DOCUMENT RESUME

ED 081 578 SE 016 107

AUTHOR	Doran, Rodney L.
TITLE	Models for Science Education Research.
PUB DATE	Mar 73
NOTE	22p.; Paper presented at the annual meeting of the National Association for Research in Science Teaching (46th, Detroit, Michigan, March 1973)
EDRS PRICE	MF-$0.65 HC-$3.29
DESCRIPTORS	*Educational Research; Literature Reviews; *Models; Research Criteria; *Research Methodology; Research Needs; Research Utilization; *Science Education; *Trend Analysis

ABSTRACT

A review of science education research studies is presented to illustrate the necessity of building a model for research activities. Present trends in research activities are analyzed by summarizing studies, particularly beginning from the Curtis 1926 Digest to the Welch and Gallagher 1972 reviews. The only existing model is one formed through classification of similar studies into groups and subsequent labeling of the groups by common attributes. A research training session oriented toward the model construction is suggested and serves as a way of accomplishing the first step. Generalized components of such a model should include input, process, output, and feedback. Criteria for a model are: logical fertility, multiple connections, permanence and stability, extensibility, casuality, simplicity, elegance, social significance, future orientation, and implication for classroom use or curriculum development. The author suggest that the outlining, elaboration and testing of models is the necessary focus of attention if improvements are to be accomplished in science education research. (CC)

Models for Science Education Research

Rodney L. Doran
Department of Instruction
State University of New York
Buffalo, New York

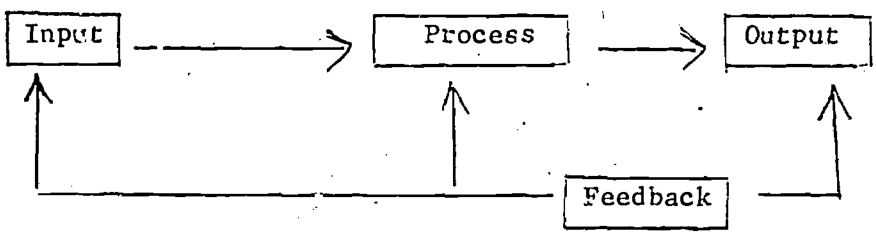
I would like to address myself to four questions related to this topic (1) Does science education have a model of/for research? (2) Is a model necessary? (3) How do we go about constructing a model? and (4) What criteria do we use in evaluating the model?

If one looks at the frequency of the word "model" in the titles of current articles, one can think of few more popular words. "Model" seems to have replaced words like; cognition, concept, process, and theoretical on the "Words to Use List". Weinstock reported "an almost unlimited use of models for the development of theory on the part of the educational research."[1] Even a word in such common use by people as ourselves may need a little clarification. In the Handbook of Research Teaching, Gage discusses paradigms, models, patterns, and schemata as being the same thing. These things (models, paradigns, etc.) "are not theories; they are rather ways of thinking or patterns for research that when carried out, can lead to the development of theory".[2] According to Tyler, "Theory is the all embracing end of basic research in seeking to provide a comprehensive map of the terrain of science education."[3] Tyler continued by stating that:

> "Concepts are the smaller areas which comprise the total map or to put the metaphor in another way, the complex of science education can be understood more readily by considering the concepts as major parts of the whole, and studying these parts in greater detail than is possible with the total."[3]

...Models are the outlines of the dynamic relationships which help to explain the process as an active one rather than as an anatomical structure. The concepts and the dynamic models furnish the map which we seek in order to understand the factors involved in, and the processes of science education. They form the major part of the theory."[3]

The use of models and systems analysis has been a widely used tool by the military, the space program, and many engineering fields. Recently it has come into vogue in education. The initial response to most new things (systems analysis included) is quite often dichotomous, either you love it or you hate it. With time educators will likely come to realize that this technique can be of some assistance with some problems and of little help with other problems. At this stage in our model development, it might be valuable to at least consider how a system approach could be helpful. Hill's Phi Delta Kappa fastback entitled How Schools Can Apply Systems Analysis presents a good overview for the person uninformed about this topic, as well as a good bibliography for further reading.[4] While models can be represented at the iconic, analogue, and formal symbolic levels, the majority of models this author reviewed utilized the analogue level of presentation. In most of the models, the major variables and their relationships are represented in some graphic or outline form. The generalized components of these models usually include: input, process, output, and feedback.



