A Study of Critical Incidents Relating to Effective Instruction in Secondary School Physics, Chemistry, and Biology

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A STUDY OF CRITICAL INCIDENTS RELATING TO EFFECTIVE INSTRUCTION IN SECONDARY SCHOOL PHYSICS, CHEMISTRY, AND BIOLOGY

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INTRODUCTION

The current international situation with its tensions and rivalries has emphasized the role of the science teachers in our secondary schools due to the increased importance of the scientist. These science teachers are held responsible for much of each new generation's introduction to the fields of science. Indeed, the public criticism would seem to indicate that there is much improvement necessary on the part of these teachers.

The increased emphasis on science due to these tensions is only one of the reasons that the task of the science teacher is becoming more difficult. The fields of science are continually expanding and the application of the ideas from these fields into other areas is becoming ever greater and more rapid. For this reason also, the need is felt for a greater degree of effectiveness on the part of the science teachers, for they now have more to do and no more time, in fact, in many instances less time, to do what must be done.

Even without any outside pressure such as has been created by the public news of the orbiting satellites there would always be a need for improving teaching. This study is made in an attempt to discover a method of increasing the effectiveness of teaching.

CHAPTER I

THE PROBLEM AND DEFINITION OF TERMS

I. THE PROBLEM

The purpose of this study is twofold. First, to compile a list of factors aiding in the effectiveness of instruction in secondary school chemistry, physics, and biology classes, and second, to determine whether or not these factors aiding effectiveness have elements in common. The problem will then be to characterize these common elements.

II. DEFINITION OF TERMS

Factors aiding the effectiveness or factors of effectiveness are those specific occurrences which a teacher credits with being, in large measure, responsible for the effectiveness of an instructional activity. They are not in general those common elements of preparation which are recognized by all teachers as being vital, but are specific occurrences that did produce effectiveness.

The common characteristics of these factors of effectiveness referred to above, shall herein be called "critical incidents" because of their critically important effect on the outcome of instructional activities. Critical incidents are meant to be factors of effectiveness in a broader sense.

Evidences of effectiveness are simply the reasons that teachers gave for feeling that a particular activity was effective.

CHAPTER II

METHOD OF THE STUDY

Science teachers were surveyed in an attempt to discover these critical incidents, believing that the teachers are in at least as good a position to detect them as their supervisors or their college instructors. If the critical incidents are detected by the science teachers themselves, the incidents have passed the final examination given all educational procedures, that is, the acceptance by the classroom teachers.[1] It is not intended that the implication given here be that a critical incident could be used in isolation, but, all other factors being equal should promote a greater degree of effectiveness if used.

Secondary school science teachers, if they revise their teaching procedures at all, conduct experimental teaching research in their own classes. A technique or procedure is tried and either used again unchanged or modified before it is used again. It is in the act of using a procedure again unchanged or changing it before using it

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[1] R. M. Cooper, "The Rise of General Education," N. E. A. Journal, 39:7, January, 1956.

again, that the science teacher is indicating that procedure's effectiveness or ineffectiveness. When a procedure is particularly effective, to the extent that the teacher is aware of something special that influenced it, then a critical incident may be involved.

The questionnaire[2] was designed to stimulate the recall of such instances and to intentionally omit aspects of teaching which are apparently well done by practically all science teachers.[3]

Basically the questionnaire requires a teacher to remember an instance of unusually effective instruction in one of his classes and then to describe that activity and the reason for its effectiveness.

The questionnaire and, for that matter, the basic idea of the study were based on work done by the American Institute of Research and John C. Flannagan[4] in developing and applying the critical incident technique to the determination and selection of personnel for various positions of importance.

This questionnaire was sent to 500 science teachers in secondary schools throughout the nation. The names and addresses

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[2]See appendix, pages 32-34.

[3]Alfred C. Jensen, "Determining Critical Requirements for Teachers," Journal of Experimental Education, 20:85, September, 1951.

[4]John C. Flannagan, "The Critical Incident Technique," Psychological Bulletin, 51:327, July, 1954.

were obtained, for a fee, from the National Science Teachers Association. Of these 500, fifty-one usable questionnaires were returned completed. A number were returned with a note stating that the time or background was not available to enable a meaningful reply to be made.

