of the discipline.

6. Does the amount of reading in the lesson impede the success of a student with limited reading ability?

No science lesson should be planned with an excessive amount of required reading. Although reading is recognized as extremely important, success in science should not be dependent upon it.

7. Are visual aids such as blackboard diagrams, slides, films, or recordings used as effective supplements to investigations?

Visual aids such as blackboard diagrams can offer significant help in organizing and synthesizing the students' investigative experiences. Once initial understanding has been obtained by way of first-hand experience, film, slides, recordings and other technical devices can serve as effective means of expanding the student's sphere of comprehension and awareness. The visual aids must not, however, serve as substitutes to the first-hand experience.

Student Behavior

The clearest indication that inquiry is taking place in a classroom is that students are actively involved in investigations.

8. Are the students making observations or collecting information which provokes a problem?

Whenever possible materials should be provided or situations created in which the students are confronted with an unexplained event which creates a problem. For example, a simple task such as planting seeds can provide many problems. Students can be given seeds, containers and soil and instructed to plant them any way they feel is best. After a number of days have passed and some seeds have grown, a number of problems present themselves. Why did only some seeds grow? Why are some plants taller than others? Why are some plants greener than others? What are the structures (cotyledons) on the side of the stems?

9. Are the students formulating hypotheses, models or predictions which aid in the solution of a problem?

Using the same example as above, student hypotheses may be as follows: some seeds did not grow because they got too much or too little water, sunlight, space or fertilizer. Perhaps some of the seeds did not grow because they got moldy. Some plants are not as green as others because they got too little sunlight. Students, after formulating hypotheses, should be encouraged to perform experiments to test their ideas or models.

10. Are the students analyzing, interpreting, and evaluating data singly, in groups, or as a class with the teacher's guidance?

Data produced by investigations should be thoroughly analyzed, interpreted and evaluated so that students are able to carefully think through the meaning of the results. This can be accomplished in various ways, generally, however, the younger the students are, the more teacher guidance is needed. A useful device for the interpretation of data (see criterion 13) is to first have them recorded on the board by the teacher. Then discussion of the data and their meanings can be carried out by the entire class.

11. Are class conclusions based on the evidence at hand or on the teachers authority?

For students to develop confidence in the inquiry process and in their ability to inquire it is imperative that conclusions be based on the data produced by the investigation, not on the teacher's authority. If it is clear to the teacher that the investigation produced unacceptable results, a further investigation should be proposed which may produce results contradictory to the original investigation. If this investigation is carried out and contradictory results are obtained, then the class has a real contradiction. In most cases the only course of action would be to perform both investigations once again to determine the source of error.

Teacher Behavior

12. While investigations are being conducted, is the teacher a fellow investigator?

This of course, does not mean to suggest that the teacher should

dominate the investigations. However, he should become a fellow investigator exhibiting enthusiasm and interest in the activities. He should walk about the room, pose individual questions to provoke further investigation, and be alert for students who might be having difficulty and need special assistance in getting started. Since the activities and investigations are being conducted by the students and perhaps have been "done" before by the teacher, the temptation may exist to sit back and ignore what the class is doing. This should be avoided. It is contradictory to ask the students to be investigators if you are not willing to become one yourself.

13. Does the teacher act as a classroom secretary when data need to be organized for class analysis?

The primary function of a teacher in the inquiry classroom is that of a guide and organizer. By recording class data on the blackboard the teacher not only helps the students organize their results but also can focus their attention on certain aspects of the data to help them in the analysis and interpretation of those data.

14. Are concepts introduced only after students have had sufficient direct experience with materials, events, or situations which enable them to comprehend the verbal presentation?

For learning to be meaningful it must be grounded in first-hand experience with the materials of the discipline. To introduce the verbal presentation of abstract concepts prior to such experience generally leads to rote memorization and noncomprehension.

15. Does the teacher provide additional materials, experiences or

events which enlarge, refine, and reinforce the meaning of the concepts previously introduced? *

Once initial comprehension of concepts or new ideas have been developed through classroom investigations, the students should be encouraged to extend their thinking and look for applications of these concepts and ideas wherever possible. Suppose, for example, the classroom investigations have led students to develop the concept of food chain by observing crickets eating grass and in turn being eaten by chameleons. This concept of a "food chain" is not very significant if all it applies to is these particular organisms. If, however, the students are provided other examples or asked for examples from their own experiences, the concept's meaning and importance is greatly extended.