Hill's analogue model of systemic analysis for education suggests that systems analysis efforts thus far in education are oriented toward solving a specific problem. An article in The Science Teacher by Jesser stresses the process nature of systematic planning which includes three basic phases; analysis, planning and design, and implementation and evaluation. Maybe such thinking could be productive when one thinks of the science education profession taking an active role in planning its research efforts.[5]

Having presented a brief discussion of the word "model" and its place in research, the first part of this talk will be concerned with a brief sketch of the early efforts as well as the present state of development of science education research models. A study of science education research reviews should give some insight to this issue. A recent article by Voelker and Wall illustrates the monumental amount of science education research reviews compiled in the last 50 years or so.[6] I selected some of what I viewed to be the most widely distributed and comprehensive reviews for my consideration in preparing this talk. While more information may be obtained by considering a broader section of these reviews, I believe the same comments would be forthcoming.

Through the years from the first Curtis Digest (1926)[7] to the 1972 Welch[8] and Gallagher[9] reviews in the Journal of Research in Science Teaching (JRST), an increasingly complex picture of science education research gradually emerged. This may be a function of an increase in the amount of research accomplished, sophistication of research techniques, an increase in the assimilation of other research field's developments, or any number of these and other reasons. The Curtis Digests categorized science education research studies as to level (elementary, high school, etc.) and subject (biology, chemistry, etc.). Through the years additional research concerns were added to the reviews, such as; science teacher education, objectives, methodology, and evaluation. The NEA "What Research Says to the Teacher" series published separate volumes on elementary school (1957)[10] and high school science (1956).[11] The ERIC Center for Science, Math and Environmental Education produced analysis of science education research separately for The Science Teacher (secondary level) and Science and Children (elementary level) in 1969. One of the two Science and Children (S & C) articles was devoted to instructional procedures,[12] the other to teacher education in science.[13] The three The Science Teacher (TST) articles were devoted to instructional procedure,[14] outcomes of instruction,[15] and teacher education.[16] This separation between elementary and secondary has continued through the present with the Welch[8] (secondary level) and Gallagher[9] (elementary level) reviews supported by ERIC and published by JRST.

A further division was accomplished by the authors of the Review of Educational Research, October 1969 issue on science and mathematics education.[17] The separate sections (Learning Studies, Curriculum Development, Evaluation, Foreign and International Program, Philosophic and Historical Bases of Science Teaching) reflect trends in research as well as the influence of the NSF curriculum projects. Many other interesting trends (increased emphasis and decreased emphasis) could be observed by a closer look than what is discussed here, such as; instruction via filmed media, computer-assisted instruction, laboratory instruction, and many others.

However, the author perceives that almost all the reviews cited here are based on category systems or "post-hoc" sorting rather than being based on some model established prior to the research. One exception to this was a "Model of the Instructional Sequence" developed in the Ramsey and Howe article in S & C.[13] This model incorporated pupil characteristics, teacher characteristics, objectives, instructional procedures, and evaluation. Unfortunately this model didn't appear to be used in the article.

The ten categories used by the ERIC Center for their series of bibliographies may have been based both on past categories of research as well as some underlying model. However, I have never heard or read of any attempts to communicate the model, beyond the listing of ten categories. Ralph Tylerhas an article in JRST described 11 areas that he thought should be the foci of science education efforts.[3] However, Tyler didn't formally relate the 11 areas to one another in the terms of a model.