In view of the small number of returns, it might appear that little has been accomplished; however, these 51 usable replies, containing 170 individual critical incidents, were made by individuals of great sincerity due to the time and effort required to complete a questionnaire of this type. Since this is not an attempt to decide a question, but to compile critical incidents, these replies are of the most value.

CHAPTER III

THE LITERATURE

The critical incident technique has been used by D. G. Ryans and E. Wendt to investigate personal and social characteristics of teachers.[1] They used the observations of people associated with teachers, such as administrators and supervisors. A. C. Jensen also used the critical incident technique to determine the critical requirements of teachers.[2] He applied the questions to teachers, administrators, and student teachers. W. Charters and D. Waples studied the personal traits of teachers by means of a similar technique.[3] They had teachers rank a list of teacher traits by relative importance. W. M. Davis polled science teachers and teachers of science teachers in order to establish factors of effectiveness in

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[1]David G. Ryans and Edwin Wendt, "A Factor Analysis of Observed Teacher Behaviors In Secondary School: A Study of Criterion Data," Educational and Psychological Measurement, 12:574-86, Winter, 1956.

[2]Alfred C. Jensen, "Determining Critical Requirements For Teachers," Journal of Experimental Education, 20:79-85, September, 1951.

[3]Werrett W. Charters and Douglas Waples, The Commonwealth Teacher Training Study (University of Chicago Press, 1929), pp. 14-19.

science teaching.[4] These are typical of the studies investigating the effectiveness of teachers by means of this technique of asking the teacher himself. They are concerned with the teacher directly; that is, with his personal and social qualities and with his preparation for teaching.

Many other studies have been made, such as that made by H. A. Smith,[5] usually on the basis of controlled experiments, to determine the relative effectiveness of one teaching procedure as compared with another. Smith compared the effectiveness of motion pictures and demonstrations by using the two techniques on separate equivalent groups. Another example of this type of study was done by C. H. Boeck when he compared the inductive and the deductive approach in teaching high school chemistry.[6] One more example is the study of J. M. Mason in testing the effectiveness of using current scientific articles in the classroom.[7]

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[4]Warren M. Davis, "Factors of Effectiveness in Science Teaching and Their Application to the Teaching of Science in Ohio's Public Secondary Schools," Science Education, 38:150-52, February, 1954.

[5]Herbert A. Smith, "A Determination of the Relative Effectiveness of Sound Motion Pictures and Equivalent Teacher Demonstrations in the Ninth Grade General Science," Science Education, 33:214-22, April, 1949.

[6]Clarence H. Boeck, "Teaching Chemistry for Scientific Method and Attitude Development, Science Education, 38:81-84, October, 1954.

[7]John M. Mason, "An Experiment Using Current Scientific Articles in the Classroom," Science Education, 38:299-304, October, 1954.

These studies have revealed much valuable information regarding just what an effective teacher is like and what types of teaching activities are most effective in given situations. They neglect, however, to consider the characteristics of effective activities in general, since they study the teacher personally in one case and only his general plan of approach in the other. Neither of these two basic approaches examines an effective activity in further detail to find out just what made it effective. Since the discovery of these elements may lead to improved science teaching, this study shall attempt to find them.

CHAPTER IV

THE DATA

The data for this study were taken from the returned questionnaires of 51 science teachers relating instances of effective instructional activities in science. These questionnaires were examined and the usable incidents were collected. An incident was considered usable if there was sufficient clarity to the statement to allow an analysis to be made.

A card was made out for each of these incidents containing the following information:

1. The area in which the incident occurred.
2. The identity of the teacher.
3. The principles contained in the activity.
4. The type of activity.
5. The reason the teacher thought the activity was effective.
6. The critical incident observed.

Since most of these teachers were not teaching in one area of science exclusively, they could not be identified with one specific field. The choice was made to identify the incidents as to the field of occurrence and the sex of the participating teacher. This information is given in Table I. There were nearly equal numbers of incidents reported in physics and chemistry with a somewhat smaller number in biology.