16. Does the teacher handle classroom interruptions by calmly walking over to the offending student or students and addressing them personally?

A common mistake made by almost all new teachers and a great many experienced teachers is to raise their voices or even yell across the room to reprimand students. This type of teacher behavior, while it may appear to be initially successful, seldom has lasting effects. It generally leads to a loss of respect for the teacher and his ability to control a classroom. Personally addressing the offending student in a calm and deliberate manner saves the student the embarrassment of being disciplined by the teacher and it saves the teacher his temper. This

* The process of discovering applications and extending meanings of concepts introduced in the classroom may involve many lessons. In programs such as SCIS, which develops concepts in a "spiral" fashion, this process is woven throughout the entire six year sequence of units. For this reason, criterion 15 may frequently not apply to isolated lessons.

type of teacher behavior should not be confined solely to the inquiry classroom.

17. Does the teacher appear confident, calm, and friendly?

These traits as well as understanding, patience, and a good sense of humor often make the difference between a successful or unsuccessful lesson, be it inquiry or otherwise.

Questioning Techniques

18. Does the teacher pose a majority of questions of a divergent or evaluative nature?

These questions are the type which allow a variety of student responses and stimulate creativity and critical thinking.

Questions are generally of two types, convergent and divergent. A question such as: "What have you observed?" "How could we find out?" "What do you think might have happened to the seeds?" are divergent in that they have no single answers. They allow for divergent and creative thinking and stimulate discussion. Questions that call for a predetermined answer are termed convergent. These types of questions can serve to center students' attention on specific details of an investigation. For example: "What seeds grew in your terrarium?" and "How many daphnia were eaten?" are convergent questions.

19. If questions posed are of a convergent nature are they formulated to focus attention on particular aspects of an investigation in which the student is having difficulty?

Convergent questions can be of value in the inquiry-centered class-

room if they are used to help a student more carefully analyze a situation, or find and correct a possible error or point of confusion. Following this type of questioning the teacher has the responsibility of asking divergent questions to once again stimulate the student to think in a wider scope.

20. Are the questions phrased directly and simply?

Ambiguous questions lead to confusion and inattention. Keep the question direct and to the point to maximize student response.

21. Does the teacher call on an individual after posing the question?

Calling on an individual prior to asking questions encourages the rest of the class to disregard the question. If you ask the question first, then the entire class is stimulated to think about the answer. Sometimes a teacher will ask questions and not call on a specific pupil. This procedure leads to a chorus of answers which can occasionally get out of hand and lead to a class-control problem.

22. Does the teacher wait at least 4 to 5 seconds for an individual's response?

Teachers often ask a question and then do not allow the student to think about his response before calling on another student. This procedure not only is unfair but it does not allow for critical thinking about the question being asked.

23. Does the teacher listen to and accept all sincere student answers as valuable contributions?

Questions in the inquiry classroom should usually be of the kind with no specific "right" or "wrong" answers. Student responses, if they

are sincere and clearly not "goof off" responses, should be accepted as worthwhile information. Questions such as: "How many turns did your propeller make?" "How long are the sticks?" "How long did ten swings of the pendulum take?" are all questions that call for information. Although responses may clearly not seem "correct" to the teacher, she has the responsibility to accept the data. Contradictions and discussion over the validity of the answer or data should come from other students and other data rather than the teacher. This procedure not only opens up the classroom to free discussion and meaningful inquiry, but it also puts the authority for correct and incorrectness in the evidence or data where it belongs.

24. <u>In answering student questions, does the teacher respond by providing additional ideas or information which enables the student to continue his thinking</u>?

Any time the teacher supplies an answer that the student or class can answer through an investigation or further thinking he stops student thinking and inquiry.

The teacher should develop the ability to respond to student questions with further questions and suggestions of possible paths of investigation to enable them to continue the investigation or thinking. This does not imply that student questions should never receive direct answers. A question such as: "What kind of a tree is this?" should be answered directly or the student provided with means that could be used to effectively obtain the information.

25. <u>Did the students and the teacher enjoy the lesson</u>?

Persons become scientists because they are curious, enjoy their subject matter, their investigations, and they enjoy pondering questions. To teach science as something other than an interesting and enjoyable enterprise is unnecessary and, in fact, a misrepresentation of the discipline.