The categories of papers and symposia presented at NARST could be used as the unit of analysis as well as research reviews. The author analyzed the last seven NARST programs which generally confirmed the trends and comments made earlier in this paper.

Pella states that "A primary concern is any area of study is with a theory of knowledge."[18] He went on stressing that "knowledge is possible only when we recognize reflected patterns or characteristics in our perceptions."[18] When such concepts are indefinite, the best one can do is to

6

describe relationships. Pella felt that this is where science education was in 1965. Has it progressed further by 1973? The future directions suggested by Pella were to form a set of adequate operational definitions, construct propositions with an empirical base, generalize from gathered data, and finally develop a theoretical sturcture. These steps seem to follow in a sequence or heirarchy. Pella stressed the need to work toward the development, for science education, of a theoretical or conceptual structure essential for fundamental progress.

According to St. John, "Science education lacks a viable theory, I believe, namely because its present theoretical framework (to the extent that there is one) is based upon common sense".[19] This criterion of common sense is "a highly restrictive one and one that has long since been abandoned by the theoreticious in the natural sciences."[19] St. John suggested that the common sense criterion will be replaced only when better, more useful theories are developed.

Similar ideas were discussed by Glass. He claimed that "If it takes a large amount of money or mental effort to purchase practical educational knowledge, then the schoolman's need for it will drop to zero. He can and does readily substitute folklore, rhetoric, and testimonials for the more costly commodity."[20] Ebel argued that the common sense criteria is used because "the things that experience has taught us about education... are far truer on the whole than most of the new things that one reads under the heading of 'News from the Researcher Frontier'".[22]

According to Watson, "the most serious criterism of much of our research is the common absence of any theoretical framework within which the particular investigation, however modest, is made."[21] Thus, we have particular results, but "little bases on which to transfer this to other contexts."[21] This situation, Watson states, leaves the reader without a "meaning system". In a similar vein, Hurd stated that "A much neglected factor in science education is a theory base."[24] This lack of education theory keeps us from ever seeing the "whole" of our enterprise.

Glass suggested that "educational change is so chaotic because innovations are not based on scientific knowledge."[20] This problem would perhaps diminish if education rested on a foundation of reliable, basic knowledge of the teaching-learning process.

Burnett stated that "The literature has not deepended and enriched because we who should have been doing the theory development and experimenting have not grown up very much. In many cases, we merely use different words to report discussions or to investigate problems that were carried on in investigations decades ago."[23]

The author feels that presently the only model that exists for science education research is a model that is formed by the classification of like studies (along selected dimensions) into groups and the subsequent labelling of these groups by the attribute they have in common. While such a model is useful to describe what has happened, it is of limited value to interrelate studies from other fields, help guide further studies, and other necessary functions.

The second big question I would like to address myself to is... "Is a Model Necessary?"

The value of models in the development of modern science was cited by Novak. He suggested that "Alchemy might have persisted until today if a model of an atom has not been devised and subjected to experimental tests."[25] Perhaps an anology can be argued between alchemy in science and common sense in education. If that analogy is valid, it is clear how important models are to science education researchers. Novak continued suggesting "It is likely that substantial advances in education would result if we could develop models of learning that have equivalent and ultimate practical value."[25] He concluded that "educational research must be based on the contribution of model systems which can be submitted to test."[25]

Models can be with implicit or explicit; some are set forth by their authors in full detail, with diagrams and elaborations while others are implicit in what the authors have done or proposed by way of research. While implicit models may be very satisfactory for the researcher who has carved out his niche and is busily researching, it seems that an explicit model would be useful for planning research and communicating results, horizontally to other educational researchers and vertially to science teachers, supervisors, and curriculum developers. Tyler reminded us that "models must not only simplify complex phenomena, they must provide a means for explaining and predicting the variation and regularities observed in the phenomena."[3]

According to Gage, "Our concern with theories and paradigms is therefore aimed at furthering more systematic and orderly approaches to the formulation of the variables and hypotheses that enter into research on teaching. We urge no movement away from facts. It is merely the ill-considered collection of facts against which we argue."[2] A major advantage of a research model is to further a more systematic and orderly approach to the formulation of the variables and hypotheses that enter into science education research. This would be far superior to the present isolated accumulation of ungeneralizable research data. This model could aid by showing areas in which research is necessary or where inconclusive results suggest the replication of studies or cross-validation via other variables in the established network.