TABLE I

IDENTIFICATION OF THE INCIDENTS REPORTED

Field	Teacher		Total
	Men	Women	
Biology	29	3	32
Chemistry	63	10	73
Physics	57	8	65
Total number of incidents reported			170

The number of incidents cited in each of the types of activity under consideration (i.e., lecture, demonstration, experiment, student project and evaluation) is given in Table II (page 11). Many of the lectures reported were not exclusively lecture, but were combinations of lecture and other types of activity. If the incident was listed under lecture by the teacher reporting it, the assumption was that it was primarily lecture. The same procedure was followed for each of

TABLE II

ACTIVITIES IN WHICH INCIDENTS OCCURRED

Type of activity	Number of incidents
Demonstrations	48
Lectures (or lecture demonstrations)	39
Experiments	35
Student projects	33
Evaluations	15
Total number of incidents	170

the other activities. There is a reasonably even distribution of the incidents between lectures, demonstrations, experiments, and projects, but a definite lack of incidents concerning evaluations. Possibly these teachers feel that their evaluations are not very effective aids in teaching.

Table III (page 12) lists the reasons the teachers gave as indications of the effectiveness of the activities. Each separate reason is followed by a number indicating the number of times it was mentioned. Most of the reasons refer to the students and their reactions.

TABLE III

EVIDENCES OF EFFECTIVENESS

Student Reactions	Number of times reported
1. Interest or attention shown	37
2. Favorable comments or questions	36
3. Correct reference to principles (later)	22
4. Quality of student result results (projects or experiments)	17
5. Extra student effort	15
6. Test results	13
7. Enthusiasm or participation	10
8. Enjoyment of lesson	3
9. Satisfaction with importance of principles	3
10. Changed wrong ideas	2
11. Aided in evaluation of students	2
12. Challenged students	1
13. Changed attitude	1
Factors other than student reactions	
14. Visible change by means of demonstration	5
15. Instructor's efforts	1
16. No reason	2
Total	170

There are three exceptions and they are listed separately at the bottom.

It is apparent from this table that student interest is rated very highly by these teachers as most of the reasons given either state explicitly or imply that a high degree of student interest is present.

Table IV (pages 14 and 15) lists the teachers' judgments as to what the critical incidents were by the number of times mentioned. Examination of this table reveals some general patterns of these factors of effectiveness that are, or are likely to lead to, critical incidents. A brief examination of some of these patterns may serve to point out several significant factors.

Those factors listed as 2, 3, 8, and 10 are concerned with unusual or unexpected occurrences. Since there were 48 references made to these occurrences, they seem to be of more significance than the others to be mentioned. This included more than 28% of all the incidents reported.

Factors listed as 4, 7, and 11 refer to means of making scientific principles fit into the students' experiences by using devices to bring the principles down to the students' level. Incidents falling under this classification numbered 29, or 17% of the total. This seems to indicate a strong feeling of importance for this factor.

TABLE IV

FACTORS OF EFFECTIVENESS

Factor	Number of times cited
1. Current public interest	17
2. Unexpected result	16
3. Spectacular	15
4. Simplification of difficult concepts	12
5. Useful products	12
6. Participation	11
7. Dramatic situation	10
8. Teacher's mistakes	10
9. Extra incentives (prizes, extra credit)	8
10. New insight	7
11. Everyday materials	7
12. Work of own choice	7
13. Practical use	6
14. Agreement with theory	5
15. Personal application (students)	5
16. Responsibility of students	3
17. Competition	2

TABLE IV (Continued)

Factor	Number of times cited
18. Visitors	2
19. Outside help	2
20. Discrimination between students (abilities)	2
21. Immediate return of papers	2
22. New equipment	2
23. Students realize importance	1
24. Religious implications	1
25. Challenge to students	1
26. Uniqueness of language in area	1
27. Personal conference	1
28. Easy access of research materials	1
29. Correlation with other subjects	1
Total	170

Items listed as 5, 13, and 15 are all connected with usefulness of scientific principles. The 23 references to this factor, comprising over 13% of the total, show that a high value is placed on use of scientific principles.

Those factors numbered 6, 12, 16, and 17 are concerned with the students taking active part in the activity. There were also 23, or 13%, of the incidents in this classification which, again, indicates a high value placed on active participation.

Groups 1 and 29 deal with prior interest on the part of the students. A somewhat smaller, but still significant number of incidents in this group indicates that prior interest has its place in stimulating effectiveness. This group contains 18, or about 10% of the total number of incidents reported.

Since 141 of the 170 incidents reported fell into these five general groups, they seem to be of the greatest value and will be referred to in Chapter V.

CHAPTER V

CONCLUSIONS

Most of the incidents used in this study can be grouped under one of four general headings. These four headings and a brief description of some of the incidents belonging under each will be given.