TABLE I

Scoring Sheet

| Criterion | Scale | Criterion Score |
|---|---|---|
| The Lesson | | |
| 1. Material and activities of interest | 0 1 2 3 4<br>students are bored — students mildly interested — students very interested | |
| 2. Materials and activities which provoke thinking, questioning, and discussion | 0 1 2 3 4<br>no thinking, questioning or discussion — 50% of students stimulated to think, question, discuss — all the students provoked to think question discuss | |
| 3. Provision within the lesson for a variety of levels and paths of investigation | 0 1 2 3 4<br>only one level and path of investigation — some lesson variety — all students able to pursue investigation at own level & own direction | |
| 4. Content fits intellectual level of the learner | 0 1 2 3 4<br>content appropriate for none of the students — content appropriate for 50% of students — content appropriate for all students | |

| Criterion | Scale | Criterion Score |
|---|---|---|
| 5. Lesson involves fundamental concept of the discipline | 0 1 2 3 4<br>content or ideas trivial, not tied to developing meaningful understanding — concept or idea of lesson of secondary significance — key concept or concepts of discipline | |
| 6. Reading does not impede lesson success | 0 1 2 3 4<br>amount of reading prohibitive to conducting lesson — 50% of students hampered by reading difficulty — no student hampered by reading difficulty | |
| 7. Visual aids used as effective supplements | 0 1 2 3 4<br>visual aids used as substitutes for investigative experience — aids used, but somewhat ineffectively — used effectively as supplements | |
| Student Behavior | | |
| 8. Students making observations and collecting data | 0 1 2 3 4<br>0 25 50 75 100<br>Percent of lesson time | |
| 9. Students formulating and testing hypotheses, models or predictions | 0 1 2 3 4<br>0 25 50 75 100<br>Percent of lesson time | |

| Criterion | Scale | Criterion Score |
|---|---|---|
| 10. Students analyzing, interpreting and evaluating data | 0 1 2 3 4<br>0 25 50 75 100<br>Percent of lesson time | |
| 11. Class conclusions based on evidence | 0 1 2 3 4<br>conclusions based on teacher authority — conclusions based on some evidence and some teacher authority — all conclusions based on evidence drawn from investigations by students | |
| Teacher Behavior | | |
| 12. Is fellow investigator | 0 1 2 3 4<br>No — about 50% of time — Yes | |
| 13. Acts as a classroom secretary when data need to be organized | 0 1 2 3 4<br>No — 50% of the time — Yes | |
| 14. Concept introduced <u>after</u> direct experiences | 0 1 2 3 4<br>No — 50% of the time — Yes | |

| Criterion | Scale | Criterion Score |
|---|---|---|
| 15. Opportunities for extending concept meaning provided | 0 1 2 3 4<br>concept introduced and not referred to again — numerous examples are mentioned and discussed — additional lessons involve concept to enlarge, refine, and reinforce meaning | |
| 16. Calmly handles classroom interruptions | 0 1 2 3 4<br>No — 50% of the time — Yes | |
| 17. Appears confident, calm, friendly | 1 2 3 4<br>No — 50% of the time — Yes | |
| Questioning Techniques | | |
| 18. Majority of teacher questions are divergent | 0 1 2 3 4<br>No — few divergent questions used — Yes | |
| 19. Convergent questions used effectively | 0 1 2 3 4<br>No — 50% of the time — Yes | |

| Criterion | Scale | Criterion Score |
|---|---|---|
| 20. Questions are phrased directly and simply | 0 1 2 3 4<br>No — 50% of the time — Yes | |
| 21. Individuals called upon after questions asked | 0 1 2 3 4<br>No — 50% of the time — Yes | |
| 22. Allows sufficient time for student response | 0 1 2 3 4<br>No — 50% of the time — Yes | |
| 23. Accepts student answers and opinions | 0 1 2 3 4<br>No — 50% of the time — Yes | |
| 24. Responds to questions by providing additional ideas, information, or clues to extend student thinking | 0 1 2 3 4<br>No — 50% of the time — Yes | |
| 25. Teacher and students enjoyed the lesson | 0 1 2 3 4<br>No one enjoyed the lesson — 50% of the students — all the students and the teacher | |