Gage suggests that even "if paradigms are not useful in discovering a new truth, they may at least be useful in communicating it so the recipient of the communication may then find the paradigm serviceable in his own work."[2] According to Hurd, "We (science educators) have a professional responsibility to find ways to bridge the gap between the product of research and the life of the classroom, and to coordinate research with operating programs within the school."[24] Research models could be indispensable to a thorough communication system.

When a research model exists, a researcher can choose some part of the model for any given effort, but the model remains in the background, providing the framework, or the sense of the whole, in which the project is embedded. Already in science education research, the amount and variety of research is almost overwhelming. Atkin described the situation like this - "We seem to be laboring with a type of reductionism in which it is very difficult to put the pieces together."[26] He called for a swing of the micro-marco pendelum back toward the macro. Several science disciplines have research going on at both the "micro" and the "macro" extremes at the same time, e.g. biologists are working at the molecule level and at the biome level, while physicists are investigating the nucleus as well as the extremes of the universe.

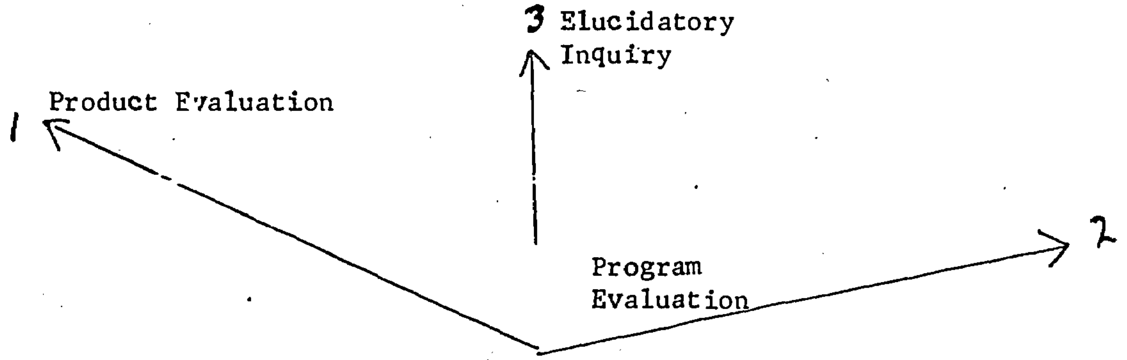
Can one still be a generalist or should one even try? The perplexing question of specialists vs. generalist is with us. Rather than attempting to solve this age-old problem, let it suffice to say that a model could aid in tieing individual research efforts to the whole, as well as, seeing how other research (science ed. or not) relate to the whole and/or to our research efforts. The whole of a given endeavor can equal or surpass the sum of the constituent parts and the whole if they relate meaningfully. A model could be extremely helpful in this regard.

Lawlor and Lawlor cite the techniques used in compiling research reviews as being represented by the phrases; voting procedure, jury method, citation analysis, subjective evaluation of significance or usefulness.[27] Certainly a model for science education research could be of considerable value for conducting such research reviews.

In addition to the basic-applied dimensions, research studies in science education have been categorized in different ways by different science educators.