A. Incidents capitalizing on student's previous interests or stimulating new interests. An incident utilizing interests already aroused in the public was described by a physics teacher in Michigan. This teacher discussed centrifugal and centripetal forces in connection with earth satellites. He felt there was an enthusiasm and interest present in his students because of the launching of American and Russian satellites.

Two other teachers reported using the earth satellite and guided missile emphasis to develop concepts of astronomy and gravitation.

Another incident utilizing current topics of interest was reported by a California physics teacher who discussed Newton's laws and the independence of forces in connection with a news item about a fighter plane shot by its own bullet. He stated that his students questioned him searchingly in an attempt to apply the principles he introduced.

Atomic structure, atom bombs, radiation and cancer were other current topics given credit for adding to the effectiveness of classroom activities due to the current emphasis on topics of that nature by public magazines and papers.

A physics teacher in New York described dramatizing magnetic principles by performing what he called his "Indian rope trick." He supported a paper clip and an attached string with a magnet not quite touching the clip. He then passed sheets of various materials between the magnet and the clip, thereby demonstrating which materials are affected by magnets and which are not. He credited the dramatization with creating student interest and aiding his effectiveness.

Another incident of this type was contributed by a chemistry-physics teacher in Missouri. He demonstrated the similarity of electrical conductivity of silicon and carbon, by heating a glass prism with a 110-volt electric current. He stated that the demonstration was spectacular and this created a strong interest in the study of silicon and carbon.

Other teachers credited explosions, bright colors and other unexpected results with creating student interest. One such incident was the accidental explosion caused by two large pieces of sodium dropped in a battery jar of water.

Still other teachers reported that their own mistakes aroused their students' interests in topics. One of these mistakes was the limewater test for carbon dioxide that should not work for carbon monoxide, but did. His students wanted to know why.

B. Incidents demonstrating the practical application of scientific principles. The incidents in this group were credited with demonstrating that science has a valuable part to play in the lives of the students.

One of these incidents was developed around new lawn building. It happens there were several new houses in the immediate vicinity and this biology teacher took up the topics of soil conservation, root structure, and plant nutrition in direct application to the new lawns being developed in the neighborhood.

Several other instances of direct practical applications were concerned with home electrical systems. By studying house wiring systems, students were given concrete uses for ohm's law, principles of resistance, and heating effects.

A number of other incidents were concerned with the construction of demonstration devices for immediate use by the same student group. A complete superhetrodyne receiver was constructed by one group. Another teacher directed his students in the production of a tape recording about the International Geophysical Year to be used in the lower grades in the same school system.

C. Incidents providing opportunity for student participation. Experiments and projects were most commonly reported that allowed students to actually participate in finding relationships such as specific heats and percentage compositions, rather than simply trying to follow a recipe to achieve the same results as are listed in any science text. Participation, as it is used here, means sufficient participation by the students so that they feel a degree of satisfaction with their part. They participate in planning or in some way other than to simply follow directions in detail.

A teacher in Kentucky explained how she accomplished this. She had her students go through a quantitive experiment in chemistry and then average their results before checking to see what the authors listed as the percentage composition. She felt that the students' participation in determining compositions percentages as a group was conducive to the effectiveness of this experiment.

Some teachers enlisted student aid in writing laboratory work sheets. These students outlined the proper procedures from their study of theory in preference to following a published recipe from a workbook.

Incidents were also reported in which personal physical products of the students' bodies were concerned. A Massachusetts physics teacher felt that determination of the actual horsepower developed by each student was very effective because of the personal participation involved.

D. Incidents tending to simplify scientific principles. Incidents using simplified devices demonstrating principles of science were commonly reported. One of these devices consisted of a chain of beads to represent a complex food molecule and a wire screen to represent a semipermeable membrane. The beads could pass through the screen separately although they couldn't in a chain. A New York biology teacher explained digestion effectively in this manner.

A physics teacher in Minnesota used some strings and a ruler to explain the mechanical production of electricity. He tried to cut the strings with the ruler and they wrapped around it. This analogy to cutting magnetic lines of force with a conductor was cited as being responsible for the effectiveness of this demonstration.

An analogy used by a physics teacher in Massachusetts to explain the transfer of heat from a substance while it is changing state was a set of stairs with a landing in it. He let the elevation represent the state of the substance and the forward progress, the loss of heat. He felt that this effectively demonstrated that a substance could lose heat without changing state.