TABLE II

Trial Lesson Record

| Lesson | Date | Topic of Lesson | School Taught | Standard Lesson Score |
|---|---|---|---|---|
| 1 | 10/24/73 | Material Objects - Grab Bags | Morton | 39 |
| 2 | 11/17/73 | Batteries and Bulbs | Morton | 46 |
| 3 | 11/19/73 | Crickets in Terraria | Morton | 33 |
| 4 | 11/30/73 | Pendulums | Kingston | 61 |
| 5 | 12/04/73 | Whirly Birds | Kingston | 69 |
| 6 | 12/07/73 | Candle Burning | Kingston | 55 |
| 7 | 1/10/74 | Growing Seeds | Morton | 80 |
| 8 | 1/23/74 | Peas and Particles | Morton | 75 |
| 9 | 1/30/74 | Examining Rocks | Morton | 85 |
| 10 | 2/06/74 | Mealworm Behavior | Morton | 94 |

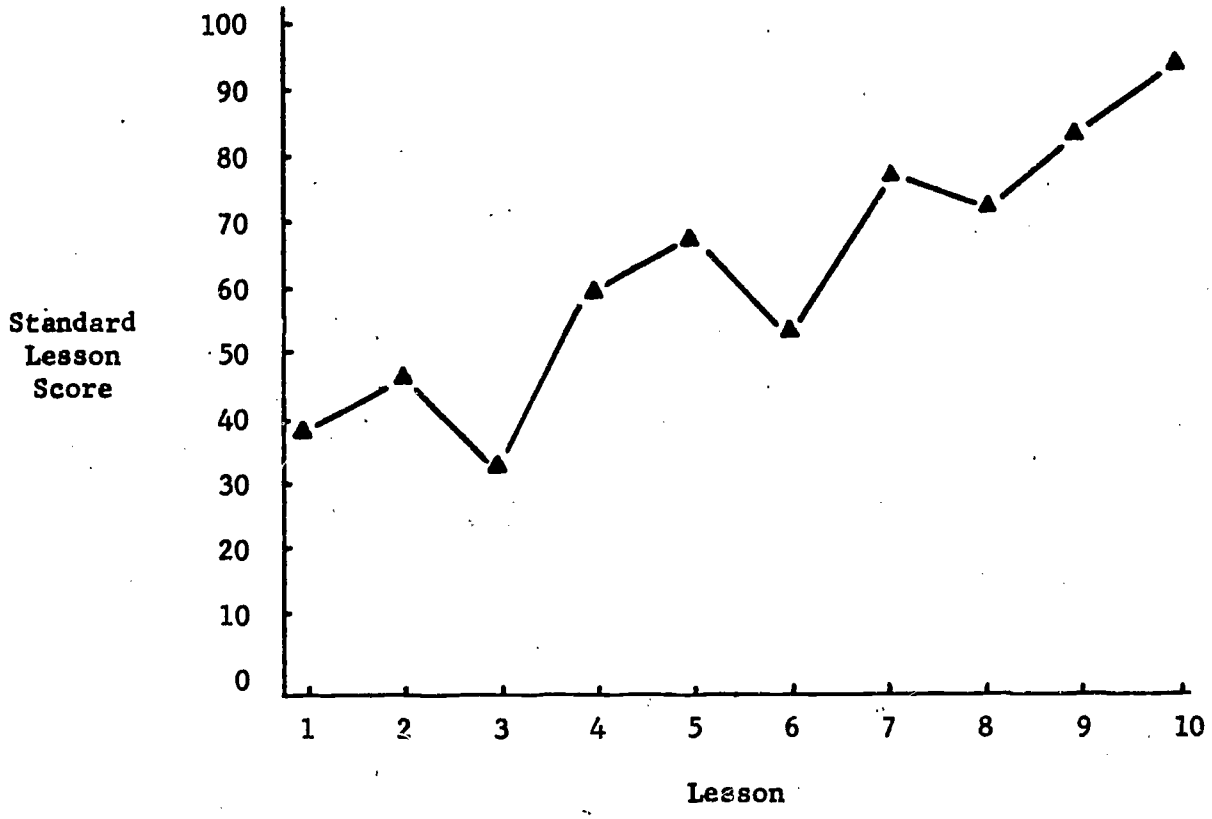



Figure 2. Sample data showing comparison of standard lesson scores of one person over ten trial lessons