Novak used the categories; Survey and Status Studies, Analytical Survey, Experimental Studies, and Curriculum Research.[25] Quite similar phrases were used by Atkin, Status, Survey, Correlational-Comparative Experimental, Analytical Experimental, and Clinical Curricular Research.[26] Several new ideas were introduced by Jacabsen as he categorized research studies into the following; Empirical, Philosophical, Policy, and Developmental (formative).[27]

Glass developed a three dimensionsal model that aids one in describing a research effort; (1) Generality across geography (2) generality across time, and (3) applicability to specific instances of the phenomena.[28]



A particular type of research will be located somewhere in this structure depending its degree of generality along each of the three dimensions. The origin of the three axes represents no generality with an increasing degree of generality as one moves out along any axis. While not as simple as the few categories, Glass' three dimensional model may be useful for describing types of educational research. A model of science education research may similarly help clarify the nature of an individual research effort. Instead of stifling particular kinds of research, a model on which all types of research are housed could help encourage the accomplishment of a variety of kinds of research and suggest the symbiotic relationship among the many research efforts.

Morgan claims that "the task of providing for the education and development of young people is immeasurabley more important and complex then building automobiles and launching rockets."[29] The enormous complexity of the educational system was emphasized by Glass as he claimed that a lake or human heart is trivial by comparison.[28] A first step toward understanding and explaining the complexities of education may be the construction of a model for researching major educational variables and their relationships.

Conceptual schemes are at the very heart of the science disciplines and some of the curriculum projects which are intended to present an accurate picture of science. Bruner's statements about the importance of the "structure of a discipline" seems to be reflected by the direction of the science curricula. If Bruner's claims about the worth of the "structure of a discipline" are true, the structure of science education research should be of prime concern to NARST. The need for a model for science education research is clearly expressed by the comment made by Glass about the direction an eager, young scholar should pursue. Glass suggested educational research where the scholar could select a very narrow domain and research it to death.[28] He would reapidly achieve world-wide eminence confident that his colleagues will never devise models or theories sufficiently general either to subsume his work or to prove it wrong.

If we don't have an adequate model for science education research and a model is necessary, the next concern is how do we go about constructing such a model.

While starting afresh with no biases and prejudices might be desirable from many points of view, it might not be desirable (in our case) or even possible. There are a variety of beginning points that one may .

One possible technique would be to use the accumulation of past research as a foundation and to build a structure that presents an organized relationship among the research studies. The advantage to this method is that it is very relevant, useful for communication, and easy to assimilate into our ways of thinking. However, it may have some disadvantage in that it is hard to look forward at the same time one is looking backward. One beginning point for such a procedure might be the model developed by Ramesy and Howe. It contains many variable and relationships crucial to science education research. Another model might be the Generalized Schema for Research in Teacher Effectiveness developed in the Handbook for Research on Teaching. This model utilized four types of variables; Prediction Sources, Contingency Factors, Classroom Behaviors, and Criteria of Effectiveness.

Another possible technique to use in forming models for science education research is to look at other disciplines and see if elements from their model have any relevance to our needs. The science disciplines and other education fields might be logical places to begin. The social sciences; psychology, sociology, anthopology, etc. might also be worthy of examination. According to Anderson, "We would do well in early theory-building to appeal to already existing theories within well-established disciplines."[30] He continues saying that "such scholarly hybridization can yield much vigor in our discipline", however...it "must bear some relevance to the educational process they are expected to explain."[30]

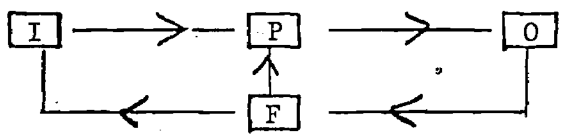
Belanger cautions that as models in behavioral science become better known, "there is a danger that they may be inappropriately imposed on educational contexts. It is more liekly, and perhaps more desirable, that educational research not only will develop their own models to represent phenomena of education but also will adopt and refine what is suggestive and useful from other areas of knowledge."[31] It seems to this author, that science education is ready for such model building activities.