A teacher in Kansas used a simplified device to illustrate Charle's and Boyle's laws of physics. She used a battery jar partially filled with water, a few marbles placed in it and a perforated cardboard piston that could be moved up and down in the jar. By heating the jar the marbles could be agitated and their motion could be restricted or allowed freedom bymoving the piston. She felt that this was an effective analogy to the motion of molecules in a gas.

These incidents are but a few of those reported, but it is hoped that they serve to illustrate the types of incidents received.

There is considerable agreement among these teachers as to the factors promoting the effectiveness of learning activities. A list of these factors has been compiled (Table IV, pages 14 and 15). Critical incidents do occur and although there is no extensive list of them given, certain general characteristics can be used to characterize them.

1. They bear heavily on the student's interests, either relying on acquired interests or helping to create new interests. The large number of references to student interest or to means of developing student interest is evident.[1]

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[1]Table IV, pages 14-15.

2. They demonstrate the value of science through practical applications. Twenty-three individual incidents credited the application of scientific principles with aiding the effectiveness of teaching activities.[2]

3. They require or provide opportunity for student participation. There were 23 incidents which included direct reference to student participation as a factor of effectiveness.[3]

4. They tend to simplify scientific principles. There were 29 incidents that referred to simplification by means of an analogy or simplified apparatus as a factor of effectiveness.[4]

If these four considerations have not been fully employed, more emphasis on their use by the science teacher should result in his increased effectiveness.

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[2]Ibid.

[3]Ibid.

[4]Page 16 and Table IV, pages 14 and 15.

CHAPTER VI

SUMMARY

The "Critical Incident Survey Method"[1] was used to contact science teachers in order to learn about their most effective teaching activities. Replies were difficult to obtain and only a small number of returns were received. These, however, contained enough critical incidents to enable a list of 29 factors of effectiveness to be made.[2]

Over half of the factors of effectiveness fell into one of four general groups. The common characteristic of each of these four groups is proposed as a partial description of a critical incident:

1. Student interest
2. Practical application
3. Student participation
4. Simplification

The problem of determining factors of effectiveness or the more general critical incidents might be further pursued by means

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[1] John C. Flannagan, loc. cit.

[2] Table IV, pages 14-15.

of the critical incident technique on a larger scale. The difficulty experienced in obtaining completed questionnaires might be partially overcome by conducting personal interviews with the teachers concerned.

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APPENDIX

APPENDIX

I am preparing a thesis dealing with "Critical Incidents" relating to effective instruction in science. I need your help in completing this questionaire. I would like to know about learning activities that you are proud of.

If you feel you cannot complete the entire set of qusetions, will you please return whatever you do complete in the enclosed envelope.

I use the words "Critical Incident" to indicate some special, out of the ordinary, factors entering into a learning situation and affecting the outcome. These incidents are critical if there presence means effectiveness and their absence, ineffectiveness.

E. Palmer, Sci. Tchr.
Grandview, Washington

Your name______________________________Subjects________________

1. Think of a time when you presented an especially effective lecture.

   1.1 What scientific principles were involved?

   1.2 Describe your technique. (Questioning, Straight lecture, etc.)

   1.3 Why did you consider this lecture to be effective? (result?)

   1.4 What was the critical incident? What specifically was the reason the lecture was effective?

2. Think of a time when you performed an especially effective demonstration.

   2.1 What principles were demonstrated?

   2.2 How did you perform the demonstration? (equipment, materials?)

2.3 Why did you feel this demonstration was effective? (results?)

2.4 What was the critical incident? What specifically was the reason the demonstration was effective?

3. Think of a time when you promoted an especially effective laboratory experiment.

3.1 What was the experiment about?

3.2 Why do you feel the experiment was effective?

3.3 What was the critical incident? What specifically was the reason the experiment was effective?

4. Think of a time when you promoted an especially effective student project.

4.1 What was the area covered by the project?

4.2 Why do you feel it was effective?

4.3 What was the critical incident? What specifically was the reason the project was effective?

5. Think of a time when you conducted an especially effective evaluation procedure.

5.1 What principles were concerned? What concepts were concerned?

5.2 Why do you feel it was effective?

5.3 What was the critical incident? What specifically was the reason the evaluation was effective?