An inner-directed search might also be profitable-namely a look at what models for research that may exist in areas within the science education context. For instance, science concept learning, student cognitive achievement, or science career selection may have elements that could be generalized to the broader concerns of science education research. Many areas of research concern within science education have developed models for their particular component or have used a modified an already existing model from another field, e.g. Novak's model of concept formation was largely influenced by ideas from cybernetics and information theory. Much research has been conducted utilizing models, developed by psychologists and other behavioral scientists. Examples include research work on Ausubel's advanced organizers, Bloom's taxonomy of cognitive objectives, Piaget's levels of logical operation, to name a few. This author is not criticizing such excellent works but rather pointing out the need to integrate these models and their research results to the overall science education concerns.

Novak, Ring and Tamir contributed a valuable service in this regard by reviewing a large number of educational research studies and interpreting them in terms of Ausubel's theory.[32] Hurd stresses the need for such types of analysis and synthesis of findings reported within science education research studies[24] Even better than such post hoc analyses would be the apriori description of a study in terms of specific parameters of a research model.

Another way of accomplishing the first step of such a model-building process might be to plan a "Research Training Session" oriented toward the construction of models for science education research. NARST Training sessions have been supported in the past by grants from the United States Office of Education. If support cannot be mustered for such sessions, NARST could encourage such activities via pre-convention sessions, working sessions during NARST convention, working committees and the like. This session could be organized by the NARST membership and attended by individuals providing a variety of perspectives and ideas. The following groups or agencies should be represented at the sessions; NSF, USOE, State Education Department colleges and universities, public and private schools, Research and Development centers, curriculum projects, the ERIC Center, NSTA, NSSA, AETS, CESI, journal editorial boards, AAAS, NARST, SSMA and others. Suggestions as how this type of session might be organized would be enhanced by an inspection of the National Cancer Plan's Planning Sessions.[33] The National Cancer Research Strategy was developed via a series of planning sessions attended by a number of specialists and generalists who have considerable experience in cancer research. Granted there are differences between science education and cancer research in terms of money and facilities available, freedom to experiment, etc. But similarities are present also, such as; the number of variables and complexity of the task, wide variety of subjects, etc. The National Cancer Institute is well aware of the assumptions required to develop such a model as well as the limitations, and so is implementing the plan as an experimental basis. Such actions seem most appropriate for a research discipline.

Much of the current model development has a corresponding schematic or graphical representation. In its simplist form, most contain the following elements; input, process, output and feedback.



Many varieties of additional elements and relationships can be added to make the model more representative of the particular phenomena it is representing. The four elements above could be a beginning point for the application of this model to a particular domian, such as science education. "Input" data could be obtained from a variety of sources, such as; pupil characteristic (cognitive development, past experiences, etc.), teacher characteristic (competencies, skills, behaviors, etc.), school environment (equipment, funding, SES, etc.) and other variables. "Process" variables could include classroom climate (democratic, unstructured) the instructional material (text, audiovisual, programmed, etc.). The variety of "output" variables might include such things as; student cognitive achievement (ala Bloom, Nature of Science etc.), student affective achievement (attitude, interest, values, etc.) student psychomotor development (lab skills, etc.) career selection, teacher behaviors. The nature of "feedback" variable could encompass success, verbal reinforcement, elimination of cognitive disequilibrium, peer group and/or parent pressures to name a few. If all research studies described clearly the nature of the input, process, output and feedback components, a giant step would have been accomplished.

Watson proposed a basic model for research on science teaching to be framed around the paradigm: "X teaches Y to Z". Thus the relevant parameters of this basic model include, the teacher, the subject matter, the pupil, as well as, the process of teaching.[21] Quite similarly, Easley described three possible dimensions of a science education research model to be the teacher, the learner and the subject matter.[28] A model for learning developed by Walberg suggested that learning was a function of instruction, aptitude, environment of learning, and their interactions.[34] Such basic models as these could be used as a beginning point for more detailed model building.

While any one of the possible procedures might be the most logical, approaching the problem from several perspectives by several procedures might be the most fruitful in the long run.

The last, and also one of the most important, concern of mine will be what criteria to use in evaluating the model I hope will be developed. Probably the most important criteria will be its capability to be modified as changes may be necessary. An inflexible model would be totally inappropriate for our use. A model must also be useful and, in our case, this becomes a multi-pronged thrust. Usefulness to science education researchers is a high priority, but consideration must also be given to its potential use by others such as; other education researchers, science teachers and supervisors, curriculum developers, etc. While a given object can't be all things to everybody, certain key elements could be a common concern to several of the other interested parties. Certainly a model should help accomplish the tasks earlier cited as necessary reasons for building the model.

Margenau suggested six requirements for the selection of concepts that are central to a science discipline.[35] These six requirements were suggested by Raven as being useful for selecting key concepts for inclusion in science curricula.[36] Might not some of these requirements also be useful for selecting key elements to include in a model for science education research? The six requirements are: logical fertility, multiple connections, permanence and stability, extensibility, casuality, simplicity and elegance. "Logical Fertility" "demands that the concept be capable of being manipulated according to the laws of logic." The manipulation need not be quantitative. Most science concepts permit logical minipulation, but it may be a valuable criteria to use for constructing models of science education research. "Multiple connections" required that may logical connections exist between other concepts or data and suggests t the connections form a circular net. Such standards allow for verification and cross-validation of constructs, and relationships. "Permanence and stability" demands that the concept be widely applicable not just to specific situations and that the concept can be applied to both old and new phenomena. Certainly of value to education research as well as science. The requirement for "extensibility" demands that the concepts be capable of explaining a wide variety of phenomena. This phrase sounds very similar to the oft-repeated demand for generalization and educational research studies. The "simplicity and elegance" requirement demands that the structure be as concise and efficient as well as complete as possible. If a model becomes too complex, it will be of limited use. Yet the components must be general or elegant enough to subsume many of the specific facts and ideas. The sixth requirement "causality" may be extremely difficult to satisfy with educational concepts in its straightest sense. However, the least we can do is to expect consistent relationships among the concepts in question.

Many other criteria may be appropriate for our concerns, such as; social significance, future orientation, implication for classroom use or curriculum development. The author would hope that criteria for evaluating this model at the same time as overall objectives are being formulated. Tyler realized that "the missing map cannot be produced over night" ...but... "the outlining elaboration and testing of such a map seems to be the necessary focus of our attention if we are to improve research in this field." [3]

References

1. Weinstock, Henry R. "The Concept of Model and Education Research." Journal of Research in Science Teaching, 4: 45-51, 1966.

2. Gage, N. C. Paradigms for Research on Teaching In N. L. Gage (Ed). Handbook of Research on Teaching. Chicago, Rand McNally, 1963.

3. Tyler, Ralph W. "Resources, Models, and Theory in the Improvement of Research in Science Education," Journal of Research in Science Teaching, Vol. 5: 52-63, 1967-68.

4. Hill, Joseph E. How Schools Can Apply Systems Analysis, PDK Fastback #6. Bloomington, Illinois, Phi Delta Kappa Educational Foundation, 1972.

5. Jesser, David L. "Systematic Planning: An Answer to Educational Dilemas?" The Science Teacher, 36(5): 32-35, 1969.

6. Voelker, Alan and Charles A. Wall. "Reseatch Reviews in Science Education:' A Bibliographic Listing" Science Education 56(4):487-502, 1972.

7. Curtis, Francis D. A Digest of Investigations in the Teaching of Science in the Elementary and Secondary Schools. Philadelphia: P. Blakiston's

8. Welch, Wayne W. "Review of Research 1968-69 in Secondary Level Science," Journal of Research in Science Teaching, Vol. 9:97-122, 1972.

9. Gallagher, James Joseph. "A Summary of Research in Science Education for the Years 1968-69: Elementary School Level," Journal of Research in

10. Craig, Gerald J. Science in the Elementary Schools. Washington, D. C.: National Education Association, 1957.

11. Barnard J. Darrell. Teaching High School Science. Washington, D. C.: National Education Association, 1956.

12. Ramsey & Howe. "Analysis of Research Related to Instructional Procedures in Elementary School Science." Science and Children, Vol. 7(8): 25-36, April, 1969.

13. Blosser & Howe. "Analysis of Research on Elementary Teacher Education Related to Teaching of Science." Science and Children, Vol 7(5):50-60 1969.

14. Ramsey & Howe. "Analysis of Research on Instruction Procedure in Secondary School Science Part II - Instruction Procedures" The Science Teacher 36(4):72-81, April, 1969.

15. Ramsey & Howe. "Analysis of Research on Instruction Procedure in Secondary School Science Part I: Outcomes of Instruction" The Science Teacher, 36(3):62-70, March 1969.

16. Blosser and Howe. "Analysis of Research - Educational Secondary School Science Teacher" The Science Teacher, Vol 36(1):87-95, January, 1969.

17. ____________. "Science and Mathematics Education," Review of Educational Research," Vol. 39(4), 1969.

18. Pella, Milton O. "A Structure for Science Education," Journal of Research in Science Teaching, Vol 4: 250-252, 1966.

19. St. John, Clinton. "Can Science Education Be Scientific? Notes toward a Viable Theory of Science Teaching." Journal Research in Science Teaching. 4:230-235, 1966.

20. Glass, Gene V. "Educational Knowledge Use," Educational Forum, p.21-29, November 1971.

21. Watson, Fletcher. "Toward Effective Research in Science Education." Theory Into Practice, 1(5): 277-283, Dec. 1962.

22. Ebel, Robert L. "Some Limitations of Basic Research in Education." Phi Delta Kappan, pp. 81-84, Oct. 1967.

23. Burnett, R. Will. "Circles, Pendelums, and Progress in Science Education." Journal of Research in Science Teaching. 2:33-42, 1964.

24. Hurd, Paul DeHart. "Research in Science Education: Planning for the Future," Journal of Research in Science Teaching, Vol. 8:243-249, 1971.

25. Novak, Joseph D. "A Prelimary Statement on Research in Science Education." Journal of Research in Science Education. 1:3-9, 1963.

26. Atkin, J. Myron. "Research Styles in Science Education," Journal of Research in Science Teaching, Vol. 5:338-345, 1967-68.

27. Jacobson, Willard J. "Approaches to Science Education Research: Analysis and Criticism." Journal Research in Science Teaching, 7(3):217-225, 1970.

28. Glass, Gene G. "The Widsom of Scientific Inquiry on Education." Journal of Research in Science Education. 9(1):3-18, 1972.

29. Morgan, Robert M. "The Science of Education: Research Ideas and Needs," The Science Teacher, Vol 34(8):32-33, November,1967.

30. Anderson,O. Roger. "Clarity in Reporting Research II." Journal Research in Science Teaching, 6(3):201-202, 1969.

31. Belanger, Maurice. "Methodology of Educational Research in Science and Mathematics" In Review of Educational Research Vol XXXIV(3):374-390,

32. Novak, Joseph D., Donald G. Ring, and Pinchas Tamir. "Interpretation of Research Findings in Terms of Ausubel's Theory and Implications for Science Education," Science Education, 55(4):483-526, 1971.

33. ________________. Convengene Technique Presentation. Washington, D.C. National Cancer Institute, 1972.

34. Walberg, Herbert J. "A Model for Research on Instruction". School Review pp.185-200, February 1970.

35. Margenan, Henry. The Nature of Physical Reality. New York: McGraw Hill Co. 1950.

36. Raven, Ronald J. "Toward a Philosophical Basis for Selecting Science Curriculum Content." Science Education; 54(2):97-103, 1970.